THE

PROCEEDINGS

OF THE

COLORADO

SCIENTIFIC SOCIETY

VOL. IV

1891, 1892, 1893

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FOR THE YEAR 1891.

SEVENTY-NINTH REGULAR MEETING.

January 5th, 1891.

In the Society Rooms, High School Building.

The President in the Chair.

Fifteen persons were present.

Mr. J. E. Steves presented specimens of wood-opal and wood-jasper from Elbert County; Dr. J. S. Newberry presented a meteorite from Pipe Creek, Texas; Mr. Richard Pearce a specimen of molybdenite from Conejos County, Colorado.

COMMUNICATIONS.—Mr. P. H. van Diest, "The Artesian Wells of Denver."

INFORMAL COMMUNICATIONS.—Mr. Geo. L. Cannon, Jr., "The Fossil Woods of the Denver Beds," illustrated by a series of specimens gathered about Denver.

The Executive Committee presented certain proposed amendments to the Constitution and By-Laws endorsed by three members, as required by the Constitution.

The Secretary was instructed to submit the same to all absent members, so that action might be taken at the next meeting.

The resignation of L. G. Eakins was read and accepted.

Mr. W. C. Wynkoop called attention to the fact that the Eighth Legislature of Colorado was about to meet and suggested that the Society take steps to aid in the establishment of a Bureau

of Mines and Economic Geology similar to that in operation in the State of California.

After some discussion the question was referred to the Executive Committee, who were empowered to present the matter to the proper Legislative committee for action.

EIGHTIETH REGULAR MEETING.

February 2nd, 1891.

In the Society Rooms, High School Building

The President in the Chair.

Ten persons present.

The following persons were elected members: Messrs. John H. Tucker, J. Dawson Hawkins, Edwin N. Hawkins, Chas. H. Livingstone and Henry A. Vezin.

The Secretary read a report of the Executive Committee on the proposed bill to establish a Bureau of Mines and Economic Geology, said bill having been introduced into both houses of the Legislature.

Discussion of the cases of delinquent members, who were two or more years behind in their annual dues.

Messrs. L. D. Ricketts and T. M. Trippe were by vote of the Society dropped from membership.

Voting on proposed amendments to the Constitution and By-Laws postponed till the next meeting.

COMMUNICATIONS.—Mr. R. C. Hills on "The Classification of the Huerfano Eocene."

EIGHTY-FIRST REGULAR MEETING.

March 2nd, 1891.

In the Society Rooms, High School Building.

The President in the Chair.

Ten persons present.

Messrs. H. F. Van Furman and Sidney Smith were elected members.

The proposed amendments to the Constitution and By-Laws were voted upon and adopted.

Among the changes was the creation of the office of Corresponding Secretary and Librarian, and Mr. P. H. van Diest was nominated for the position by Mr. O. J. Frost.

The Secretary read an invitation from the Committee of Organization, Washington, D. C., inviting the Society to take part in the meetings of the Fifth International Congress of Geologists at Washington, D. C., in August, 1891.

COMMUNICATIONS.—Mr. J. Dawson Hawkins, "On the Separation of Manganese in the Volumetric Determination of Zinc."

EIGHTY-SECOND REGULAR MEETING.

April 6th, 1891.

In the Society Rooms, High School Building.

The Vice President in the Chair.

Ten persons present.

Mr. P. H. van Diest was unanimously elected to the newly created office of Corresponding Secretary and Librarian.

Mr. Thos. Charlton, of West Cliff, Colorado, donated some specimens of native lead to the Society's museum.

Resolutions of sympathy were adopted, and the Secretary directed to send the same to Charter Members Hermann Beeger and Richard Pearce on account of their recent illness; the hope was expressed that they would soon be able to renew their former active interest in the proceedings of the Society.

INFORMAL COMMUNICATIONS.—Mr. F. F. Chisolm on "The Corundum Mines of North Carolina," illustrated by an excellent series of specimens.

EIGHTY-THIRD REGULAR MEETING

May 4th, 1891.

In the Society Rooms, High School Building.

The Vice President in the Chair.

Fifteen persons present.

Mr. L. J. W. Jones was elected to membership.

Mr. P. H. van Diest presented to the Society on behalf of Madame Von Rath an engraving of the late Professor Von Rath, which was ordered to be suitably framed and preserved.

COMMUNICATIONS.— "Types of Past Eruptions in the Rocky Mountains," by Mr. R. C. Hills.

"Notes on Some Twin Crystals of Selenite from a Cave Near Stanton, N. M.," by Mr. R. C. Hills.

Mr. F. F. Chisolm gave an interesting description of the mica mines of North Carolina, with specimens illustrating many of the industrial uses of the mineral.

EIGHTY-FOURTH REGULAR MEETING.

June 1st, 1891.

In the Society Rooms, High School Building.

The Corresponding Secretary in the Chair.

Nine persons present.

Messrs. Henry E. Wood, Geo. E. Kedzie and Bela Kadish were elected members of the Society.

COMMUNICATIONS.—Prof. Chas. S. Palmer "The Nature of the Chemical Elements." (Second Paper).

EIGHTY-FIFTH REGULAR MEETING.

September 7th, 1891.

In the Society Rooms, High School Building.

The President in the Chair.

Ten persons present.

This was the first meeting after the summer vacation.

Mr. Roy Wrigley, a former member, who had been dropped for non-payment of dues, was reinstated, he having satisfactorily explained his delinquency to the Society.

The matter of the visit of the delegates to the International Geological Congress to Denver was discussed, and a Committee of Reception and Entertainment was appointed to receive and care for the distinguished guests.

At a subsequent meeting the committee consisting of Hon. N. P. Hill, Hon. J. B. Grant, Geo. L. Cannon, Jr., R. C. Hills,

Mr. P. H. van Diest, Henry A. Vezin, James Murdoch, Richard Pearce, Chairman, and Franklin Guiterman, Secretary, met and arranged for a visit to the Omaha & Grant Smelting Co., The Boston & Colorado Smelting Co., a drive through the City, and afterwards an informal reception to be tendered by Mrs. Richard Pearce.

EIGHTY-SIXTH REGULAR MEETING.

October 5th, 1891.

In the Society Rooms, High School Building.

Mr. O. J. Frost was invited to the Chair.

Seven persons present.

Resolutions of thanks to Messrs. Richard Pearce and L. S. Storrs were passed in acknowledgment of their efficient services in connection with the visit of the delegates of the Fifth International Geological Congress.

COMMUNICATIONS.—Prof. Chas. Skeele Palmer, "The Nature of the Chemical Elements." (Third Paper).

EIGHTY-SEVENTH REGULAR MEETING.

November 2nd, 1891.

In the Society Rooms, High School Building.

The Vice President in the Chair.

Fifteen persons present.

Mr. Irving Hale was elected to membership.

COMMUNICATIONS.—Prof. Chas. Skeele Palmer, "The Nature of the Chemical Elements." (Fourth Paper).

George L. Cannon, Jr., "Notes on a Discovery of Radiolites Austinensis Roemer."

INFORMAL COMMUNICATIONS.—Mr. P. H. van Diest exhibited sections of borings near Moffatt and Garrison in San Luis Valley, and made some remarks on same.

Mr. E. N. Hawkins called attention to the differences which resulted from the lack of uniform methods of procedure in assays of metals and ores, and after discussion a committee was appointed to ascertain the different methods in vogue, with a view to selecting a standard to be endorsed by the Society.

EIGHTY-EIGHTH REGULAR MEETING.

December 7th, 1891.

In the Society Rooms, High School Building.

The Vice President in the Chair.

Thirteen persons present.

Messrs. John Howcutt and J. H. Tucker were elected members.

The Chair announced the death that day of Mr. Hermann Beeger, one of the Charter Members.

Mr. Richard Pearce spoke in feeling terms of the merits of the deceased, of his kind and manly character and the interest he has always taken in the welfare of the Society. It was resolved to publish in the Proceedings an obituary notice of Mr. Beeger.

COMMUNICATIONS.—Mr. E. N. Hawkins, Chairman of the Committee, read the report on "Ways and Means by which a Uniform Standard might be obtained in the Methods of Determinations used by the Chemists and Assayers of Colorado."

December 21st, 1891.

In the Society Rooms, High School Building.

The Vice President in the Chair.

Nine persons present.
The following officers were elected for the year 1892:

President, ... Geo. L. Cannon, Jr.
Vice President, ... Prof. Charles S. Palmer.
Secretary, ... Franklin Guiterman.
Treasurer, ... O. J. Frost.
Cor. Sec'y and Librarian, ... P. H. van Diest.

EXECUTIVE COMMITTEE.

Richard Pearce,   F. C. Knight,
Irving Hale,   Henry. A. Vezin,
E. N. Hawkins,   F. Guiterman,
Geo. L. Cannon, Jr.

The retiring President, Dr. Wm. P. Headden, delivered his address, entitled, "A Study of the Formation of the Alloy of Tin and Iron and the Description of Some New Alloys."

ABSTRACT OF MINUTES

FOR THE YEAR 1892.

EIGHTY-NINTH REGULAR MEETING.

January 4th, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Twelve persons present.

The reports of the Secretary, Treasurer and Curator for 1891 were read and approved.

Messrs. J. W. Edwards, A. M. Campbell and Philip Argall were elected to membership.

Messrs. J. H. Tucker and J. N. Hughes tendered their resignations, which were accepted.

NINETIETH REGULAR MEETING,

February 1st, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Thirty persons present.

Messrs. W. H. Aldridge and H. P. Bellinger, of Pueblo, and Mr. W. H. Bunce, of Ouray, Colo., were elected members.

COMMUNICATIONS.—Mr. Irving Hale, "The Present Limitations of Electric Power in Mining."

Mr. Richard Pearce presented the Society some specimens of Boleoite, a new mineral from Boleo, Lower California, composed of oxy-chloride of copper, chloride of lead and chloride of silver.

NINETY-FIRST REGULAR MEETING.

March 7th, 1892.

In the Society Rooms, High School Building.

The Treasurer, Temporary Chairman.

Sixteen persons present.

Messrs. Wm. Byrd Page, G. M. Gouyard, H. H. Taft, Stephen Rickard, John Roger, L. S. Noble, Francis W. Cragin, E. P. Matthewson, W. J. Hamilton, E. W. Johnson, J. H. Wilson and C. H. Hanington were elected members.

On recommendation of the Executive Committee, Mr. L. D. Ricketts was reinstated to full membership.

COMMUNICATIONS.—Mr. F. F. Chisolm, "Remarks on Some Gypsum Specimens from an Alabaster Quarry near Canon City, Colo." "Remarks on Secondary Mineralization assumed to be in progress in some of the mines on Smuggler Hill, Aspen, Colo."

Mr. A. S. Dwight exhibited some sapphires and garnets taken from the placers near Helena.

Mr. P. H. van Diest gave a brief description of a visit to Cripple Creek mines, referring to the prominent geological features and mode of occurrence of the ore deposits.

NINETY-SECOND REGULAR MEETING.

April 4th, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Twenty-three persons present.

Mr. Andrew Washburn, of Denver, was elected a member and Mr. C. B. Beach an associate member.

COMMUNICATIONS.—Mr. Richard Pearce submitted a communication from Prof. B. Sadtler, of the School of Mines of Golden, giving results of two analyses of furnace products from the Boston and Colorado Smelting Company, at Argo, Colo.

Mr. John B. Farish, "The Ore Deposits of Newman Hill, near Rico, Colo.;" the paper was accompanied by an exhibit of rocks and mineral specimens.

NINETY-THIRD REGULAR MEETING.

May 2nd, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Fifteen persons present.

Messrs. Fred. G. Bulkley and Henry Fulton were elected to membership.

An amendment to Article 5 of the Constitution was submitted for approval to be voted on at a future meeting.

It was decided to hold the next meeting in Pueblo, in view of the large membership there, and the date chosen was June 11th.

COMMUNICATIONS.—Prof. Chas. S. Palmer, "The Nature of the Chemical Elements." (Fifth Paper.)

Prof. Palmer announced that he was about to leave for an extended visit to Leipzig, Germany, and tendered his resignation as Vice President.

It was the sense of the Society that the resignation be not accepted, and Prof. Palmer withdrew it.

June 11th, 1892.

Held in Pueblo.

The President in the Chair.

Twenty-one persons were present.

Mr. P. H. van Diest announced the death of Dr. John F. Main, the fourth member lost during the ten years of the Society's existence. He gave a brief sketch of the life of the deceased.

It was resolved that an obituary notice be incorporated in the Proceedings for the year.

Messrs. Ellsworth Bethel, J. O. Ellinger, August Rath, J. J. Crooke, W. H. Howard, Felix Cremer, Dr. H. C. Hahn and W. C. Brace were elected members.

The amendment to the Constitution and By-Laws, creating additional Vice Presidents, was passed.

COMMUNICATIONS.—Mr. A. S. Dwight, "Occurrence of Sapphires in Montana."

Report of the Committee, "The Technical Determination of Zinc."

Mr. August Rath exhibited a fine specimen of plattnerite from Wood River Mining District, Idaho.

NINETY-FIFTH REGULAR MEETING,

September 5th, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Sixteen persons present.

The Librarian reported the donation to the Library by Mr. Fred. Bulkley, of Aspen, of a set of several hundred volumes of Geological Reports.

A vote of thanks was unanimously tendered Mr. Bulkley.

Messrs. B. Sadtler and E. C. Eddie were elected members.

A communication was received from Mr. W. S. Ward, Chief of Mining Department of the World's Fair at Chicago, asking the assistance and co-operation of the Society in his work. A Committee was appointed to confer with Mr. Ward in regard to the proposed assistance.

INFORMAL COMMUNICATIONS.— Mr. F. F. Chisolm exhibited some interesting productions of artificially precipitated crystallized gold obtained from heterogeneous solutions, the nature of which was not made clear. Under the microscope a distinct crystalline structure was shown. Further communication was promised.

NINETY-SIXTH REGULAR MEETING.

October 3rd, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Fifteen persons were present.

Mr. R. W. Guss was elected a member.

COMMUNICATIONS.—Dr. Whitman Cross, "The Post Laramie Beds of Middle Park, Colo."

NINETY-SEVENTH REGULAR MEETING.

November 7th, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Sixteen persons were present.

Prof. L. C. Hill was elected a member, and Mr. G. E. Jewell an associate member.

The Committee appointed to confer with Mr. W. S. Ward in regard to assistance to be rendered in making an exhibit for the World's Fair, of Colorado minerals and ores, reported. It was decided to offer Mr. Ward the use of such specimens as the Society had in its collection, provided they were packed, placed for exhibit at Chicago, and returned under the direction of the curator, Mr. R. C. Hills.

Mr. van Diest called attention to the fact that the second meeting in the coming year would mark the centenary meeting of the Society.

The question of a banquet was discussed and suggestions as to manner of holding same proposed.

COMMUNICATIONS.—Mr. F. C. Knight, "A Method for the Volumetric Determination of Lead."

Prof. Geo. L. Cannon, Jr., "The Paleozoic Beds of the Colorado Front Range."

NINETY-EIGHTH REGULAR MEETING.

December 5th, 1892.

In the Society Rooms, High School Building.

The President in the Chair.

Twenty-one persons present.

The Executive Committee presented a list of nominations of officers for the next year, to be voted on at the annual meeting.

The question of the Centenary meeting banquet was discussed and it was unanimously resolved to hold the same at an early date in the following year.

The President appointed. as Committee on Arrangements, Messrs. Irving Hale, J. B. Farish, P. H. van Diest, Geo. C. Munson and Harold V. Pearce.

ANNUAL MEETING.

December 19th, 1892.

In the Society Rooms, High School Building

The President in the Chair.

Thirteen persons were present.

The nomination of officers for the ensuing year were read, and the following persons elected:

President, Mr. A. Eilers elected, but subsequently declined office.

Vice President (1), ... O. J. Frost, Denver.
Vice President (2), ... A. S. Dwight, Pueblo.
Secretary, ... F. Guiterman, Denver.
Cor. Sec'y and Librarian, ... P. H. van Diest, Denver.
Treasurer, ... R. M. Hosea, Denver.

EXECUTIVE COMMITTEE.

Richard Pearce,	F. C. Knight,
Geo. L. Cannon, Jr.,	J. B. Farish,
P. H. van Diest,	Anton Eilers,

F. Guiterman.

The address of the retiring President was then read, entitled, "The Geology of Denver," by Geo. L. Cannon, Jr.

Mr. O. J. Frost took the chair, and a vote of thanks was tendered the retiring President for his courtesy and the ability with which he had filled the chair during the year.

ABSTRACT OF MINUTES

FOR THE YEAR 1893.

NINETY-NINTH REGULAR MEETING.

January 2nd, 1893.

In the Society Rooms, High School Building,

The First Vice President in the Chair.

Sixteen persons present.

Report of Treasurer read.

Report of Corresponding Secretary and Librarian read, showing that the Library was now catalogued and of easy reference.

Secretary's report showed a gratifying increase in membership and number of papers presented.

Messrs. L. D. Godshall and Prof. Wm. C. Strong were elected to membership.

COMMUNICATIONS.—Dr. Wm. P. Headden, "The Production of Columbous and Tungstous Oxides in forming Compounds of Tin and Iron," illustrated with crystallized exhibits under the microscope. Discussion.

Mr. Whitman Cross, "A Series of Peculiar Schists near Salida."

ONE HUNDREDTH REGULAR MEETING.

February 6th, 1893.

In the Society Rooms, High School Building.

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The First Vice President in the Chair.

———

Eighteen persons present.

Messrs. Edwin G. Dexter, of Colorado Springs, L. G. Eakins, Denver; Wm. D. Church, Denver; Francis T. Freeland, Leadville; were elected members.

Mr. P. H. van Diest reported the donation to the Library of 324 volumes of scientific books, by Mrs. Catherine Main Yorston, the property of Dr. J. F. Main, our deceased member.

The same are catalogued, and in each is pasted a slip stating the donation by Dr. Main.

A resolution was passed to present Mrs. Catherine Main Yorston an engrossed vote of thanks.

The resignations of F. K. Mixer and T. W. Stanton were accepted.

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ONE HUNDRED AND FIRST REGULAR MEETING.

March 6th, 1893.

In the Society Rooms, High School Building.

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Geo. L. Cannon, Jr., Chairman Pro-Tem.

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Seventeen persons present.

Messrs. G. S. Raymer, Idaho Springs; Max Boehmer, T. Arthur Rickard, Victor C. Heikes and S. W. Tyler, Denver, were elected members.

The Librarian reported that a bound set of the Proceedings of the Society had been delivered to Mr. W. S. Ward for exhibit at the World's Columbian Exhibition, in the Mining Department. He also reported the receipt of a bound set of Geological Reports of Pennsylvania, eight volumes.

The Society's collection of eruptive rocks and its meteorite were also delivered to Mr. Ward for exhibition.

INFORMAL COMMUNICATIONS.—Prof. B. Sadtler, "The Geologic and Economic Features of the Tin Cup Basin."

ONE HUNDRED AND SECOND REGULAR MEETING.

April 3rd, 1893.

In the Society Rooms, High School Building,

Mr. R. C. Hills, Chairman Pro-Tem.

Twenty-two persons present.

Messrs. Chas. H. Moore, Leadville; C. D. Chanute, Denver; C. H. MacNutt, Amethyst; M. B. Holt, Pueblo; F. M. Smith, Pueblo; F. E. Harnden, Pueblo; L. L. Woods, Pueblo; F. Aller, Pueblo; J. K. Surls, Pueblo; W. B. Budrow, Pueblo; S. A. Harsh, Golden, were elected members, and A. H. Osborne, Golden; W. B. Milliken, Golden; Wallace A. Stevens, Golden, were elected associate members.

COMMUNICATIONS.—Mr. Irving Hale, "The Latest Method of Electric Car Control."

ONE HUNDRED AND THIRD REGULAR MEETING.

May 4th, 1893.

In the Society Rooms, High School Building.

Mr. Richard Pearce, Chairman Pro-Tem.

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Twenty-two persons present.

Mr. J. W. Root, Pueblo, was elected to membership.

COMMUNICATIONS.—Mr. L. D. Godshall, "A Review of the Russell Process." Discussion.

INFORMAL COMMUNICATIONS.—Mr. Richard Pearce, exhibited some highly interesting specimens of tin ore from Durango, Mexico. This ore occurs in veins in granite and the cassiterite is associated with specular iron ore, with a kaolinized gangue. Some of the cassiterite shows itself as a pseudomorph after the specular iron, and one specimen shows the cassiterite in boitryoidal mass, which suggests that this may also be a pseudomorph after kidney iron ore.

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ONE HUNDRED AND FOURTH REGULAR MEETING.

June 5th, 1893.

In the Society Rooms, High School Building.

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The First Vice President in the Chair

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Twenty-one persons present.

Messrs. Forbes Rickard, Nicolai Anderson, Edmund B. Kirby, Stuart Croasdale, Frederick Roeser and W. L. Austin, Denver, were elected to membership.

Discussion on a proposition by Mr. W. S. Ward to have the meteorite belonging to the Society, and now at Chicago, cut, resulted in postponing such action.

The question of holding outside summer meetings was dis-

cussed, and a committee afterwards decided that owing to the disturbed financial conditions prevailing such meetings were not advisable at the time.

ONE HUNDRED AND FIFTH REGULAR MEETING.

September 4th, 1893.

In the Society Rooms, High School Building.

Mr. J. A. Porter, Chairman Pro-Tem.

Twenty-three persons present.

COMMUNICATIONS.—T. A. Rickard, on "Certain Dissimilar Occurrences of Gold Bearing Quartz." Discussion by Mr. Argall, illustrated by a series of specimens from New Zealand.

ONE HUNDRED AND SIXTH REGULAR MEETING.

October 2nd, 1893.

In the Society Rooms, High School Building.

The First Vice President in the Chair.

Twenty-one persons present.

The Librarian reported that the Catalogues of the Society's Library were ready for distribution.

The Curator reported the donation of several specimens from the Upper Miocene.

COMMUNICATIONS.—Mr. P. H. van Diest, "Evidences of the

Formation of Ore Bodies by Lateral Secretion in the John Jay Mine at Boulder, Colorado."

Discussion by Messrs. F. Guiterman, Richard Pearce, T. A. Rickard, R. C. Hills and Philip Argall.

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ONE HUNDRED AND SEVENTH REGULAR MEETING.

November 6th, 1893.

In the Society Rooms, High School Building.

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The First Vice President in the Chair.

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Twenty-eight persons present.

COMMUNICATIONS.—Prof. Chas. S. Palmer, "The Nature of the Chemical Elements." (Sixth Paper.)

Mr. Richard Pearce described some eruptive dykes at Manchester, Mass., on the Atlantic coast, which filled joints in the country rock, having the peculiarity that the eruptive rock contained an "astonishingly small percentage of silica."

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ONE HUNDRED AND EIGHTH REGULAR MEETING.

December 4th, 1893.

In the Society Rooms, High School Building.

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J. B. Farish, Chairman Pro-Tem.

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Thirty-one persons present.

The Executive Committee presented a list of nominations of officers for the ensuing year, to be voted on at the annual meeting.

COMMUNICATIONS.—Mr. Francis T. Freeland, on "The Solution of the Equations $X_2+Y=7$; $Y_2=X=11$. Discussion by Mr. R. M. Hosea, who presented a graphical solution of the same.

Mr. W. L. Austin, "Nickel,—Historical Sketch." (First Paper.)

Mr. Philip Argall, "Nickel,—The Occurrence, Geological Distribution and Genesis of Its Ore Deposits."

INFORMAL COMMUNICATIONS.—Mr. T. E. Schwarz described an interesting ore occurrence in the "Independence" mine at Cripple Creek

The ore occurs on either side of a fissure in the granite, near its juncture with the overlying porphyry; it consists of a mineralized granite extending inward from the fissure for some distance. The peculiarity of the deposit is that there is an entire absence of any vein filling or gangue. The mica of the granite has been replaced by the gold bearing mineral.

A porphyritic dyke, an offshoot from the main overlying mass, follows the fissure for a short distance, and then swings off into the granite, but continues parallel to the fissure at a distance of about fifty feet from it.

Apparently the ore deposit is independent of any visible connection with the dyke except for the short distance where it follows the fissure.

The mine offers an excellent opportunity for the study of the relation of the intrusive dyke to the ore occurrence.

The question of holding an annual dinner was discussed, and the Secretary instructed to send out requests to members for subscriptions thereto.

ANNUAL MEETING.

December 18th, 1893.

In the Society Rooms, High School Building.

The First Vice President in the Chair.

Twenty persons present.

The attention of the Society was called to the fact that a letter had been received February 6, from Mr. Anton Eilers, declining his election to the Presidency for 1893.

On motion it had been decided to accept same conditionally in the hope that Mr. Eilers might reconsider his action.

The year had, however, drawn to a close without any further communication from Mr. Eiler, and it now became necessary to take some final action in the matter.

On motion, therefore, it was resolved to declare the office of President vacant for the year 1893.

As only one ticket was presented for officers of the ensuing year, the Secretary was instructed to cast the ballot of the Society for the following nominees, who were elected:

President, ... Prof. C. S. Palmer, Boulder.
Vice President (1), ... John B. Farish, Denver.
Vice President (2), ... A. S. Dwight, Pueblo.
Secretary, ... Franklin Guiterman, Denver.
Cor. Sec'y and Librarian, . . . P. H. van Diest, Denver.
Treasurer, ... R. M. Hosea, Denver.

EXECUTIVE COMMITTEE.

Richard Pearce.   H. Van Furman.
A. A. Blow.   P. H. van Diest.
Philip Argall.   F. Guiterman.

Prof. Chas. S. Palmer.

The retiring Vice President, Mr. O. J. Frost delivered an address entitled, "The Question of a Standard of Value."

REPORT OF THE SECRETARY.

It is with a feeling of great gratification that the Secretary submits his report covering the life of the Society for the years 1891, '92 and '93.

This period may justly be characterized as one of uninterrupted progress, the evidence being furnished in the rapid increase of membership and the number of papers submitted.

At the close of the year 1893 the membership list shows 116 members in good standing and four associate members, making a total of 120.

The standard of the papers heretofore read before the Society has been uniformly high, and that of the valuable communications presented during the last three years has been no less so. The range of the subjects treated in the fields of natural and applied sciences has been a wide one, and it is with pride that the Secretary can point to the fact that the treatment of the subjects considered has generally been one of original research, the results of which have commanded the respect of the scientific and technical world.

The feeling prevalent among the members of the Society is one of pride, enthusiasm and hope; the first being caused by what has been accomplished, the second inspired by the vigor of the organization's growth, both in numbers and character, and the last founded on the earnest desire that the future of the Society may be one of ever broadening scope and usefulness, not only in a scientific direction generally, but to the public at large as well.

The work which has been done by the successive executive officers in furthering the welfare of the Society, their unity of purpose to make it eventually the medium of all scientific communication emanating from Colorado, and the success which has attended those efforts, have found a full appreciation in the members, and it may be added that the evidence of this appreciation has been accepted by those officers as an ample repayment for the labors expended.

FRANKLIN GUITERMAN,
Secretary.

REPORT OF THE CORRESPONDING SECRETARY AND LIBRARIAN.

The Corresponding Secretary and Librarian takes pleasure in stating that the growth of the Society's Library has kept pace with the rapidly increasing membership.

It is a fitting commentary on the value of the Society's publications to note the demand for same on the part of all leading American and foreign Scientific Societies.

The wisdom of the Executive Committee in authorizing the Secretary to publish at once in pamphlet form all papers submitted, has been demonstrated in the benefit derived not only by the Society itself, but by its library as well. The step has greatly stimulated the demand for our publications and has resulted in a vigorous increase in exchanges.

In addition to this ever enlarging list, the library has received a number of donations, among which may be specially enumerated, one of a large number of books and geological reports from our member, Mr. F. G. Buckley, and another, a splendid collection of 324 volumes which comprised the scientific library of our late member, Dr. John F. Main, the gift being made to the Society by his widow.

It may be said that we have now the nucleus for a future scientific reference library, and everything points to its rapid development.

A catalogue of our books has been compiled and issued. Those who may not have received same can get copies on application to the Librarian.

<div style="text-align:right">

P. H. van Diest,
Cor. Sec'y and Librarian.

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REPORT OF THE TREASURER.

For 1891.   RECEIPTS.

Balance January 5, 1891	$ 266.71	
Dues......................................	730.00	
Sales of Proceedings.......................	8.50	
		$1,005.21

EXPENSES.

Printing and publications...................	72.65	
Postage and incidentals.....................	31.35	
Museum	267.38	
Periodicals................................	13.00	
Janitor....................................	25.00	
Balance	595.83	
		$1,005.21

For 1892.   RECEIPTS.

Balance, January 5, 1892....................	$ 595.83	
Dues......................................	1,000.00	
Sales of Proceedings.......................	22.50	
Donation from J. A. Kebler.................	10.00	
		$1,628.33

EXPENSES.

Printing and publications...................	$ 687.13	
Postage and incidentals.....................	67.95	
Museum	102.00	
Periodicals	6.00	
Library....................................	23.65	
Janitor....................................	25.00	
Balance	716.60	
		$1,628.33

O. J. FROST, Treasurer.

For 1893.

RECEIPTS.

Balance January 10, 1893.....................$ 716.60
Dues 1,060.00
Sales of Proceedings......................... 34.45
Interest..................................... 44.64
——————— $1,855.69

EXPENSES.

Printing and publications...................$ 391.90
Postage and incidentals...................... 83.45
Museum 2.80
Periodicals 9.61
Library 168.15
World's Fair exhibit......................... 3.00
Uncollected checks........................... 20.00
Balance...................................... 1,176.78
——————— $1,855.69

R. M. HOSEA, Treasurer.

ON THE ARTESIAN WELLS OF DENVER.

BY P. H. VAN DIEST, DENVER, COLO.

The artesian wells of Denver have, from their importance to this community, received at the hands of the Society the consideration to which they are justly entitled. The literature on this subject may be found in Volumes I and II of the Society's Proceedings, articles in the former having been contributed by Messrs. Whitman Cross, F. F. Chisolm, Regis Chauvenet and the writer, and in the latter by Mr. Charles G. Slack.

As a complement to these papers the writer submits the results of later observations which were made at the request of Mr. S. F. Emmons, who desires to use them in his monograph on "The Geology of the Denver Basin," the object in view being to ascertain if possible what aggregate amount of water might be figured as available from artesian sources for the Denver district, and furthermore to determine as far as could be done, what influence one well has upon another, and what might be the causes in the decrease in the supply where such had been observed.

The data furnished by these investigations have been compiled in such a way that they will form an addition to the tables made by Mr. Slack, the arrangement being such that comparisons between the observations of that gentleman made in 1886 and by the writer at the end of the year 1890, will be at once simple and easily comprehensible.

In addition to Mr. Slack's list of wells, there have been added the observations on ten others bored before 1886, and of fifty-seven which were sunk between 1886 and the end of the year 1890.

In all, therefore, the investigations cover 202 artesian wells of Denver, which include the 135 studied by Mr. Slack.

Of these wells, but one of those bored before 1886 is now flowing; of those bored since 1886 but four are flowing, while 120 only furnish water by pumping. The remaining seventy-seven have been either abandoned or are plugged. It was impossible in most cases to obtain any data by which an estimate could be made of the daily discharge of the wells. From some the water is drawn by means of a hand pump in quantities much smaller than the well could furnish without a lowering of its natural water level; from others again considerable quantities of water are pumped for use in boilers and in large buildings, the result being not only a gradual lowering of their own water level, but also that of those wells in the vicinity, which are sunk on higher ground. A few examples of the influence of one well upon another may be cited.

The water in the "Agerer Snively" and "Heidner" wells, which are located in proximity, rises to the surface, and even occasionally overflows when pumping at the "Tegeler" (now known as the " Denver Land & Ice Co's.") well, which is located near by, has ceased for several days. The "Hanson," " Brown " and "McClelland" wells, which are in the neighborhood of each other on Grant Avenue, flowed until pumping began on the "Artesian Ice Co's," well not far away, when the water level sunk some four to seven feet below the surface. When the pumping ceased the natural flow was again resumed. In other portions of the Denver district the influence of one well upon another is not so marked, and the effect is even at times hardly perceptible, although it may be stated as a general rule that there is a gradual loss of pressure.

These conditions are no doubt brought about by the heterogeneous character of the sandstones of the Arapahoe beds under Denver and, in conjunction with it, are due to the variability in thickness of the confining layers composing these beds. Thus, in some localities, the water-bearing strata may be very porous within a limited area. Wells which are sunk in such territory and are subject to pumping will drain the water quicker than it can be replenished from the adjacent and surrounding denser strata, in

consequence of which an oscillating water level is observed. In other localities where the strata are uniform both in character and thickness, such fluctuations are apt to be less marked. It may be stated, however, that in all localities, whether the water level has been subject to variations or not, a gradual lowering of the same has taken place, this fact having been already noted in the year 1884, only one year after the first well had been sunk. The lowering of the level became very marked as the number of wells increased, and it still continues to be the case on account of the vigorous pumping which has been resorted to in many cases.

The history of the Denver artesian wells may briefly be summarized as follows.

The first wells were bored in the year 1883; the water flow then showed great pressure, rising in cases of the wells sunk at the lowest points in the basin more than 100 feet above the surface. With the advent of additional wells, all in proximity, the water from the strata at higher points was drained faster than natural sources could supply it, in consequence of which a diminution of pressure soon made itself felt. The natural flow ceased in one well and then another, operating always in the direction of the higher planes to the lower, until pumping had, as a rule, to be resorted to.

An attempt to compare the depths of water below the surface in abandoned or plugged wells with the differences of elevation in the localities in which such wells were sunk had to be given up, for the necessary data in street levels could not be procured from the City Engineer's office.

The investigations have forced upon the writer the unpleasant conclusion that the number of wells which have already been sunk in Denver are far in excess of the water resources of the territory which they drain. It has been suggested that the reason of the decrease in the artesian water supply could be found in the improper construction of the casing of the wells, or to the clogging of the pores of the sandstone strata by the silt carried in suspension in the water. Such hypothesis has, however, been vitiated by the demonstration in the major number of instances that a diminished flow of water was not overcome by the cleaning and deeper sinking of the wells, and that the lowering of the water

levels made itself felt alike in all wells irrespective of the fact whether they were poorly cased or not.

The studies of the Tertiary formation in the vicinity of Denver by Messrs. Whitman Cross and George H. Eldridge have modified to a large extent the views that were entertained as to what may properly be considered the collecting area for the water supply of the artesian wells under discussion. There is no longer any doubt, that with the exception of the "Windsor" and "County Court House" wells, the water for the remaining ones is derived from the Arapahoe beds of the Miocene Tertiary. This Tertiary basin is by no means an ideal one, bounded on all sides by the upturned edges of pervious strata which are confined within water tight beds. The encasing strata are in many cases leaking layers of variable thickness, and the basset edges of the pervious beds are exposed for but a small extent fourteen miles south of Denver; they again appear along the foot-hills some twelve miles west and also, but slightly upturned, about six miles north of the city. The collecting area may safely be accepted, therefore, as not covering more than forty miles in linear extent. The average thickness of the water bearing strata of the wells in and around Denver may be taken at 135 feet. Forty miles contain 211,200 feet, which multiplied by 135 gives 28,512,000 square feet of water collecting territory.

The data obtained relative to the original height of flow above, and the present level of water in the wells of Denver below the surface, give an average difference in height of seventy feet. A mass of sandstone covering an area of 28,512,000 square feet, seventy feet thick, contains 1,995,840,000 cubic feet. The absorption capacity to saturation of such a mass can be estimated at 7% of its weight, based on the results obtained on similar material by a committee appointed by the Society in their investigations on building stones. Seven per cent of the weight of the given mass of sandstone would be equivalent to 349,272,000 cubic feet of water, or 2,619,540,000 gallons, which may be assumed to be the amount, in addition to the rain fall, which has been supplied to the wells of Denver during the six years of existence, on the collecting area.

It is difficult to estimate the actual yearly supply of water on the collecting area with any degree of accuracy, but the following calculation may be taken as an approximation.   On basis of a yearly rain fall of fourteen inches, and assuming that 25% of such precipitation enters the earth, in six years we would have 1·75 feet. At such depth in a collecting area of 28,512,000 square feet there would be 49,896,000 cubic feet, or 374,220,000 gallons; or, calculating back per day an equivalent of 170,900 gallons every twenty-four hours.   If we add to the 49,896,000 cubic feet as above obtained, the previously estimated amount of 349,272,000 cubic feet of water which were drained out of the saturated sandstone beds, we have a total of 399,168,000 cubic feet, covering a period of 2,190 days, equivalent to 1,367,025 gallons supply in that time.

Mr. Slack estimated that in February, 1886, the average capacity of all the wells in and about Denver produced 2,900,000 gallons of water every twenty-four hours.   At that time the production was at a maximum.   If we consider the great reduction in the supply of the wells since 1886, and compare the estimate furnished above with Mr. Slack's figures, it would appear as if the former approximated the truth.

· It is not improbable that the collecting area gathers a larger amount of water than has been estimated, but on the other hand, a great deal of such surplus may leak to lower strata and be carried away from the basin which furnishes Denver's artesian water supply, to reappear at other points as brooks or springs.   All facts being duly considered, the writer is of the opinion that the average supply of water permanently available for artesian wells around Denver from a depth not exceeding 800 feet may conservatively be taken at 170,000 to 180,000 gallons.   It may also be said, on the basis of previous assumptions, that if all the wells were plugged, it would take about forty years before the water bearing strata of the Tertiary beds of the Denver basin would again be in the condition of saturation existing at the time the first well was sunk.   Deeper wells may, however, increase the daily amount of water obtainable.   There is hardly any doubt that the basal sandstones of the Laramie lie about 1,500 feet below the city; in other words, the Montana shales will not be reached before that depth is obtained.   It is very probable that at such depth a large

supply of water can be expected, for these sandstone beds are very thick, and as they crop out in the mountains at somewhat higher altitudes than the Arapahoe and Denver beds, their waters have in consequence a higher fountain head.

That soft water can be expected from these basal sandstones of the Laramie is demonstrated by a well in Section 12, Township 1, South Range 70, west of the 6th Principal Meridian, about six miles easterly of Boulder. The last coal seam, five feet thick, was encountered in that well at a depth of 124 feet. Following this came five feet of clay, then 208 feet of the Laramie sandstone from which bed an excellent flow of soft water was obtained.

DISCUSSION.

Mr. R. C. Hills.—The so-called artesian basin of Denver is really a broad synclinal trough, corresponding approximately to the course of the Platte River. I regard the Laramie as the geological terrain from which Denver may expect a permanent supply of artesian water, rather than from the more recent beds of the post-Laramie group which furnish the present diminishing supply. The thickness and area of the former is very much greater, while the alternation of permeable and impermeable strata is highly favorable as supplementing the structural conditions and assuring an artesian flow within the synclinal area. My own experience with deep borings in the Laramie of the Denver basin goes to show that the flow steadily increases with depth. That while the water is carbonated, and more or less mineralized, it is generally quite palatable.

In considering the source of supply I do not think that the entire area of the Denver and Arapahoe beds should be regarded as a water-shed. The supply is, no doubt, in the main, derived from the numerous streams flowing over the tilted outcrop near the mountains, and depends on the capacity of the rocks for receiving and conveying it.

REMARKS ON THE CLASSIFICATION OF THE HUERFANO EOCENE.

BY R. C. HILLS.

In the description of the Eocene beds of the Huerfano lake-basin, communicated to the Society in 1888, certain convenient terms were made use of which, from the imperfectly understood relation of these beds to other members of the Lower Tertiary, were necessarily provisional and merely employed in a general sense.

It seems desirable, in the interest of systematic geology and as a prelude to further investigations in that region, that these terms should be better defined and rendered more specific in their application.

The term "Poison Canon Series" was first employed as a convenient designation for the lithological sequence of Eocene beds at the locality where they were first studied and where the two lower members especially are characteristically developed. A complete section of the upper one, however, is not shown at Poison Canon, the inclined strata extending some distance into the Muddy Creek Valley beyond. Subsequently the term "Huerfano series" was used with reference to the Huerfano Eocene beds collectively, and, since this term necessarily includes all the beds exposed in Poison Canon, it seems appropriate to retain it in the sense it was originally employed, as a designation for the entire Eocene series of the Huerfano lake-basin, in preference to the former term "Poison Canon Series."

The general designation "Huerfano beds" was originally applied to the stratigraphical sub-division of the Eocene recog-

nized in the Huerfano and Cuchara basins.   As it is now appar-
ent that these several sub-divisions cannot all be referred to the
same stage of sedimentation, this term cannot be consistently em-
ployed as a specific designation for more than one of the stages
recognized.   It is therefore proposed to restrict the term "Huer-
fano beds" to the upper of the three sub-divisions described in
Vol. III, Part II, page 218 of the Proceedings of the Society.

In previous papers relating to this subject the conclusion was
expressed that the synclinal trough occupied by the Huerfano
Tertiary lake had its origin in the post-Laramie movement, that
sedimentation began in the earliest Tertiary and was continuous
up to the close of the Huerfano Eocene.   The mammalian remains
of the Huerfano beds—restricting the term to the upper of the
three sub-divisions—indicate equivalence with the Bridger Eocene
of Wyoming. If then, the interpretation of the structural evidence
is correct, the middle and lower sub-divisions are the Huerfano
equivalents of all the Rocky Mountain Eocene sediments older
than the Bridger; that is, of the Green River and Wasatch beds,
and probably others still older whose deposition immediately fol-
lowed the post-Laramie disturbances—or may have been in part
contemporaneous with them—before any marked change in the
life systems had taken place.   In this category we may include
the Arapahoe and Denver beds of Cross and Eldridge, the rem-
nants of similar beds near Canon City, the Ruby beds, and prob-
ably a narrow strip overlying the Laramie in South Park, together
with certain beds on the Yampa near Hayden.*   In all of these
cases the principal distinguishing feature is a radical change in
the composition of the sediments, which in the Denver basin
is coupled with great erosional unconformity.   To what extent
these beds may be represented at the base of the Huerfano Eocene
series is in the highest degree problematical.   Thus far not the
least evidence of organic remains has been discovered in either of
the lower members, and pending further explorations it is only
possible, in regard to age, to group them together and refer them
to the Lower Eocene.   Unconformity by erosion is not to be ex-

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*Since this paper was read similar beds to those of Ruby Peak have been observed
by T. W. Stanton on the Rio Las Animas, reference to which is made by Dr. Cross. "Amer.
Jour. Sci., Vol. XLIV," pp. 27-31, July, 1892.

pected in the face of evidence which I have previously shown to
be strongly indicative of a continuous deposition of sediments
throughout the interval between the post-Laramie and post-
Eocene—or more probably in this case post-Bridger—movements.
It is true that great angular unconformity exists between the
Laramie and the base of the Eocene; nevertheless, none has been
detected between the Eocene members themselves. Hence, the
two sub-divisions below the Huerfano beds are founded upon lith-
ological differences and stratigraphical position, features which,
unsupported by other evidence, are not always to be regarded as
sufficient grounds for separating, chronologically, one class of sedi-
ments from another. The distinguishing characters of the sev-
eral members as defined in the communication to the Society on
this subject in 1889 are, however, strongly marked, and they
would be more conveniently referred to under appropriate desig-
nations. It is therefore proposed that the name "Cuchara beds"
be applied to the middle member of the series, after the Cuchara
River, where they form the surface exposures north and south of
La Veta; and that the name "Poison Canon beds" be applied to
the lower member, after the locality on Poison Creek, where
they are characteristically developed. The relation of the several
formations may be expressed in a condensed form as follows:

$$\text{Huerfano Series (Eocene).} \left\{ \begin{array}{l} \text{Huerfano Beds.} \quad = \text{Bridger Group.} \\ \text{Cuchara Beds.} \\ \text{Poison Canon Beds.} \end{array} \right\} \text{Lower Eocene.}$$

As thus defined the Huerfano beds extend from the Grape
Creek Divide southeast to a point nearly due east from South
Veta Mountain, but excepting the small remnant at West Spanish
Peak, are wholly wanting in the Cuchara valley owing to erosion.
The Cuchara Poison Canon beds are continuous throughout the
area occupied by Eocene sediments as shown approximately on
the map accompanying the original communication in 1888, modi-
fied by the corrections stated in the second paper on the same
subject communicated to the Society at the meeting of October,
1889.

THE SEPARATION OF MANGANESE IN THE VOLUMETRIC DETERMINATION OF ZINC.

BY J. DAWSON HAWKINS.

For the volumetric determination of zinc, there are but two methods which satisfy the requirements of commercial work, namely, the sulphide and the ferrocyanide. In Colorado, the number of determinations to be made, and the speed required necessitate the use of the latter.

The preparation of the ore for the titration is generally described by the name of "Low's Method," which in brief, consists of treating the ore with nitric acid and ammonium nitrate, evaporating to dryness and extracting the zinc from the dried mass, by means of ammonia. Here, it is only under certain conditions that the manganese remains insoluble, and is not carried into solution with the zinc. All the manganese that is carried thus into solution is titrated as zinc, since the ferrocyanide of manganese is insoluble in the acid liquid.

Experiments made in the laboratory of the Globe Smelting and Refining Company several months ago, showed that when there is enough sulphur present to combine with the manganese on oxidation, and form the sulphate, the manganese will be carried into the ammoniacal solution, but when sulphur is absent, the manganese will remain with the ferric-hydrate as the insoluble peroxide.

Several methods are applicable, and are at present in use for the separation of the manganese from the zinc in the ammoniacal solution, namely, the addition of ammonium carbonate; of permanganate of potassium; of chlorate of potassium; of bromine

water, and of hydrogen di-oxide.   The last method is the one
with which this paper will deal particularly.

Two objections to the ammonium carbonate method are, that
the excessive amount of ammonium salts present render the com-
plete precipitation of the manganese very uncertain; and that, if
the carbonate is added to the hot solution, it will decompose
before it has had an opportunity to produce its effect.

In the permanganate method, all the manganese is thrown
down by the addition of the permanganate to the ammoniacal
solution of zinc and manganese.   Any excess of the precipitant
may be easily decomposed by boiling the solution.   Here, how-
ever, the amount of peroxide of manganese precipitated is very
largely increased over the original contents of manganese in the
solution, and the amount of zinc carried down with it is greatly
augmented.   The following results show the extent to which this
is true:

In a solution containing,

$$ZnO—0.1500 \text{ g.}$$
$$MnO—0.0717 \text{ g.}$$

the manganese was precipitated hot by the addition of perman-
ganate of potassium solution, the solution boiled and filtered.
The precipitate contained,

$$ZnO—0.0358 \text{ g.}$$

This precipitate was re-dissolved and re-precipitated.   The pre-
cipitate contained,

$$ZnO—0.0057 \text{ g.}$$

This method is a very undesirable one owing to the large
amount of manganese introduced into the analysis, and the incon-
venience and inaccuracy of working caused thereby.

The addition of chlorate of potassium to the alkaline solution,
and boiling, causes all the manganese to be precipitated as a hy-
drated peroxide.   If the solution contain but little ammonium
chloride, the precipitation is complete, otherwise but little or no
manganese will come down.

The addition of bromine water to the ammoniacal solution of
manganese, and boiling, precipitates all of the manganese.   A large

quantity of ammonium salts is, however, very undesirable, as complete precipitation may be hindered.

Much superior to any of the foregoing methods is the one in which the manganese is precipitated by means of hydrogen di-oxide.

This method depends upon the fact, that in alkaline solutions, manganese is easily transformed to a higher oxide, and therefore becomes insoluble.

The exact reaction that takes place has not yet been definitely ascertained, but the result is a precipitate of hydrated manganic oxide and the liberation of free oxygen.

The "rationale" of the method is briefly as follows:

To the *hot* ammoniacal solution containing the zinc and manganese, add about 5 cc of hydrogen di-oxide, and heat to boiling. All the manganese is precipitated in a compact form, and is easily filtered. The peroxide of hydrogen has no effect on the zinc, but nevertheless, some zinc is carried down by the manganese. Re-solution and a second precipitation eliminate the zinc. The operation is very short, and is very neat and clean. The following experiments indicate to what extent the zinc is carried down.

In a solution containing,

(1.) ZnO—0·1500 g.
                        MnO—0·0735 g.

the manganese was precipitated hot by hydrogen di-oxide. The precipitate contained,
                        ZnO—0·0110 g.
                        _____

(2.) ZnO—0·1500 g.
                        MnO—0·0514 g.

The manganese precipitate contained,
                        ZnO—0·0090 g.
                        _____

(3.) ZnO—0·1800 g.
                        MnO—0·0147 g.

The manganese precipitate contained,
                        ZnO—0·0095 g.

(4.)   ZnO—0·0600 g.
                        MnO—0·0735 g.

The manganese precipitate contained,

                        ZnO—0·0090 g.
                        _____

(5.)   ZnO—0·0750 g.
                        MnO—0·0588 g.

The manganese was precipitated cold and filtered. The precipi-
tate contained,

                        ZnO—0·0165 g.
                        _____

(6.)   ZnO—0·1350 g.

                        MnO—0·0147 g.

The manganese was precipitated cold, and filtered.   The precipi-
tate contained,

                        ZnO—0·0176 g.

Experiments (5) and (6) demonstrate that when the precipi-
tation takes place in the cold, the precipitated manganese carries
down with it much more zinc than would have been the case had
it been precipitated from hot solutions.

(7.)   ZnO—0·1500 g.
                        MnO—0·0715 g.

In this case the precipitation with hydrogen di-oxide was re-
peated. The manganese on second precipitation was found to
contain only a trace of zinc.

For an exact determination of the zinc, the precipitation of
iron and manganese should always be repeated, as in all cases
where the oxides of these metals are precipitated in the presence
of zinc, some zinc is always carried down.

In accurate analytical work, care should be taken that pure
hydrogen di-oxide is used, as the commercial article is frequently
contaminated with alumina.

TYPES OF PAST ERUPTIONS IN THE ROCKY MOUNTAINS.

BY R. C. HILLS.

Read at Meeting, May 18th, 1891.

That broad territory of the western United States usually referred to as the Cordilleras, or which lies between the eastern foot-hills of the Rocky Mountains and the Pacific Coast, has witnessed some of the grandest eruptions recorded in geological history; remarkable not only for their magnitude, but for the interesting varieties of mountain structure they developed. While a great deal has been written about this territory in a general way, and the geology of extensive tracts within its boundaries roughly outlined, it has not yet been sufficiently explored to admit of a comprehensive discussion of the relations of the eruptive bodies of the entire field.

Nevertheless, something may be said regarding the principal eruptions of what is probably the best known portion of it, viz:—the region lying between the Great Basin and the eastern border of the Rocky Mountains—a region defined by an orography peculiarly its own, and including a group of typical and highly interesting eruptive mountain bodies.

In some parts of this region manifestations of igneous activity have been much more frequent than in others. Thus, in western Colorado and northern New Mexico, eruptive masses, of various types, have been the most important factors in developing the structural features of the great ranges, and detached uplifts, characterizing this portion of the Rocky Mountain system; while in other parts of the region—a few local instances excepted—their influence in that respect has been altogether subordinate.

It is not the intention in the present paper, which is of a pre-liminary nature, to offer very much that is new in detail; the principal object being, to indicate from an orographic standpoint, the relative importance of the different types of Cenozoic eruptive bodies, merely as an introduction to a fuller discussion of the subject of Rocky Mountain eruptions.

PERIODS OF ERUPTION.

Pre-Tertiary Eruptions.—Rocks whose time of eruption unquestionably antedated the post-Laramie revolution, are met with in several localities; notably in the Sangre de Cristo and Mosquito ranges, in the San Juan Mountains and at numerous points along the Archæan uplifts. They are chiefly represented by diorites, though relatively smaller bodies of diabase, and still more basic rocks, are not wanting. The numerous veins, or dykes, of coarse pegmatite, abounding in the granite masses of the principal ranges may also be regarded as pre-Tertiary intrusions.

Nearly all the eruptive bodies of this age underwent deformation and displacement during the subsequent mountain-making movements. But, while their presence modifies to some extent the structure of the country, important orographic effects cannot be attributed to their eruption—at least, not in connection with existing elevations. Indeed, as compared with the enormous quantity of material erupted in Cenozoic time, that of pre-Tertiary age is insignificant, and need scarcely be taken into account in considering the sum total of orogenic results.

Cenozoic Eruptions.—Among the disturbances that have affected the region in question, there are two that overshadow all others in mountain-making importance. These disturbances took place respectively at the close of the Laramie and Bridger epochs. The former was accompanied by explosive eruptions of andesitic material, which furnished the enormous accumulations of stratified sandstones and conglomerates, constituting the upper member of the group to which the term "post-Laramie" has been provisionally applied.*

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*It is proper to remark, that the tufaceous material of the Denver beds is believed by Dr. Cross to have been derived by erosion from a neighboring overflow of andesite which was completely removed by that agency.

Coincident with the post-Bridger movement, there were eruptions of diorite, augite-diorite, hornblende-and augite-porphyrites and porphyries; and at a time somewhat subsequent further eruptions of porphyrites and dolerites.[*] All of these eruptions were on a grand scale, and so far as known, altogether intrusive.

At some intermediate time, probably about the close of the Wasatch Eocene, there were extensive eruptions of andesitic breccia in the southern half of the region; followed by outpourings of hornblende-andesite, trachyte and rhyolite. In the latter part of the Tertiary, there were extensive eruptions of basalts; represented in some localities by single overflows, in others by a succession of them. Near the close of the Pliocene epoch accumulations were formed of fine volcanic dust, which contains the remains of horses and camels. Among post-Pliocene or early Quaternary eruptions were limited outpourings of quartz-trachyte or rhyolite,[†] and more extensive ones of basalt and tephrite, accompanied by intrusions of similar material. The late Quaternary and recent eruptions consisted of scoriaceous basaltic lavas, some of which may have been erupted but a few hundred years ago.

Regarding the granite cores of the Rocky Mountain ranges, it may be said, that while most of them occupy nearly the same position as the land masses whose existence dates from the Laurentian period, the eruption of the material now composing them took place during the Tertiary, and that the process was a slow, but more or less continuous one varied by epochs of acceleration corresponding to phases of pronounced orogenic movement.

THE STRUCTURAL GROUPS.

According to their mode of occurrence, rocks that are termed eruptive belong to one or the other of two prominent groups—intrusive and extrusive; or, as they are sometimes designated, plutonic and volcanic. These groups are usually distinguishable pe-

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[*] S. F. Emmons has cited evidence to show that the eruptions of the Leadville and Ten-Mile districts, in the Mosquito Range, were pre-Tertiary. "Orographic movements in the Rocky Mountains," Bul. Geo. Soc. Am. page 271.

[†] This statement has reference to the peculiar trachyte containing free quartz occurring near Whitehead Peak in the Elk Head Mountains and described by Zirkel. "Microscopical Petrography," page 161.

trographically, though this is not always the case, for the interior portion of an extruded mass, of relatively large dimensions, may have consolidated under somewhat similar conditions to the body of an intruded mass, of relatively small dimensions, derived from the same source; and thus have developed the same phases and consequent texture.

But such occurrences are exceptional and, as .a rule, there is at least a textural difference between the rocks of the two groups, even when of common origin, while from the standpoint of geol- ogical structure, the two lie far apart.   In considering the rela- tions of the several kinds of eruptive rocks to mountain making, regard will be had for this distinction, more especially in the use of terms.   For instance, the name dolorite is here intended to mean a Tertiary intrusive rock of basaltic composition; the name basalt, being applied to the extrusive representative only—though in many cases, and notwithstanding the textural difference, petro- graphers would be inclined to term them both basalts.   In like manner the name andesite, which is often applied indiscriminately to the representatives of it in both groups, is restricted to the ex- trusive and more typical rock of its kind; the allied intrusive rock being termed porphyrite, rather out of deference to common usage in this country than to any merit the name is thought to possess.

TYPES OF ERUPTIVE BODIES.

INTRUSIVE BODIES.

The eruptive bodies of this group, including thereunder the granite masses of the principal ranges, are, as compared with those of the other group, of predominant occurrence in the region speci- fied.   Nearly all those members that are purely of igneous origin —referring more particularly to bodies of mountain dimensions— were formed on the principle of the laccolite.   Hence, the pre- vailing structure, resulting from the eruption of intrusive igneous rocks, is that so characteristically exemplified in the Henry Moun- tains; or, is a modification or amplification of that structure.

The many occurrences of this kind so similar and symmetri- cal in form, are a distinguishing feature of the region, and consti- tute a group of mountain bodies nowhere else so typically devel- oped.

The cause that led to the formation of these peculiar intru-
sions is suggested by the associated geological conditions.   East
of the Wasatch Range, which is the geological and structural
dividing line between the Rocky Mountain area and the Great
Basin, the Cretaceous terraines are extensively developed; the
soft, shaly beds of the Colorado and Montana groups having an
aggregate thickness of several thousand feet.   These shaly beds
are separated from the soft strata of the Upper Jurassic generally
by massive sandstones of this age capped by about 200 feet of
Dakota sandstone, and are surmounted by from 1,500 to 3,000 feet
of Laramie sandstones.   But, except in central Colorado, where
there are soft, gypsiferous strata of Carboniferous age, the region
does not afford clays and shales of a lower horizon than the rela-
tively thin Jurassic formation.   It is in the shaly beds that nearly
all the intrusive bodies of regular form have expanded; by far the
greater number in the marine Cretaceous (Colorado and Montana
groups); more rarely, partly in these beds and partly in the Juras-
sic, while in a few instances their expansion took place in the Car-
boniferous strata referred to.   It may, therefore, be said, that
were the marine Cretaceous absent in the region during the epochs
of eruption, these typical mountain masses would have been so
rarely developed that they would scarcely have attracted more
attention than ordinary irregular intrusions—indeed, the majority
of the eruptions would have given rise to surface flows.

Range Structure.—The principal ranges of southern Wyom-
ing, Colorado and northern New Mexico, are long and often rela-
tively narrow protrusions of granitic material flanked by upturned
sedimentary beds.   They possess, therefore, the structures com-
mon to many ranges in other parts of the world.

How far such material should be considered eruptive, is a
question that scarcely admits of a satisfactory answer; nor would
it be practicable to attempt its discussson in a preliminary paper.
However, in justification of the assignment to this division of a
rock of so much orographic importance, this much may be stated.
That the squeezing up of the cores of the ranges, especially of
such as are high and narrow, like the Sangre de Cristo, was essen-
tially a mild form of plutonic eruption; and while it is probable
that, owing to the slow rate at which the up-squeezing pro-

gressed, the surface of the mass was, in all cases, thoroughly consolidated and practically rigid, the deeper parts were always sufficiently plastic to admit of deformation and contortion, or even of the intrusion of the structureless material of one zone into that of a neighboring or higher zone not so completely altered.

In much of the range granite, there is a total absence of stratification, foliation and cleavage. But there are likewise extensive exposures wherein these structures are plainly discernible—indicating that much of the material represents sediments that have been metamorphosed under great pressure, accompanied by more or less movement. It may be that part of the structureless material represents similar metamorphosed sediments that have been subjected to conditions producing semi-fusion, since it is often apparent that the one graduates into the other.

Between the stratified and massive granitic rocks, no definite relationship or order of arrangement can be made out. Presumably, the structureless material occupied the lowest position previous to the earliest (Laurentian) upheaval; the gneissic and schistose material resting irregularly upon, or graduating into it; though tongues and bosses injected from the lower zone, probably penetrated the upper one in all directions. In the disruption and deformation incident to the ·squeezing up process, the original relationship of the component rocks of the upper zone has, in most respects, been confused or destroyed. It is doubtful if the light-colored or grayish granitic rocks that cover broad areas along the range axes, show anything more than the disrupted material of this upper zone; though it may be true, as others have maintained, that the red granite commonly met with near the axial lines, is really part of the original, deep-seated zone.

Granite Quaquaversals.—The granite uplifts of the White River and Uncompahgre plateaus, and of Rawlins, Wyoming, are excellent examples of quaquaversal structure, or that which is presented by a single conical uplift whose strata are inclined from a common center. Such granite masses differ from those of the great ranges in this important particular, that they are simply local expressions of regional dynamic movement; whereas, the others are regional expressions of the same movement. Another important difference is the fact, that throughout the greater part

of geological history the former were areas of sedimentation, while the latter have, with few exceptions, always been lines of granite eruption.

Henry Mountain Structure.—Typical examples of this structure are furnished by the Henry Mountains, first studied and described by Gilbert. It is developed by the intrusion of a lens-shaped mass of eruptive material, conformably into sedimentary strata— the mass varying in relative dimensions from a thin sheet to a dome-like body of mountain proportions. Generally, the beds uplifted by the intrusion are traversed radially by a system of dykes; in some cases but few in number and scarcely noticeable, in other cases quite numerous and prominent.

The intruded rock is usually, though not always, intermediate in composition; but the modified forms of the laccolite generally consist of a rock, more acid or more basic, as the case may be, than the ordinary type. Thus, the most common dome-shaped bodies consist of hornblende-porphyrite, hornblende-diorite or augite-porphyrite; the flat, sheet-like bodies are usually dolorite; while others again, whose vertical diameter is excessive, like the enormous beehive-shaped intrusions of Gunnison County, contain orthoclase in abundance, as large porphyritic crystals distributed through a matrix of porphyrite. It is, therefore, true in a broad sense, that the more acid the intruded mass, the greater its relative vertical diameter.

The typical laccolite and its several modifications, are among the most numerous of the eruptive mountain bodies in this region; indeed are highly characteristic of it, being nowhere so perfectly and symmetrically developed. Outside of the Henry Mountain occurrences, at least thirty others of mountain dimensions might be cited.

The Compound Laccolite.—It is often the case, that, in addition to the secondary dykes, formed during the uplifting of the sedimentary arch by this type of eruption, sheet-like apophyses are sent off from the main body and penetrate the strata conformably; though in nearly all cases these sheets constitute but a small portion of the whole erupted mass. The La Plata Mountains of southwestern Colorado, furnish an example of a series of sheets or discs, differing from the preceding in the fact that the

complex apparently represents a large portion of the material erupted—the original compound body being largely made up of sheets and apophyses, varying in horizontal extent and united with one another, under a common arch of sediments, by a central eruptive core.

This interesting group of mountains seems to have been carved by erosion out of a single dome-shaped uplift, produced in the manner suggested, by the injection of a large quantity of fine-grained hornblende-porphyrite, with some diorite of similar composition, into soft Mesozoic strata. The eruption took place some time after the close of the Wasatch Eocene; but, as the later Eocene terraines are wanting in this part of the region, it is uncertain whether or not it was associated with dynamic manifestations contemporaneous with the eruption of similar material elsewhere.

The peculiar structure of the La Plata Mountains was first pointed out by Holmes, who suggests its probable origin in a diagram illustrating the original conditions at Mount Hesperus previous to erosion.*

Some idea of the aggregate dimensions of the intruded material may be had from the fact that the marine Cretaceous beds capping Mount Hesperus are about 6,500 feet higher than the same formation at the base of the mountains ten miles distant; and judging from the altitude of the Carboniferous beds nearer the center of the uplift, the Cretaceous beds at that point must have been at least 2,000 feet higher than at Mount Hesperus, which is some distance west from the apex of the dome. It is not certain that this elevation of fully 8,500 feet resulted from one eruption, though the greater part of it undoubtedly did.

The Multiple Laccolite.—This interesting modification is well illustrated in the case of the Spanish Peaks; though the neighboring group, comprising the less imposing Silver Mountain and Veta Mountain peaks, has in part a somewhat similar structure. In its typical form it consists of two or more eruptive bodies, injected at different times in substantially the same place, each injection producing a simple laccolite beneath an arch of sediments common to all the laccolites in the group.

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* Hayden's Report for 1875, pp. 270-271.

The eruptive mass of the Spanish Peaks was apparently compounded in this manner. Different bodies of porphyry, hornblende-porphyrite and augite-porphyrite, conformable among themselves and with the overlying partly metamorphosed sediments were, with the latter, subsequently faulted and displaced by the intrusion of an enormous mass of augite-porphyrite—probably the last of a sequence of laccolite intrusive eruptions at that particular center.*

It is evident that the true character of such structure, where the sedimentary beds of the surrounding country are still in their original horizontal position, could only be disclosed, either by the extension of erosion below the base of the uppermost laccolite of the complex, or else, as in the case of the Spanish Peaks, by a final eruption of such magnitude as to fracture and displace the original dome.

The neighboring mass of Silver Mountain, is the middle portion of three connected laccolites of hornblende-porphyrite, of which the westerly one forms the body of North Veta Mountain. The mass of this mountain rests partly upon a somewhat larger mass of fine-grained, light-colored porphyry, intruded at a later date and forming the body of South Veta Mountain. Other bodies of this porphyry occur in the same formation (marine Cretaceous) both north and south, and are no doubt related to the first, but the latter is the only one in contact with the porphyrite.

It is apparent, that rocks so far removed from one another as porphyry and augite-porphyrite, must represent independent phases, if not independent epochs, of eruption; and hence, that the locality of the Spanish Peaks has experienced a number of such eruptions, all intrusive in character. As previously noted, these eruptions were supplemented, at a subsequent date, by others of dolerite more widely distributed, and during the Middle Tertiary and later, the conditions established by dynamic movement invited manifestations of igneous activity in that neighborhood. What these conditions probably were, will be suggested by the diagrams referred to in the last footnote, which show, in the two cases represented, the proximity of the great fold at the east-

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*Diagrams intended to illustrate the structure of the Spanish Peaks and Silver Mountain will be found in the Proceedings of the Society, Vol. III, page 26.

ern base of the Sangre de Cristo Range. Though not shown to
that extent in the diagrams, this fold amounted to an abrupt over-
turning of the strata, and determined the establishment of a nar-
row zone of weakness along its synclinal axis. The eruptions of
the Spanish Peaks, Oak Creek, Veta, Silver and Sheep mountains
occurred along this zone of weakness; while along the fold to the
east of it, except near the Huerfano River where the upturning
exceeded 20 degrees, eruptive bodies, other than dykes and sills,
are wanting.

   The Consolidated Laccolite.—This modification consists of
two or more laccolites of common origin connected with one
another by a continuous sheet. The form is well illustrated by
the two groups just referred to. The bodies of North Veta Moun-
tain, Silver Mountain and the Black Buttes—four in number—are
not only identical in composition, but are connected on the sur-
face by dykes which rise from the intervening sheet below. In a
similar manner the Spanish Peaks are shown to be connected with
the Three Buttes intrusion.* The general arrangement of each
group of bodies is roughly along a line transverse to the axis of
the Huerfano north and south synclinal trough in which all of the
bodies are situated. While it is not the intention here to enter
into details regarding the complex dynamical geology of the
Huerfano Basin, it may be well to explain that, independent of
the systems of radial dykes associated with the laccolites, there is
a distinct system of dolerite dykes of late date, which are quasi-
parallel and likewise cut the country transverse to the synclinal
axis. The conclusion therefore is, that while the bulk of the
material erupted reached the laccolite horizon more readily along
the line of crushing and weakness referred to in the preceding
section, the points of eruption were determined by cross-fissures,
and that each bulge of a consolidated complex marks a point of
maximum injection due to local enlargement of the fissure, or
other favorable condition. Since the Veta Mountain porphyry is
also represented by a body some distance to the eastward of the
main mass, there is reason to infer the existence of a cross-fissure
even in this case. Hence, it seems highly probable that the four

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*The relation of these several bodies in the field is shown on the Sketch-Map, "Pro-
ceedings," Vol. III, page 150.

principal eruptions of this area were determined by the same num-
ber of independent movements, each of which produced fissures
transverse to the regular orogenic axis of the country. Such evi-
dence is in conformity with the view that regional or other move-
ments are usually manifested along lines of previously developed
weakness.

Dykes and Irregular Intrusions.—The systems of radial dykes
commonly associated with typical laccolites have been already
mentioned and no further reference to them at this time is neces-
ary. But there are other systems of dykes which are not radially
arranged, though produced on the same principle. Where highly
fluid basic lavas have been ejected into sedimentary beds conform-
able with their stratification, the result has been the formation of
one or more sills, or sheets of variable extent, thinning out peri-
pherally, though usually by almost imperceptible degress. Such
a sheet is really that modification of the simple laccolite which
results from extreme fluidity of the lava. In such cases the
fissuring of the overlying strata gives rise to the formation of
dykes of the same material, which are often rudely parallel. For
instance, the northern half of the Raton coal field, which includes
the Spanish Peaks, for a distance of fifty miles north and south is
traversed by a system of east and west dykes rising from a num-
ber of sills in the underlying marine Cretaceous. A similar sys-
tem, of smaller extent, occurs in the La Plata coal field near the
line between Colorado and New Mexico; and a third one in the
Yampa coal field north of the Yampa River. While these dykes
have no great vertical extent, they are usually quite numerous,
and though of little importance as factors in mountain making,
they have greatly modified the structure of certain sections of the
country.

The remaining dykes of the region are those which probably
extend to profound depths, and occupy the fissures through which
most of the extravasated material reached the surface. As com-
pared with the secondary dykes they are few in number and of no
orographic importance.

Most of the irregular intrusive bodies of Cenozoic age, while
quite numerous, are relatively of small dimensions. The majority
of the occurrences containing rocks of intermediate composition,

such as porphyrites and diorites, were probably erupted some time during the late Eocene, since many of them were evidently derived from the same magma as neighboring regular and larger bodies, whose relation to some epoch of disturbance can be defined within reasonable limits.   Others again, are themselves related to these disturbances in such a way that little doubt exists as to their probable age.   On the other hand, the occurrences of basic composition belong to the late Tertiary or early Quaternary.   These, also, are quite numerous in some localities, more particularly in the Elk Head Mountains, where they are represented by prominent necks and ill-defined bodies of feldspar- and nephelin-dolerite.

EXTRUSIVE BODIES.

Extrusive eruptions, several of them on a vast scale, have been quite common in the region under consideration, and as regards quantity of material erupted they exceeded in magnitude those of the preceding group if the granites were excluded.

The eruptive bodies of this division arrange themselves into three sub-groups, according as they have resulted from (1) a succession of overflows in one locality, (2) single overflows, and (3) scoriaceous, or cone eruptions.   These sub-groups, in the above order, are associated with the following types of mountain structure, which, it is needless to remark, are not described as being peculiar to this region, but as constituting some of its prominent orographic features.

Tushar Structure.—This term was introduced by Powell during his investigations in the Plateau Province, and was applied to the structure developed in the Tushar Mountains.   In regard to it he says:[†]

"When a plain or valley, which receives extravasated material from below, remains at a base level of erosion during the period of successive eruptions, flood of lava is piled on flood of lava until a vast mass of material is accumulated, from which the rains and streams carve mountains."

A mountain thus formed is made up of layers of eruptive material, rudely stratified, horizontally, so that the planes of contact are distinguishable on the surface of the exposures.   Such a

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[†] Geology of the Uinta Mountains, page 19.

mountain, or group of mountains, resting on a base of exposed sediments would represent this structure in its typical form. But certain causes tend to modify this form in important particulars For instance, according to the amount of erosion, the summits may be precipitous or spire-like; in other cases truncate, or the ridges may terminate in a broad plateau bounded by high escarpments. Further modification may result from the conditions of eruption, which may have taken place at a common center and given rise to conformable stratification; or from several centers, giving rise to unconformable stratification through partial, instead of complete, overlapping of the successive flows.

The San Juan Mountains of southwestern Colorado undoubtedly afford the best example of Tushar structure when developed on a grand scale and completed by the activity of erosional agencies. This magnificent group of mountains, several of whose summits exceed 14,000 feet in elevation, has been carved out of material, the upper 5,000 feet of which consists of several varieties of eruptive rocks, arranged in horizontal layers of variable thickness, some representing phases of eruption, others independent epochs. The layers have a slight general inclination to the eastward, due to subsequent elevation of the axis of the old San Juan land-mass—the main body of the eruptive area lying to the east of this axis being covered by a peripheral portion of it only.

Previous to Tertiary time there had been eruptions of diabase, diorite and probably porphyry, but their structural value is altogether subordinate. The earliest Tertiary eruption covered the country, from the San Juan axis to the Conejos Range, with coarse, andesitic breccia * which accumulated to a maximum depth of 1,500 feet. This eruption was followed by outpourings of andesite, and later on by others, among which trachytes and rhyolites are represented. The last eruptions consisted of basalts; though the most of this material was erupted near the eastern border of the area subsequent to the period of elevation referred to. It is also true that several of the later eruptions of medium and acid rocks occurred in the eastern part of the area—indicating

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*The application of the term andesite, even adjectively, to a rock of anogenic origin is open to objection, but its use may be tolerated in cases like the one above where the rocks in question now occupy an extrusive position.

that there were two or more centers of igneous activity. The out-
flow was probably, in most cases, from fissure and not from cen-
tral vents, as both the breccia and andesites are represented by
dykes cutting the formation at lower horizons.

The majority of the San Juan summits are craggy and pinna-
cled, but a few of the highest peaks, such as Mount Sneffles, Un-
compahgre and the Matterhorn are distinctly truncate, so that
they doubtless mark the uppermost limit of the accumulated flows,
the total thickness of which was about 5,000 feet.

The White River Plateau.—This plateau affords a fine ex-
ample of mountain configuration during the intermediate stages
of erosion leading to the production of a group of mountains of
the Tushar type. Here, also, while the successive flows extended
over the axis of elevation the main portion of the eruptive area
lies on one side of it, in this case to the northward. Owing to the
fact that the eruptions belong, on the whole, to a much later
period than those of the San Juan Mountains, the aggregate
amount of erosion has been less, and it is only at the northern ex-
tremity of the area, in what is known as the "Flat Tops," that a
few independent mountains of truncated form have been segregated
from the broad mass of the plateau. Again, the elevation of the
axis of the plateau preceded the epoch of eruption—whereas the
San Juan elevation was subsequent to the eruptions of that group,
except those of basaltic material. Hence, the most precipitous
border of the San Juan Mountains is near the center of upheaval,
while in the case of the White River Plateau the conditions are
reversed; the southern slopes being rounded and accessible, the
northern terminating upward in a deeply indented array of cliffs
and semi-detached table mountains.

The eruptions were probably volcanic, in the sense that most
of the material issued from a central vent located in the vicinity
of Trappers Lake, or Shingle Peak. Outflows of basaltic lava
appear to have alternated with showers of ejectamenta, until the
mass of stratified accumulations near the focus of eruption reached
a thickness of 3,000 feet. Subsequently, the top of the plateau
was scored down by ice, evidence of which action abounds, so that
above the general level of the eruptive area, which has an eleva-
tion of about 11,000 feet, there are a few isolated frustums that

rise from 1,000 feet to 1,500 feet higher and probably mark the upper limit of the accumulations.

Raton Mountains.—The main eruptive mass of the Raton Mountains—a plateau-like elevation on the line between Colorado and New Mexico—resembles that of the White River Plateau in its essential features, though the individual overflows were fewer in number and less extensive. It is doubtful, however, if the eruptions were of the same character; there being no evidence of a central vent, or of discharges of ejectamenta. On the contrary, there are several dykes cutting the Laramie beds which support the eruptive mass of the plateau; and, throughout the district, dykes and sills derived from a magma similar in composition to the basaltic overflows are of common occurrence.

Simple Plateau Structure.—In the Grande River country, the Rio Grande Valley, the Elk Head Mountains, and several localities in New Mexico and the Plateau Province there are striking examples of the development of plateau configuration, through the protection afforded by single overflows of basaltic lava, which resisted erosion more stubbornly than the sedimentary rocks of the region. Such lavas were generally erupted in a highly fluid condition, and distributed pretty evenly over the surface of the level country toward which they flowed.

The time at which these plateau basalts were poured out appears to have been subsequent to the period that witnessed the eruptions of the White River Plateau and Raton Mountains. The fact that certain small patches of Wyoming Conglomerate, occurring within the eruptive area of the Elk Head Mountains, do not contain eruptive material, points to the probability that, in this area at least, the eruptions took place as late as the early Quaternary.

While it is not certain that all of these overflows were strictly volcanic, it is highly probable that the majority of them were. The presence of old necks, or plugs, wherever erosion has been sufficient to reveal them, leaves little room for doubt in this respect; especially in such localities as the Zuni Plateau, the Elk Head Mountains, and the Leucite Hills.

Uinkaret Structure.—This term was applied by Powell to the structure developed in the Uinkaret Mountains of Arizona, which

he describes as having resulted from successive outflows of lava, each at a somewhat lower level than the preceding one, yet over-lapping its lower edge—the complex flanking, or in part surround-ing, a lava-capped core of sediments, brought out in relief by denudation during the period of eruption, and protected, from time to time, from further erosion by the floods of lava poured out at its base. So far as known this is the only example of the kind in the region under consideration.

Volcanic Structure.—Nearly all the eruptions of late Quatern-ary time were of scoriaceous basaltic lavas, ejected from craters whose position is generally marked by small cinder cones which rest upon a platform of scoria. Such cones are common in north-eastern New Mexico, in the vicinity of Mount Taylor, and in other parts of the Plateau Province described by Powell and Dutton.

The vastness and complexity characterizing many existing volcanoes are wanting in the extinct types of this region. Yet the structure is essentially volcanic, closely resembling the craters of Auvergne; especially, in northeastern New Mexico.

Probably the grandest example of simple volcanic structure that the region affords, is the mass of Mount Taylor just men-tioned. According to Dutton, it is a simple cone of andesite erupted from a central vent, traces of which still remain, though the eruption is thought to have occurred during the Tertiary period. The cone rises to a height of 3,000 feet above the plat-form of lava on which it rests. This platform, which shows many partly obliterated volcanic vents, has the extreme horizontal dimensions of forty-seven and twenty-three miles, and its mean height above the surrounding country is about 2,000 feet.*

TUFACEOUS BODIES.

The explosive eruptions of greatest magnitude, were those which occurred during the post-Laramie revolution. The mate-rial then thrown out, accumulated in enormous quantities in the lagunes along the mountain borders, forming extensive stratified deposits of sandstone and conglomerate of an aggregate thickness

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*Sixth Annual Report of the Director of the U. S. Geological Survey, page 164, et seq.

ranging from 100 to 2,000 feet. Such rocks consist of grains and rounded pebbles of andesite, cemented together by fine particles of the same material, often associated with an abundance of red heulandite, which also acts the part of a cement and imparts a decidedly red tint to many layers of the formation.

Owing to the manner in which the deposits were laid down, they are as distinctly stratified as ordinary conglomerates of sedimentary origin. Hence, they possess the bedded structure characteristic of these rocks. Only one instance can be cited—that of Ruby Peak in Gunnison County—where any considerable portion of a mountain mass has been carved out of this material; so that while it sometimes forms part of a mountain body that owes its origin to igneous activity, the bedded structure is subordinate to that which developed the mountain itself.

Tufaceous accumulations which were not deposited in water do not possess true bedded structure, though a rude stratification is often apparent. They consist of compact and fine grained rocks of andesitic and rhyolitic composition, like the building stones of Del Norte and Castle Rock; or of loosely aggregated, andesitic breccia like that of the Conejos Range and the Galesteo Valley, but not firmly consolidated and jointed like that of the San Juan Mountains. Owing to the ease with which most of these tuffs are eroded, they are much less extensive than the preceding, and really of little orographic importance.

Other deposits are occasionally met with, known as volcanic ash, which appear to have been erupted under water or in presence of it. They consist almost entirely of loosely cohering, fine particles of glass. The deposits of this kind in the basin of the Huerfano contain the remains of horses and camels.

STRUCTURAL DISTRIBUTION OF THE ROCKS.

The following list contains the most common eruptive rocks of the region, arranged according to frequency of occurrence in the structural type specified, and frequency of occurrence of the types themselves:

Intrusive Rocks.

Granitic Rocks.		Range structure.
Hornblende-porphyrite		Henry Mountain,
Augite-porphyrite	Rocks which occur as	Mount Gothic,
Orthoclase-porphyrite	laccolites or modi-	Spanish Peaks,
Hornblende-diorite	fied forms of the	Silver Mountain and
Augite-diorite	laccolite.	La Plata Mountain
Quartz-porphyry		structure.
Olivine-dolerite		
Pegmatite		
Nepheline-dolerite	Rocks which occur as	Structure developed
Diabase	dykes, necks, and	in the Raton coal
Syenite	irregular intrusive	field and Elk Head
Phonolite	masses.	Mountains.
Peridotite		

Extrusive Rocks.

Hornblende-andesite		
Augite-andesite		
Andesite breccia		Tushar and San Juan
Basalt	Rocks which occur as	structure.
Rhyolite	overflows.	Simple plateau
Trachyte		structure.
Dacite		
Leucite-basalt		
Scoriaceous basalt.	Cone-eruptions.	Volcanic structure.

Tufaceous Rocks.

Conglomerates	Stratified or rudely	
Sandstones	stratified deposits,	Bedded structure.
Ash beds	the material of ex-	
Breccias	plosive eruptions.	

DISTRIBUTION IN TIME AND PLACE.

If the sequence of Cenozoic eruptions in any one area be taken as a criterion, it will appear beyond question that the earliest consisted largely, if not wholly, of material of intermediate composition, and the latest of material of basic composition. The eruptions that took place during the intervening time were partly of intermediate rocks and partly of acid rocks, with the latter pre-

dominating towards the top.   This distribution in time can only be made out where there has been a long sequence of eruptions in one locality, as in the San Juan Mountains or in the Huerfano Basin, and cannot be extended, as a generalization, to the entire region; though it is quite probable that could a satisfactory correlation of eruptive bodies of the entire field be effected a still more definite relation throughout the series might be shown.

Considered as a whole, the rocks of the region, excluding the granites, are overwhelmingly of intermediate composition—resembling in this respect the rocks of the Basin region.   In the region to the south, on the other hand, basic rocks predominate, and the same may be said of the region to the northwest.   Thus, during Cenozoic time, the principal and earlier eruptions of intermediate material took place mainly in the Rocky Mountain area in question, while the later eruptions of basic material were more extensive in the regions to the south and northwest, for instance, in southern New Mexico, southern Arizona and Idaho.

INFORMAL COMMUNICATIONS.

Twin Crystals of Selenite.—Mr. R. C. Hills exhibited some peculiar twin crystals of selenite reported to have been obtained from a cave near Fort Stanton, New Mexico.   The crystals are said to occur at a point about two miles from the mouth of this cave, which is of unknown extent.   The forms exhibited by the crystals are P. ∞P and ∞P∞.   The twinning-plane is the orthopinacoid. The crystals occur as long, flat needles, with a decided concave curving of the prism faces.   When broken transversely the re-entering angle between the cleavage planes approximates 133°, and between nicol prisms the twinning is seen to extend to the very tip of the needle-like termination.

THE NATURE OF THE CHEMICAL ELEMENTS.

BY CHARLES SKEELE PALMER,

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It will be remembered that in the first paper attention was called to the facts, viz: that the atomic weights are the chief constants of the chemical elements; that these follow each other in a fairly regular progression; that in this progression the elements, beyond hydrogen, arrange themselves naturally in series; that the natural grouping is shown best when the elements are arranged in series, whether short or long, which begin with an alkali metal and end with a halogen non-metal; that these series, whether short or long, have a similar progressive variation in (a) physical properties, (b) chemical properties, and (c) in chemico-physical properties as shown by the remarkable curve of Lothar Meyer, of atomic weights and volumes; or better by the recast of this curve by the writer, in terms of absolute atomic volumes and gravities—in short that the series, whether short or long, have a similar physical and chemical orientation in accordance with only two extremes.

Further, it will be remembered that from the facts as stated, the inference was drawn that the "elements" so called are made up of two sub-elements or ingedients, viz: kalidium (Kd.) and oxidium (Od.) †

At that stage of the investigation nothing in detail was advanced as to the nature of these ingredients, kalidium and oxidium, but the hypothesis was advanced provisionally.

We will now proceed to examine this hypothesis of two sub-elements in its various forms and applications.

THE HYPOTHESIS OF TWO DISTINCT SUB-ELEMENTS AS SUCH.

The Additive Mode.—We will assume, for the sake of argument, that kalidium and oxidium are *real sub-elements*, and have united with each other in varying but distinct proportions to form our "elements," as the elements unite with each other to form acids, bases and salts. The illustration may be given that if we had several parallel series of varying mixtures of sand and sugar, on arranging these series of mixtures, one would at once refer them to their probable ingredients, viz: pure sand and pure sugar.

In the argument we will consider mainly the relations of the elements of the typical complete, short series including lithium, beryllium, boron, carbon, nitrogen, oxygen, and fluorine, which we will call collectively the lithium series, and similarly, the following sodium series.

On the hypothesis that kalidium and oxidium combine with each·other as distinct substances in varying proportions to form the members of a series such as the lithium series, they may combine in two simple modes, viz: by way of addition or by way of substitution. Thus to express these modes by formulæ we would have in the lithium series, by the addition mode:

Li.$=$Kd.; Be.$=$Kd. $+$ Od.; B.$=$Kd. $+$ Od.$_2$; C$=$Kd. $+$ Od.$_3$:
N.$=$Kd. $+$ Od.$_4$; O.$=$Kd. $+$ Od.$_5$; F.$=$Kd. $+$ Od.$_6$.
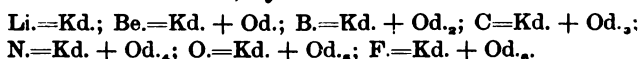
By the substitution mode we would have:

Li.$=$Kd.$_6$; Be.$=$Kd.$_5$ $+$ Od.; B.$=$Kd.$_4$ $+$ Od.$_2$; C.$=$Kd.$_3$ Od.$_3$;
N.$=$Kd.$_2$ $+$ Od.$_4$; O.$=$Kd. $+$ Od.$_5$; F.$=$Od.$_6$.
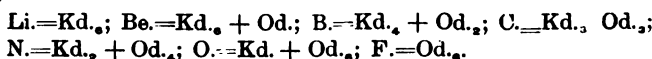
Now according to the addition mode we should find a *regular* difference between any two successive atomic weights. This regularity we do not find in the differences.

Li.	Be.	B.	C.	N.	O.	F.
7	9	11	12	14	16	19

Differences,	2	2	1	2	2	3

Now if we call *one* the smallest unit of oxidic increment, because $C^{-12-}-B^{-11-}=1$, there should be one (unknown) element between Li. and Be.; also one between Be. and B.; also one between C. and N.; also one between N. and O.; also two between O, and F. But the beautiful consistency of the valence and other chemical relations of the lithium series, and the failure to find any such missing elements, or even to feel the *need* of them in developing the comparative chemistry of this series, precludes the probability, to say the least, of any such intermediate elements.

But if we suppose a constant increment of *two units* in the lithium series. we obtain,

Li. Be. B.   C.   N.   O.   F.
7 — 9 — 11 — 13 — 15 — 17 — 19
Common differences,   2   2   2

and deducting 1 from three cases, gives us the actual or approximate atomic weights. This deduction of 1 might be analogous to the loss of one or more molecules of water from so-called normal compounds.

But this supposition of "normal" and "meta" elements, as compounds of kalidium and oxidium, involves too much uncertainty, and also implies that some element having an atomic weight of 1 represents this difference. Hydrogen probably could not be this measure of difference, for hydrogen is inherently basiferous, and the hypothetical element implied in the difference 1 from the normal, should be neutral or equally basic and acid, as water is in common condition. In another form this problem of "normal" and "meta" elements, will come up later and promises to be of much value, viz: in the discussion covering the *exact* or *average* atomic weight.

On the other hand, the decreasing ratio of the oxidium increment to the kalidium nucleus, resulting from the additive mode in the *successive* lithium, sodium, potassium and rubidium series, is in accordance with the well known fact that, as a whole, the series considered as units grow more basic (kalidic) rather than acid (oxidic).

Thus the increment of $Od._6$ to the nucleus $Li.^{-7-}$ would give a higher per cent. of oxidic nature for fluorine, than would $Od._6$ to the nucleus $Na.^{-23-}$ for chlorine, etc.

But on the whole, in spite of the favorable argument of the decreasing acidity of the successive series, the failure to satisfy the numerical relations of the atomic weights, as illustrated in the lithium series, and equally so in subsequent series, justifies us in *rejecting the simple additive mode* of combination of kalidium and oxidium: this being inadequate to explain fairly the actual progression of known atomic weights.

The Substitution Mode.—We proceed next to examine the substitution mode.

According to this method, as indicated above, we should have the formulæ given in the table below in column 3.

1	2	3	4	5
Li.	7·01	$Kd._6$	$Kd. = 1·16$	
Be.	9·0	$Kd._6 + Od.$	$\{\ Kd. = 1·2$	$Od. = 3·0$ (Between).
B.	10·9	$Kd._4 + Od._2$	$\{\ Kd. = 1·45$	$Od. = 2·5$ (Between).
C.	12·0	$Kd._3 + Od._3$	$\{\ Kd. = 1·$	$Od. = 3·0$ (Between).
N.	14·0	$Kd._2 + Od._4$	$\{\ Kd. = 0·64$	$Od. = 3·32$ (Between).
O.	15·96	$Kd. + Od._6$		$Od. = 3·17$
F.	19·	$Od._6$		

Solving these formulæ, column 3, as for simple equations of two unknown quantities, and comparing two equations consecutively, in order, we obtain the respective values for oxidium and kalidium indicated in columns 4 and 5. *The results are by no means satisfactory for the simple substitutive mode of combination of oxidium and kalidium.* The values for kalidium and oxidium should be approximately constant. The value of kalidium varies from *plus* 1·45 to *minus* 0·64, and that of oxidium from 2·5 to 3·17.

Another method of illustrating the variation of the hypothetical figures from the actual ones is shown in the following table, where the values of oxidium and kalidium, in fluorine and lithium respectively, are substituted in the formulæ for the intermediate elements.

1	2	3	4
Li. = 7· Be. = 9· B. = 10·9 C. = 12· N. = 14· O. = 15·96	$\frac{1}{3} = \begin{cases} 1·16+ \\ \text{or} \\ Kd. \end{cases}$	Li. = $Kd._0$ Be. = $Kd._0$ Od. B. = $Kd._4$ $Od._2$ C. = $Kd._3$ $Od._3$ N. = $Kd._2$ $Od._4$ O. = Kd. $Od._6$	Li. = 7· 7· Be. = 5·80+ 3·16 = 8·96 B. = 4·64+ 6·32 = 10·96 C. = 3·48+ 9·48 = 13.96 −1 = 11·96 N. = 2·24+12·64 = 14·96 −1 = 13·96 O. = 1·16+15·80 = 16·96 −1 = 15·96
F. = 19·	$y = \begin{cases} 3·16+ \\ \text{or} \\ Od. \end{cases}$	F. = $Od._6$	F. = 19· = 19·

The results are unsatisfactory in the cases of carbon, nitrogen and oxygen, in each of which the results are about one unit too large. It will be remembered that these elements exhibited irregularities, and with about the same deviation, according to the simple additive mode. The matter will be discussed later.

The comparative chemistry of the successive series in exhibiting *increasing basiferous* tendencies in the higher orders, is an argument decidedly against the simple substitutive mode of combination. For, according to this mode, similar termini of the different series should consist respectively of pure kalidium and pure oxidium, and, therefore, lithium, sodium, potassium and cæsium, on the one hand, should be equally basiferous; and, on the other hand, fluorine, chlorine, bromine and iodine should be equally acidiferous. Such, however, is not the case. Therefore we observe that both the arguments from the numerical comparison of the theoretical formulæ, with the actual atomic weights and from the comparative chemistry of the different series, are against this simple substitutive mode.

Thus, we conclude, provisionally, that neither the simple additive, nor the simple substitutive mode of combination of kalidium and oxidium will satisfy both the numerical relations of the atomic weights and the chemical relation of the series, considering the hypothetical sub-elements as real matter of sub-atomic weights numerically comparable with known atomic weights. It must be observed that the results do not dispose of the question of the *composition* of the elements in terms of *oxidium* and

kalidium, but only point to another mode, and probably an excessively fine degree of subdivision of the atom in terms of subatoms; i. e., that the atom is made up of parts excessively minute as compared with the atom.

THE HYPOTHESIS THAT HYDROGEN IS THE PROXIMATE INGREDIENT OF THE ELEMENTS.

This view, called the hypothesis of Prout, is frequently referred to in recent publications. As introduced here, it would imply that hydrogen is composed of the hypothetical kalidium and oxidium, and represents an intermediate stage between these on the one hand, and our actual, heavier elements on the other. We observe that hydrogen *per se* can not be regarded as the simple ingredient of the higher elements, because:

(a) There should be only even multiples of hydrogen as unity for atomic weights; one variation—as 35·37—for chlorine destroys the argument.

(b) Hydrogen is inherently basic, and, while it might be looked upon as the prototype of the metallic and basiferous (kalidic) elements, it cannot be looked upon as the prototype of the non-metallic and acidiferous (oxidic) elements.

(c) Hydrogen is probably a part of a complete and independent series the other members of which are at present unknown, and there is no good reason to look upon hydrogen as more elementary than the other elements, or to degrade it from the rank of the other known elements to which it is clearly related in nature and origin.

Thus, a calculation of the hypothetical missing elements between hydrogen and lithium gives the following results. If we calculate up from hydrogen, using the ratios of increase in the lithium series, we obtain the figures in the upper line of Table A. If we calculate down from lithium, using the ratios of sodium to fluorine and thence to lithium, we obtain the figures in the second horizontal line of the table; we then get 2·137 for pre-lithium. If we calculate for pre-lithium up from the 2·606—the terminal figure

TABLE A.

CALCULATION FOR TWO INTERMEDIATE SERIES SHOWING IMPROBABILITY.

H. 1.	? 1·295 $\frac{Li.}{Be.} = \frac{1}{1·295}$	? 1·554 $\frac{Li}{B.} = \frac{1}{1·554}$	? 1·707 $\frac{Li.}{C.} = \frac{1}{1·707}$	? 1·910 $\frac{Li.}{N.} = \frac{1}{1·910}$	? 2·276 $\frac{Li.}{O.} = \frac{1}{2·276}$	? 2·606 $\frac{Li.}{F.} = \frac{1}{2·606}$
? 3·28 $\frac{F.}{Na.} = \frac{2·606}{3·28·}$						
? 2·137 $\frac{F.}{Li.} = \frac{5·57}{2·137}$	? 2·47 $\frac{F.}{Be.} = \frac{5·57}{2·47}$	? 3·32 $\frac{F.}{B.} = \frac{5·57}{3·32}$	? 3·65 $\frac{F.}{C.} = \frac{5·57}{3·65}$	? 4·27 $\frac{F.}{N.} = \frac{5·57}{4·27}$	? 4·865 $\frac{F.}{O.} = \frac{5·57}{4·865}$	? 5·57 $\frac{Na.}{F.} = \frac{Li.=7}{5·57}$
Li. 7·01	Be. 9·1	B. 10·9	C. 11·97	N. 14·01	O. 15·96	F. 18·26
Na. 22·99	Mg. 23·94	Al. 27·04	Si. 28·	P. 30·96	S. 31·98	Cl. 35·37

of line one—we obtain 3·28, which is larger than 2·137, obtained by calculating down. Thus, there is an *over lapping* of figures, and hence there is probably no mathematical opportunity for the existence of *two* complete series between hydrogen and lithium.

The value of fluorine is 18·26, the figures provisionally announced by Moisson two years ago; they are also the approximate figures obtained from the actual density of fluorine, as given by the most recent measurements.*

Moreover, if these figures, 18·26, are not in harmony with the calculation for two intermediate series, still less would be the figure 10, a higher figure, giving a ration of decrease and a corresponding discrepancy.

If, however, we calculate the rate of increase for each step in the lithium series, and also for the sodium series, and then assume that the rate of increase for the missing numbers of the hydrogen series is as much larger than the lithium series, as is the rate of the lithium series greater than that for the sodium series, we obtain the results given in the first horizontal line of Table B.

The results clearly show the numerical possibility for the existence of *one complete short series* of seven members between hydrogen and lithium, of which series hydrogen is a member.

The calculation given above assumes that hydrogen is the first or most basiferous (kalidic) member of its series, an assumption which is fairly well warranted by the following considerations, viz.:

(a). If hydrogen be not the basic terminus of its series, there should be elements below it with a valence less than that of hydrogen. Such instances are not known, except possibly in the case of the ambiguous elements of the middle of the long series, in the so-called VIIIth Group of the old classification; Pd_2H, Na_2H and K_2H may be cases in point, or they may be of the nature of alloys; but there are no *volatile* compounds which would indicate a lower valence than that of hydrogen, and the alkyl or organo-metallic compounds of the elements indicate their respective normal valences on the basis of hydrogen as unity.

(b). The second argument in favor of the view that hydrogen

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* Moisson, Ann. de Chem. et Phys., Jan., 1892 p. 131.

TABLE B.

CALCULATION FOR ONE INTERMEDIATE SERIES, VIZ.: THE PROBABLE HYDROGEN SERIES.

	? 1·62	? 2·056	? 2·402	? 2·97	? 3·688	? Pre-Flourine 4·428
H. 1.	1·04 1·297 / 1·297 1·62	1·176 1·555 / 1·555 2·056	1·217 1·71 / 1·71 2·402	1·348 2·001 / 2·001 2·97	1·391 2·265 / 2·265 3·688	1·538 2·61 / 2·61 4·428
Li. 7.	Be. 9·08 $\dfrac{\text{Li.}}{\text{Be.}} = \dfrac{1}{1·297}$	B.10·9 $\dfrac{\text{Li}}{\text{B.}} = \dfrac{1}{1·555}$	C.11·97 $\dfrac{\text{Li.}}{\text{C.}} = \dfrac{1}{1·71}$	N.14·01 $\dfrac{\text{Li.}}{\text{N.}} = \dfrac{1}{2·001}$	O.15·96 $\dfrac{\text{Li.}}{\text{O.}} = \dfrac{1}{2·265}$	F.18·28 $\dfrac{\text{Li.}}{\text{F.}} = \dfrac{1}{2·61}$
Na. 23.	Mg.23·94 $\dfrac{\text{Na.}}{\text{Mg.}} = \dfrac{1}{1·04}$	Al.27·04 $\dfrac{\text{Na.}}{\text{Al.}} = \dfrac{1}{1·176}$	Si.28 $\dfrac{\text{Na.}}{\text{Si.}} = \dfrac{1}{1·217}$	P.31 $\dfrac{\text{Na.}}{\text{P.}} = \dfrac{1}{1·348}$	S.32 $\dfrac{\text{Na.}}{\text{S.}} = \dfrac{1}{1·391}$	Cl.35·37 $\dfrac{\text{Na.}}{\text{Cl.}} = \dfrac{1}{1·538}$

represents the basiferous terminus of its series is found from the
general comparative chemistry of hydrogen. This will be consid-
ered later in detail.*

It may, however, be anticipated here that:

(1) The comparison of the known volatile hydrogen com-
pounds of the non-metallic elements indicates that hydrogen is
antithetic to the non-metals and has a clear valence of one, anal-
agous to lithium, sodium and potassium.

(2) Hydrogen masks its active chemistry by reason of its
excessive volatility; but under pressure, it replaces copper, silver
and gold from their salts. The location of hydrogen, in the table,†
over the copper group is only provisional and approximate.

(3) The different series were probably distinct in their origin
and evolution, and we shall not expect to find more than a general
parallelism between similar elements of different series.

(c). The third argument for the view that hydrogen repre-
sents the basiferous terminus of a series, is found in the similar
orientation of all distinct series, whether short or long. The
interpretation of this fact given in the succeeding pages of this
paper, implies that the hydrogen series experienced a mode of
disintegration, evolution and differentation similar to that of the
other series. Hence, in view of our ignorance of other members
of the hydrogen series, we need not assume unknown elements for
all the gaps in the first line of Table B of this paper, but we will
find it necessary to assume the existence of at least *one non-
metallic element* at the acidiferous terminus of the hydrogen
series to balance the basiferous kalidic hydrogen. This hypo-
thetical element we name provisionally *pre-fluorine* (Pre.F.); its
atomic weight will be about 4·4. The remarkable properties
which it must possess will be discussed in the Fourth paper.

Thus, we observe on the whole that hydrogen is probably as
genuine and substantial and stable an element in its independent
series, as are the other known elements in their respective series;
and there is no good reason for relegating hydrogen to the office

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*See fourth paper of the series, read at the November meeting, 1891.
†See page 294, Proceedings of 1890.

of an approximate ingredient, or for assuming that it is made up of other known elements of more gross atomic mass than itself.

To state that *both* hydrogen and the other elements may have the same sub-elements in common, is another form of the Hydrogen hypothesis entirely distinct from the original Prout's hypothesis, and, indeed, it is just the problem which we are considering.

Thus we observe that we can not find good evidence to justify our illustration of a series of mixtures of sand and sugar for the mode of union of kalidium and oxidium. The illustration was faulty in implying that our so-called elements could be even hypothetically resolved into pure, isolable, concrete kalidium and oxidium, as the mixture of sand and sugar can be resolved respectively into pure, concrete, sand and sugar.

How, then, shall we regard *kalidium* and *oxidium?*

The facts on which their inference rests are still facts and the inference is still the simplest interpretation of those facts. It is probable that while kalidium and oxidium are the proximate ingredients of our known elements, they are so in a modified sense which requires careful examination and definition. We therefore proceed to consider the hypothesis that:

The generic kalidium and oxidium are not necessarily concrete, isolable varieties of matter, but they represent the embodiment of those antithetic properties which are synonomous respectively with basiferous and acidiferous properties.

We shall gain help in forming this conception by pausing for a moment to consider the sagacious views of the ancient Greeks respecting the supposedly elementary nature of Earth, Air (or Vapour), Fire and Water. It is not true as is frequently crudely stated, that the Greeks regarded these as elements *per se;* but rather as representing all the possible combinations of any two of the following properties, viz.: *hotness, coldness, wetness,* and *dryness.*

These four properties give mathematically six combinations, viz.: (1) Hotness and coldness—an absurdity. (2) Wetness and dryness—an absurdity. (3) Hotness and wetness, air or

vapour (as steam). (4) Coldness and wetness—water. (5) Hotness and dryness—fire. (6) Coldness and dryness—earth.

That the Greeks, from the double combination of their four supposed elemental properties derived only four supposed elements, is an illustration of the keenly exact intuition of that gifted people, so far as they studied natural phenomena.

Without attempting in any manner or degree to excuse them from the charge of entertaining conceptions both superficial and worthless in a scientific sense, we would, however, call attention to the form of their conception and its value for our present service, and this is true, in general, whether the Greeks originated their hypothesis themselves or borrowed it from some other more ancient people.*

We thus observe that *kalidium* and *oxidium* probably represent the *typified, contrasted basiferous* and *acidiferous properties,* and inasmuch as distinctions of matter probably imply not only distinctions in mass but also distinctions in *structure,* they therefore suggest distinctions in possibilities of internal motion; consequently we reduce the contrasted properties implied in oxidium and kalidium to contrasts of sub-atomic structure and mechanics.

In suggesting this explanation, at first glance, we would seem to come abruptly to an impossible barrier in the progress of our thought. For, granting that kalidium and oxidium do represent the contrasted fundamental *types of sub-atomic structure and mechanics,* what light can we gain as to their real meaning and interpretation?

Now, the elements are a part of the external phenomena and processes called nature; indeed, they are the *whole* of the known substance of that nature. If any general theorem of science has been proven, it is that all the processes of nature play their part in the great process called evolution.

To assume that the elements *per se* were *made things* at the *beginning* of this process, or, indeed, that there *was* any *assignable and conceivable beginning* to the process, is to make a most dogmatic and unwarrantable assumption. The burden of proof rests

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*See E. Von Meyer, Gesch. der Chem, p. 8 and foot note; or, McGowan's translation of the same, pp. 9 and 10; also, Kopp. Gesch. der Chem., Theil I, pp. 30 and 31; also, Liebig's Letters on Chem., p. 71 (Blyth's translation).

decidedly on the one making the assumption. Therefore, the elements, as a part of the process of evolution, must represent the products of anterior processes. They have their own history, their own process of formation, and from the study of the presumable nature of this process of the evolution of the chemical elements, we shall certainly gain assistance in conceiving the nature of oxidium and kalidium.

THE MAIN FACTS RESPECTING THE CHEMICAL ELEMENTS AND THEIR INTERPRETATION AS REGARDS THE PROBABLE PROCESS OF ATOMIC EVOLUTION.

The Miscrocosmic Hypothesis.—We now come back to fundamentals and ask what are the main facts as regards the natural classification of the elements, and how are these facts to be explained? We will find that the facts themselves suggest a most beautiful mode of evolution of the microcosm which is as simple and elegant in its outline as is the nebular hypothesis for the macrocosm. We will, therefore, designate this as the *microcosmic hypothesis*.

(a) The *first* fact regarding the elements is that the figures for their atomic masses form a simple progressive series of numbers without duplication. The apparent identity of the atomic weights of cobalt and nickel can be only a temporary anomaly, for the comparative chemistry of the two indicates beyond doubt that cobalt must have a less atomic mass than nickel.

(b) The *second* great fact is, that the elements probably not excepting hydrogen, are arranged in *distinct series*, whether short or long, of similar physical and chemical orientation; these series are removed each from its neighbor by distinct intervals; there is no overlapping or ambiguous duplication.

(c) The general nature of chemical affinity is probably to be referred to electrical phenomena. Electro-chemical theories have frequently been the fashion in the chemical world; but let us enumerate some of the principal facts which point clearly in this direction.

1st. There are only two kinds of contrasted electric and mag-

netic polarities, and there are only two kinds of contrasted chemical extremes.

2nd.   The basiferous elements in general and the acidiferous elements as contrasted seem to have inherent, electro-positive and electro-negative charges respectively, or inherent capacities or receptivities for these charges.

3rd.   Faraday's law of electrolosis; viz.: "Equivalent quantities of electricity require equivalent quantities of the ions for their transport."

4th.   The new hypothesis of the process of electrolosis and of the structure of solutions. (Theories of Arrhenius and of Planck.)

5th.   The inherent magnetic polarity of certain molecules, as $Fe_3 O_4$ ($Fe_2 O_3$, Fe O) and $Cr_5 O^7 = 2(Cr_2 O_3$, Cr O) in which one element exists at the same time in two distinct states of oxidation. [The inference from this point will be considered later in detail; the provisional hypothesis will be advanced that whenever a molecule consists essentially of one element, in two distinct states of oxidation, such a molecule should exhibit properties implied in magnetic polarization.]

6th.   The simplest hypothesis of electric conductivity in metals and alloys. [This subject will also be specially treated in a later paper. It may be here anticipated that the hypothesis entertained regards the atoms of metals as made up of kalidic and oxidic *sub-ions* or *ionicules*, which conduct electricity the better according as the equilibrium between these is better adjusted; thus, the best metallic conductors, copper, silver and gold, have in general their correct location in the periodic arrangement, inasmuch as they are each to the right of the centers of their respective series.]

7th.   The para-magnetic and dia-magnetic relations of the elements, it being an independent observation of the writer that according to the arrangement in long and short series, the elements in the left half of the table are in general para-magnetic, and the elements in the right half of the table, dia-magnetic. [This subject will also be the special topic of another paper].

8th.   The electric polarity of many hemi-morphic crystals.

9th.   The hitherto unexplained fact, that while nitrogen, oxy-

gen, fluorine, chlorine, bromine, etc., do not form stable compounds with each other, being similarly elements chemically, yet in each case *two* atoms of the same element do unite respectively to form the fairly stable molecules N_2, O_2, F_2, Cl_2, Br_2, etc. It would be premature to discuss this here in detail, but even compounds may be explained by the union of similar magnetic atoms lying together according to a head and tail arrangement. [This will be discussed later.]

Other arguments might be adduced, but the enumeration given above is sufficient to indicate the close connection which undoubtedly exists between chemical and electro-magnetic action.

Now, we have these three great facts, viz.: *First,* The progression of the atomic weights; *second,* the serial grouping of the elements according to similar kalidic and oxidic orientation, and, *third,* the electro-chemical nature of kalidic and oxidic property and action.

With these three facts clearly in mind, let us look for some one continuous and uniform process which will explain each of these facts in turn, and which will include the genesis of each series and of each element.

(1). How shall we explain the regular progression of atomic mass?

The simplest explanation is to suppose that there was at an early stage of matter, *one ground substance* which, to borrow a convenient term, we will call *"protyl."* It should be emphasized here that although we make use of Prof. Crooke's term, yet in the mind and judgment of the writer there is *no connection whatever* between his theory and the present investigation, and, indeed, to go further, the writer does not know of any distinct statement of the outlines of atomic evolution other than the one developed in this series of papers, which can be utilized either as a safe guide in speculation on the origin of the elements, or as a working hypothesis for their comparison.

Now, let us suppose this "protyl" to have been brought into a mass, or masses—whether one or many, is indifferent here, as is also the size. This mass we can not certainly call a *molecule,* i. e. a *little mass;* nor a *magne-mole,* i. e. a *large mass.* We will, therefore, call it the *protyl-mole.* The presumable condition of this

protyl-mole must have been one of the most intense heat, and probably far more intense than anything realized in the visible universe in these latter frigid days. Let us suppose that the matter composing this *protyl-mole* suffered condensation, and in accordance with this condensation there was developed a pressure which acted in a manner analogous to the laws of liquid pressure, viz.: that this condensing pressure would increase *directly as the depth*. As the result of this pressure, the material of the *protyl-mole* would be differentiated in specific gravity, according to the increasing specific gravity at increasing depths. In this regular progression of the increasing specific gravities of the protyl matter we have the seat of the explanation of the progression of the atomic weights as we know them. Not that atoms as such were probably completely differentiated at this stage; but that the progression of the atomic weights was foreshadowed in the progressive degrees of condensation at increasing depths of the *protyl-mole*, we need not doubt.

The *second* great fact of the serial arrangement of the elements in similar orientation would seem to imply that, after the condensation of the *protyl-mole* and perhaps during its process, there occured a spherical weathering, probably due mainly to the intense radiation of heat, whereby the *protyl-mole* broke up into a succession of similar *shells* of varying and probably increasing depth and thickness; thus, each of our known series would in order be represented by a shell, weathering off from the molar nucleus; and, counting from without inward we have positive evidence of a successive formation of at least *eight* shells, viz.: the hydrogen shell, the lithium shell, the sodium, potassium, the rubidium and cæsium shells, and, beyond this, those which we may call the platinum and the uranium shells, respectively.* Below the uranium shell, and within it, there may have been formed shells with elements having heavier atomic weights, and outside of hydrogen and above it there may have been previously formed a succession of lighter shells made up of elements too light and too tenuous to be detected by our coarse balances and apparatus.

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* See table and diagram in the First Paper, Vol. III., Proceedings.

Further, as any one shell was first thrown off, its elements would exhibit at this stage only possibilities of that variety of chemistry which we designate *passive chemistry,* and which involves only a *difference in degree,* but not in kind. As each shell would continue to radiate heat and to disintegrate under the combined action of its own instability and also of disturbance from the contracting protyl nucleus within, we would have a second period and type of differentiation in which we would probably find the seat of the explanation of that chemistry which involves a *difference in kind,* and which we designate as *active chemistry.* [The definition and description of *passive* and *active* chemistry will be given in the fourth paper of this series.]

Now, in the process of disintegration of these successive rings, and in the process of the disintegration of the *protyl-mole.* there would probably be induced an axial rotation of the mass as a whole. This rotation of the rings would result in the filling out of the shells at their poles, and a contraction of their substance toward their equators, thus changing these shells into rings.

We now observe that as each series is represented by one of these successive shells, and that, inasmuch as each series has a similar orientation to the corresponding shells, they must have experienced similar successions of conditions in their development and disintegration.

We now turn to the *third* fact of the electro-chemical nature of affinity. This is really very closely connected with the contrasted orientation of any one series repeatedly referred to. As the lighter elements were developed, on the outside of the heavier elements presumably, lithium, sodium, etc., were formed in the exterior strata of their shells, and fluorine and chlorine in the interior strata of their respective shells.

To explain the contrasted structure implied in the kalidic and oxidic extremes, all that we need to show here is that the conditions of disintegration of the *inside* parts of all shells or rings were similar, and also that the conditions of the *outside* parts of all shells or rings were similar; and that the conditions of *inside* parts in disintegration were relatively different from all *outside* parts and *vice versa.*

In general, this difference is illustrated by the following:

The original conditions of each shell imply a regular increase of specific gravity in any series from kalidic to oxidic extremes. Now, the present conditions of the elements in known series illustrate a progressive increase in atomic weight, but a progressive increase in specific gravity only to the middle of the series. This retrogression of specific gravity is illustrated by the retreating branch of the two forked curve in the diagram of the first paper.[*]

Shall we explain this apparent discrepancy simply by putting both sides of the paradox together, and by supposing each to be correct in its own sequence of time? This would imply that while originally the elements in any one series were packed in order of increasing specific gravity, just as they were separated from the apparent nucleus, yet, when the shell disintegrated under the complex conditions previously referred to, the separating atoms expanded; that the inside half of each shell expanded most, and that the atoms of the inside parts expanded most of all; and that, while this expansion took place, producing a retrograde specific gravity in the last half of each series, yet this re-arrangement of the specific gravities did not disturb the regular progression of the atomic weights.

Here we observe that as each ring disintegrated it expanded; the outside of each ring, outward, and the inside of each ring relatively inward toward the nucleus. This local expansion of each shell or ring, taken in connection with the centrifugal force of the protyl-mole as a whole, would probably produce a peculiar twisting motion and structure where the conditions of the outside and inside would be relatively different. Thus, we find a plausible explanation for contrasted structure and mechanism of the outside or kalidic, and the inside, or oxidic parts of each series, ring or shell. This period of disintegration of the protyl shells was probably the most important one for the history of atomic evolution.

This expansion of the ring in disintegration offers the explanation referred to in the first paper, of the apparent intersection of the first branch of a curve by the second branch of the preceding curve. As mentioned before, the interference is, however, probably accidental.

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[*] See opposite page 303, Proc. C. S. S., Vol. III, 1890.

Thus we observe that the *three essential facts* give their own interpretation of the probable outline of atomic evolution, involving, first, an early period of protyl condensation in the mole; second, the weathering of this protyl mole into shells; third, the rotation involving the change of the shells into rings with their subsequent disintegration. From the probability that the shells expanded not only as a whole, but also in parts, we derive the direct inference that the atoms expanded; and, therefore, are made up of *smaller parts*, viz.: "sub-atoms" or "atomicules," which separated from each other in the expansion of the atom as a whole. Thus, when the sodium shell was yet a part of the protyl-mole, the phosphorus, sulphur and chlorine atoms must have had progressively heavier atomic weights; but, when the sodium shell expanded as a *whole*, each part expanded, and the phosphorus, sulphur and chlorine atoms, while retaining their relative mass, became progressively lighter in specific gravity on expanding towards the inside periphery of the shell; and these phosphorus, sulphur and chlorine atoms expanded because they were made up of *compressed parts*.

The irregular increase of atomic mass, and the irregular variation of specific gravity, would indicate a *multiplicity* of *stages* of *sub-division* and *granulation* of matter below the atom.

The analogy of this microcosmic hypothesis with the nebular hypothesis is too obvious to require comment. It is, however entirely accidental. The statement of the micro-cosmic hypothesis can be only preliminary. The detailed consideration suggests two lines of work: 1st. The completed and corrected statement of the hypothesis as a basis for speculation in atomic evolution. This line of work will probably soon pass from the hands of the mere chemist to the expert mathematician and physicist. 2nd. From the standpoint of pure chemistry, this hypothesis must be applied to the comparative study of the elements and their series. It must be shown that it obeys the known laws of evolution in differentiation; and here a large field opens for the chemist. Some of the principles of this new comparative chemistry will be considered in the Fourth paper of the series.

THE NATURE OF THE CHEMICAL ELEMENTS.

(THIRD PAPER)

By CHARLES SKEELE PALMER,

Professor of Chemistry, University of Colorado.

Read at Meeting, October 5th, 1891.

In the investigation of the nature, relations and origin of the chemical elements, and in the details of the new Comparative Chemistry, it is an essential point to determine accurately the series limits of the elements in their so-called "periodic" classification. In the present investigation, the writer has based his work on the following classification, as figured and tabled in the First Paper, viz.:

Series I.   Hydrogen: At present a unique instance of a series comprising only one known member; and this represents not the strongly basiferous chemistry of the common alkalies, but, rather, something analogous to the weakly basiferous nature of the copper, silver and gold groups in their monad valence compounds. This does not preclude the possibility that hydrogen is at the basiferous terminus of its series, as the other missing members of this first series are probably highly acidiferous.

Series II.   Lithium to Fluorine   } Short Series of seven

Series III.   Sodium to Chlorine   }   members.

Series IV.   Potassium to Bromine   } Long Series of seventeen members.

Series V.   Rubidium to Iodine, wanting only Eka-Manganese

Series VI.   Cæsium to Eka-Iodine, ⎫
Series VII.   Eka-Cæsium to Dwi-Iodine, ⎪ Incomplete, but
        and including the Plati- ⎬ probably a Long
        num Groups and contigu- ⎪ Series of not less
        ous heavy metals ⎭ than seventeen
Series VIII. Dwi-Cæsium to Tri-Iodine, ⎫ members.
        and including Thorium ⎬
        and Uranium.   · ⎭

The chief evidence offered hitherto is:

(a). The comparative evidence of the physical properties.

(b). The comparative evidence of the chemical properties.

(c). The comparative evidence of the chemico-physical properties, as shown roughly in Lothar Meyer's curve of the elements in terms of their atomic weights and atomic volumes; or, much better in the author's re-cast of this curve in terms of the atomic volume and atomic gravity of hydrogen as unity, whereby each complete series is represented as an open two-branched paraboloidal curve, and this, whether this series be short or long.

Any new evidence bearing on this investigation is evidently of high value; and the main object of this very fragmentary paper is to call attention to an important contribution in the form of a paper found in the Philosophical Magazine for January, 1883, by Mr. A. P. Laurie, of Kings College, Cambridge, Eng., on "The Relations Between the Heats of Combination of the Elements and Their Atomic Weights." In this paper, which is as valuable as it is brief and concise, Laurie gives the heats of combinations of the elements with chlorine, bromine, and three diagrams for the respective cases.*

A copy of Laurie's diagram for chlorine is added with this paper as far as the cæsium series; beyond this it is too fragmentary to be of value. The numbering of the series is an addition by the present writer, for obvious purposes, as is also the addition of the symbols.

The following observations are pertinent:

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*A similar diagram; of Laurie's work is to be found on p. 230 of Mr. M. P. Muir's "Principles of Chemistry," First Edition, and also on p. 96 of Muir and Wilson's "Elements of Thermal Chemistry."
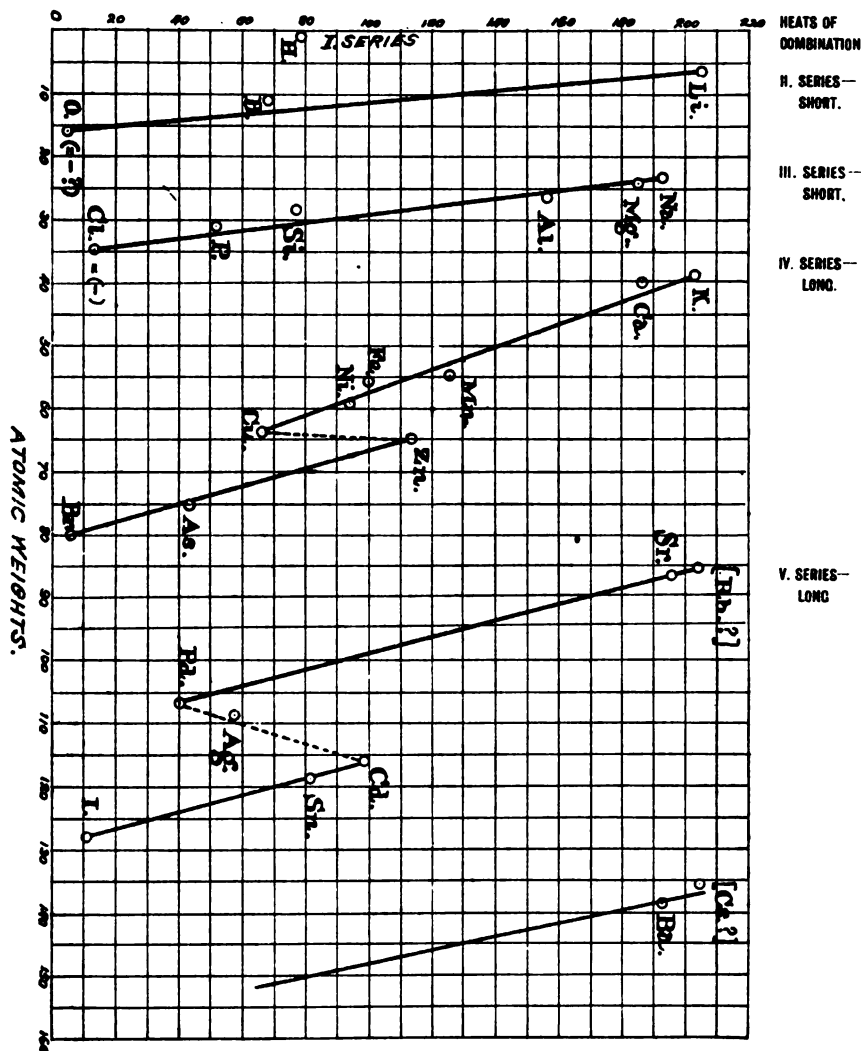
COPY OF A. P. LAURIE'S CURVE OF THE HEAT
RELATIONS OF THE ELEMENTS
WITH CHLORINE.

Philosophical Magazine, January, 1883.

1. The elements fall into just the same series as described by the present writer, with similar termini and similar orientation.

2. There is an irregularity in the middle of the long series in the region commonly called the " VIIIth Group" in the old classification, and designated as the 8th, 9th, 10th, and 11th groups of the new classification. This irregularity needs explanation, and such is probably forthcoming; but it does not militate at all against the correct location of the termini of the series, nor against the grouping of the series as a whole. It may be premised here that the probable explanation will be found in the "double induction" hypothesis to be considered in the next paper, and outlined in the preceding one.

3. The weakly basiferous nature of hydrogen, as already noticed in this paper.

The projections of Laurie, given in 1883, are susceptible of much improvement and many additions, and it is the aim of the writer to undertake shortly such a recalculation. But all credit should be given Laurie for his original projections of these heat relations of the elements, and for the high value in evidence which they afford in the task of explaining the nature of the chemical elements.

THE NATURE OF THE CHEMICAL ELEMENTS.

BY CHARLES SKEELE PALMER,

Professor of Chemistry, University of Colorado,

It will be remembered that in the first paper, there was assumed the existence of two sub-elements, viz.: kalidium and oxidium, as the essential ingredients of all our known chemical elements.

It will also be remembered that in the second paper it was shown that the interpretation of the sub-elements, kalidium and oxidium, as being real, concrete, isolable varieties of matter, was not in harmony with the known facts respecting the atomic weights, according to any simple mode of combination.

Neither was the theory, which regarded hydrogen as an intermediate ingredient between the known elements and oxidium and kalidium, in accordance with the facts respecting the atomic weights and the chemical behavior of the elements.

The inference was therefore made, that kalidium and oxidium represent typical, contrasted, properties of opposite chemical affinities, and this, probably, in the way of typical, internal, mechanical, arrangements or structures.

But this implies clearly, a process of the making of the chemical elements in distinct, successive, series. This conception of the evolution of the chemical elements led easily and directly to the preliminary statement of the probable mode of evolution, which was called for convenience, the *microcosmic hypothesis.* This hypothesis, as illustrated by diagrams, was shown to be a plausible

explanation of the three great facts of comparative chemistry, viz.:
(a) The progression of the atomic weights. (b) The natural
arrangement of the elements in series of similar orientation, and
(c), the possibility of contrasted, mechanical structure to explain
the actual contrast of one of the opposite chemical affinities and
their possible nature.

The further development and discussion of this hypothesis
branches out now in two distinct directions, each of which will be
the subject of a special paper. In one direction must be traced
in more detailed manner, the different stages implied in the evolu-
tion of the elements according to the microcosmic hypothesis.

It may be anticipated here that from the facts known at
present, there need be inferred only one stage of granulation be-
low the atom, viz.: the atomicules; also the probable structure of
the carbon atom as being made up of inter-penetrating plus and
minus tetrahedra, which hypothesis will involve a slightly new de-
parture in the stereo-chemistry of that element; also, that the micro-
cosmic hypothesis is capable of including within its limits the
nature and evolution of that tenuous variety of matter called the
"luminiferous ether," thus leading to the inference that the
ether may be a molecular compound of kalidic and oxidic ether,
analogous to a chemical salt, a view in origin entirely independent
with the writer but coincident with the view of Lodge and others;
these facts furnish, also, an illustration of the possible contrast in
type of structure of positive and negative electrical action, besides
many other points of vital interest for the theoretical development
of the hypothesis.

As already stated, this line of development of the microcosmic
hypothesis leads directly to the field of the advanced mechanician
and mathematician for whom it will certainly prove most promis-
ing and most fruitful ground; but in the long run this line of
chemical mechanics must probably be relinquished by the pure
chemist as not being within his sphere. On the other hand, the
second great branch of the line of development of the microcosmic
hypothesis does lead directly to the latter, and the legitimate work of
pure chemistry. This line of thought involves the application of
the principles of evolution in general and of chemical evolution in
particular, to the detailed comparative study of chemical fact; and

this application of the principles of evolution and of what may be
called the New Comparative Chemistry itself, predicts a great and
brilliant day for the development of advanced, *anorganic* chemistry,
which is indeed the real science of chemistry.

The discussion of the general principles of classification, of
the general principles of comparison, and of the application of
the idea of evolution thereto, will form the chief objects of con-
sideration in this paper.

CLASSIFICATION.

In the first paper of this series, the author ventured to pro-
pose a slight, but important, recast of the old arrangement result-
ing the so-called short and long serial arrangement.* Some of the
principles by which the correctness of this classssfication may be
judged were referred to; for example, that this arrangement in
short and long series was made with special reference to the termini
of the series.

Let us now examine this more in detail, and for illustration let
us consider that series, which is, perhaps, on the whole, best known,
viz.: the sodium series, including sodium, magnesium, aluminium,
silicon, phosphorous and chlorine.

Now, it will be observed on careful study, that there may be
traced two distinct varieties of chemical behavior and action; and
these are well known, though they are not usually clearly distin-
guished and emphasized. These varieties or modes of chemical
behavior I am accustomed to designate respectively as (a) the
passive, and (b) the *active* mode.

THE PASSIVE MODE OF CHEMICAL BEHAVIOR.

(*a*)   To illustrate this mode, let us consider the well known
list of the normal hydroxyl compounds.   We find the following, viz.:
$NaOH$, known; $Mg(OH)_2$, known; $Al(OH)_3$, known; $Li(OH)_4$,
known   by   inference   from H_2SiO_3 and R_4SiO_4 ; $P(OH)_5$,
known   by   inference   from HPO_3, H_3PO_4, and $H_4P_2O_7$;
$S(OH)_6$, known by inference from H_2SO_4 and $H_2S_2O_7$, etc.,
and $Cl(OH)_7$, known by inference from $HClO_4$ and similar com-

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*See Table 1, p. 294, Proc. 1890.

pounds of iodine. Now, in this series of normal compounds, all of which we have every reason to believe are simple, genuine, possible compounds—there is no difference of kind but only one of degree.

In progressive order from sodium to chlorine the elements illustrate increasing oxidation by the hydroxyl group, and thus each of these elements of the sodium series acts as a *reducer* in this passive mode. In this mode there is evidently no difference in kind, but only one of degree varying with the number of hydroxyl groups with which the element in question can combine.

Although the sodium compound NaOH is basic, yet it would seem to be so in spite of its oxidized condition. The hydroxyl group, as such, can not add to the inherent basic property of sodium. As the number of hydroxyl groups increase, there appears an increasing tendency to illustrate the acid property and the acid nature of the normal compounds of phosphorous, sulphur and chlorine.

In a word, all the members of the sodium series in the passive mode, as illustrated above, are acting as reducers in contrast with the oxidizing functions of the hydroxyl group, and the differences in the members of the series as illustrated, are difference of degrees mainly, or, as is commonly said, differences of valence power.

The details of the probable nature of valence will be considered in a later paper on valence structure.

The respective lower degrees of oxidation illustrated in normal phosphorous acid $P(OH)_3$, normal sulphurous acid $S(OH)_4$, and normal chlorous acid $Cl(OH)_3$, and normal chloric acid $Cl(OH)_5$, are only additional illustrations of these elements—phosphorous, sulphur and chlorine, with lower valences in the same passive mode.

The result of this illustration is interesting as showing that in the passive mode all elements with their highest normal valence act as *reducers*, i. e., they combine in increasing degree with the hydroxyl group.

The application of this passive mode to classification will be considered later in this paper.

THE ACTIVE MODE OF CHEMICAL BEHAVIOR.

(b) It requires nothing more than a passing notice to observe
that the principles and functions of oxygen and the oxidizers, and
of acids and of acidification, are of paramount importance and
that their compounds possess the best characteristics, and are most
marked in chemical differentiation.

We have no complete illustration in any one series of the
active mode, and, in general, only the oxidic portion of any series
will illustrate the behavior of elements in this mode. The follow-
ing compounds of the lithium series illustrate the perfect valence
balance of the series when the latter part is in the *active mode*,
viz.:   SiF; BeO; BN; and the compounds SiH_4 and $SiCl_4$.

Now, the first three elements in each series, in their respec-
tive compounds, are acting here as reducers, and probably with the
same valence as in the hydroxyl illustrations in the *passive mode*;
but the latter members of the series, viz.: nitrogen, oxygen and
fluorine, and phosphorous, sulphur and chlorine, are acting as
oxidizers in the *active mode* and with a lower valence, than their
respective normals. Yet the basiferous elements may be said to
be active in simply balancing the acidiferous members in the com-
pounds NaCl, MgO, AlP.

Now, carbon in CH_4 and CCl_4 illustrates the perfect val-
ence balance of the series, and incidentally it must be observed
that if the tetradic valence of carbon is correctly interpreted by the
modern school of organic chemists (including such names as Le Bel
and Van t'Hoff, Baeyer, Wislicenus, Victor Meyer and others), as
implying a *tetrahedral* form for the carbon atom—and such un-
doubtedly is at least the provisional interpretation of the principle
facts—then it is probable that the tetrahedron theory requires a
slight addition which is as obvious and simple as it is necessary,
viz.: that the carbon atom may not be a *simple* tetrahedron in its
structure, but rather a double tetrahedron of the nature of an in-
terpenetration twin of the plus and minus tetrahedra.

This may be illustrated by such a form as fig. 172, Plate IX
of Kopp's Atlas of Crystalography, or by the crystalline form of
the diamond; and this would imply that in methane (CH_4) the
valences are grouped about the four solid angles of one tetra

hedron—say the *plus* variety, and in tetra-chlormethane the valences are grouped about the four solid angles of the other tetrahedron— the *minus* variety; and that when a hydrogen in methane is replaced by a chlorine atom, this chlorine atom will not take the place of the substituted hydrogen atom, but will, according to the analogy of the attraction and repulsion between unlike and like magnetic poles respectively, place itself at a *diametrically opposite* point which will be in or near the center of the triangular plane of the tetrahedron opposite the hydrogen valence, or what amounts to the same thing, at one solid angle of the opposite tetrahedron.

Thus, by successively replacing the hydrogens of methane by chlorine, or hydroxyl or other similar acidiferous atoms or radicals, we would pass from the valences located about the solid angles of the one tetrahedron to the valences located about the angles of the other tetrahedron; and the various conditions of the latent or active valences of carbon, as illustrated in the above series, are typical for carbon in all other conditions where only single-bond valence is found.

The applications of this hypothesis, and its harmony with known facts will be discussed in a later paper of this series; the idea to be emphasized is that carbon *must* have eight valences, of which only four can at any time be active, and these four may be all the plus variety, or all the minus, or some of both.

While it is probably only a matter of relative terms to say whether carbon, in either or both of its series of compounds, i. e., in oxidized or reduced condition, is acting in the active or passive sense, it is essential to note that carbon in these varying conditions illustrates, elegantly and accurately, the balanced condition of the valence activity of the series.

Now, returning to the last three members of this series which do show an active chemistry, viz.: nitrogen, oxygen, and fluorine, both in the binary compounds, BN, BeO, and LiF, and in other compounds such as the normal cyanides RCN for nitrogen; all oxygen acids for oxygen; and compounds like fluor-benzoic acid for fluorine, we have elements which illustrate the typical idea of active chemistry, which is that of oxidation. It is probable that subsequent discussion will show that all the elements in the lithium series beyond and including boron, all the elements of the

sodium series beyond and including silicon, and other acidiferous elements respectively, possess the same balanced valence conditions as carbon, though usually the conditions are latent or incomplete in some respects.   But, in this active chemistry, the essential idea is that of oxidation, both in binary and terary acids and salts.

It is not maintained for a moment that there is anything startlingly new in this determination and definition of the passive chemistry on the one hand, and of the active chemistry of oxidation on the other; but it is a matter of first importance which must be kept clearly and constantly in mind, and must be applied carefully and consistently in the individual and serial comparison of the chemical elements.

Comparison of the Old and New Arrangements.

Repeated reference has been made to the ambiguity and inaccuracy of the old classifications of the elements in periodic relation.   Only two of these old arrangements will be considered in detail, viz.: the first arrangement of Mendeléeff, which is practically identical with the arrangement of Lothar Meyer, and the second arrangement of Mendeléeff.

I hope to show, what is quite obvious on careful study, that neither of these arrangements is entirely in harmony with known facts, and that their arrangements are not in harmony with each other; and that, while no arrangement, probably, can represent all the facts, yet the author's arrangement is approximately satisfactory, and also allows more elasticity and latitude of interpretation where such is required.

The First Classification of Mendeléeff.

(a).   For convenience we insert here this classification.

Now if we consider simply the relations of the lithium series and the sodium series, no particular fault can be found in placing lithium over sodium, beryllium over magnesium, boron over aluminium, carbon over silicon, nitrogen over phosphorous, oxygen over sulphur and fluorine over chlorine; and this, even though we regard these series as entirely distinct from each other, but developed under similar conditions.   And just here let us notice what are

OLD PERIODIC CLASSIFICATION ACCORDING TO MENDELÉEFF—FIRST METHOD.

GROUPS.

SERIES.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.		
1	H. 1									
2	Li. 7	Be. 9	B. 11	C. 12	N. 14	O. 16	F. 19			
3	Na. 23	Mg. 24	Al. 27	Si. 28	P. 31	S. 32	Cl. 35·4			
4	K. 39	Ca. 40	Sc. 44	Ti. 48	V. 51	Cr. 52	Mn. 55	Fe. 56	Co. 58	Ni. 59
5	Cu. 63	Zn. 65	Ga. 69	Ge. 72	As. 75	Se. 79	Br. 80			
6	Rb. 85	Sr. 87	Y. 89	Zr. 90	Cb. 94	Mo. 96	?	Ru. 103	Rh. 104	Pd. 106
7	Ag. 108	Cd. 112	In. 113	Sn. 117	Sb. 120	Te. 125	I. 127			
8	Cs. 133	Ba. 137	La. 139	Ce. 140	Di. 142	?	?	?	?	?
9	?	?	?	?	?	?	?			
10	?	?	Yb. 173	?	Ta. 182	W. 184	?	Os. 191	Ir. 193	Pt. 194
11	Au. 198	Hg. 200	Tl. 204	Pb. 206	Bi. 307	?	?	?	?	?
12	?	?	?	Th. 232	?	Ur. 240				

the relations of similar elements in different series as compared with each other. If the general outlines of the microcosmic hypothesis, as enunciated by the writer, be true, the elements were made in successive independent groups or series; and if elements similar in location, but in distinct series, resemble each other, that is a matter, if not accidental, at least of secondary importance. And in so far as similarly located elements of distinct series resemble each other, this is evidently due to similarity of conditions, for these similar elements, however great their similarity, were probably made at different times.

If we find similarity between similarly located elements of different series, let us accept it; but the wonderful thing is, not that these elements should differ from each other, but that they should resemble each other at all.

As an illustration of the true independent relations of elements in distinct series, we may offer the following picture: In looking at the tree tops on a range of hills which meet the horizon and seem to branch out against the sky, at first sight, we gain the impression that these trees must form one continuous line of forestry on one contiuous ridge; a nearer examination, however, reveals the fact that the horizon limit is made by distinct tree tops on distinct hill tops; these hill tops are often separated by wide valleys and deep chasms, and the similarity of distinct trees in similar projection against the horizon is not due to the fact that they are all of the same species, of the same age and on the same hill; but, that though comprising many different species, of many different ages and on many different hills, yet the products of similar but distinct conditions will present a high degree of similarity; thus, trees on the crests of hills, even though the hills be distinct, will resemble each other very closely, and so will our elements, though of different species, of different periods of growth, resemble each other if they have a similar locus or position in different series.

Thus, for example, let us take the members of the alkali family. The apparent reason for their resemblance is found in the fact that they each are at the basiferous terminus of their respective series; yet they have great and constant differences from each

other which are sufficiently explained by the fact that they are in distinct series.

Now, in proceeding to examine Mendeléeff's first classification, we notice that the discrepancy of natural relations becomes apparent in growing degree, in attempting to write in the first seven members of the potassium series under the seven members of the sodium and lithium series respectively. Thus, potassium is best compared with sodium and lithium, and calcium fairly well with magnesium, scandium only tolerably with boron and aluminium, titanium less tolerably with carbon and silicon, vanadium, worse still, compares with nitrogen and phosphorus, and the discrepancy grows more violent in chromium with oxygen and sulphur, and in comparing manganese with fluorine and chlorine.

Space will not allow us to discuss this adequately, but, in a word, it would seem that that chemist's judgment must be dormant who can seriously accept a classification which violates the simplest rule of comparison.

In detail, how can a classification be tolerated which places manganese in the same family with fluorine or even chlorine? The physical properties of the halogens are in violent discord with those of manganese; and though manganese does imitate chlorine in such compounds as the permanganates, so far as valence is concerned, so, also, does manganese imitate sulphur and chromium in forming the manganates. And if it be said that the premanganates are isomorphous with the perchlorates, so also is it stated that the manganates are isomorphous with the chromates and sulphates and ferrates, this evidently proves too much and breaks down the limits of strict classification; it only proves that, whatever the element, the valence structure is the conditioning circumstance in effecting the external form.

Manganese resembles the halogens chiefly in its passive chemistry in the heptad valence; it is unlike them in physical property, in the tendency to show artiad valence, in the entire want of active chemistry, and, in general, in the inertia of its chemical conduct.

Where are the *manganates?* The word is hardly known in chemical literature.

And chromium, with oxygen and sulphur! Here the discord is probably a trifle less violent than in the case of manganese. But though chromium differs from it in physical properties, in wanting an active chemistry, and in general chemical inertia. Where are the *chromides*, which should resemble the oxides and sulphides?

A similar discrepancy appears in less exaggerated form in comparing vanadium with the nitrogen family and titanium with the carbon group; and in general we will observe that, bromine and iodine both resemble fluorine and chlorine much more clearly, chemically, than does manganese, and that in spite of a much greater separation from fluorine and chlorine in *atomic mass*. And similarly, selenium and tellurium resemble oxygen and sulphur much more than does chromium, and this, in spite of the greater atomic mass of the former.

Let us glance a moment at the basic end. Lithium and sodium and potassium, followed by copper and silver and gold! Shades of Sir Humphrey Davy!

These two classes of elements are so distinct in their physical chemical behavior that it is safe to say that no intelligent chemist would ever have dreamed of putting them together had not the accidental harmony of their old classification strained a point or two for temporary convenience.

In the case of beryllium and magnesium which might be grouped with calcium, strontium, and barium on the one hand, or with zinc, cadmium, and mercury on the other, there is a fair ground for discussion. Indeed, at first glance the matter of location is almost indifferent. The question will be discussed later in this paper.

Further, scandium oxide is said to be alkaline (!), while boron and alumium oxides certainly are only weakly basic with strong acids, and weakly acid with strong bases. Hence we must demur to this arrangement if a better can be found.

THE SECOND ARRANGEMENT ACCORDING TO MENDELÉEFF.

(*b*) The table illustrating this form is inserted for convenience.

OLD PERIODIC ARRANGEMENT ACCORDING TO MENDELEEFF—SECOND METHOD.

SERIES.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.			I.	II.	III.	IV.	V.	VI.	VII.
1											H.						
2 and 3	Li,	Be.	B.	C.	N.	O.	F.				Na.	Mg.	Al.	Si.	P.	S.	Cl.
4 and 5	K.	Ca.	Se.	Ti.	V.	Cr.	Mn.	Fe.	Co.	Ni.	Cu	Zn.	Ga.	Ge.	As.	Se.	Br.
6 and 7	Rb.	Sr.	Y.	Zr.	Cb.	Mo.	?	Ru.	Rh.	Pd.	Ag.	Cd.	In.	Sn.	Sb.	Te.	I.
8 and 9	Cs.	Ba.	La.	Ce.	Di.	?	?	?	?	?	?	?	?	?	?	?	?
10 and 11 ...	?	?	Yb.	?	Ta.	W.	?	Os.	Lr.	Pt.	Au.	Hg.	Tl.	Pb.	Bi.	?	?
12 and 13 ...	?	?	?	Th.	?	U.	?	?	?	?	?	?	?	?	?	?	?

We will dispose of the matter briefly. In the first place in so far as the table represents the relative arrangement of the "long series" only, viz.: postassium to bromine, and rubidium to iodine, no exception can be taken. But in the violent dislocation of the short series we will observe that all that was mentioned against putting manganese with the halogenes, chromium with the oxygen group, and titanium with the carbon group, is in point here, particularly as regards the acid end of the lithium series and the basic end of the sodium series.

Also, the corresponding members of the short series which are naturally in pretty close accord with each other, are rudely separated. The arrangement obliterates the close analogies of the short series. Moreover, this arrangement, like the other one of Mendeléeff ignores the fundamental principle of comparing the series with each other by making parallel the *terminal* similarities. In a word, this arrangement is unsatisfactory if a better can be obtained.

THE NEW ARRANGEMENT IN SHORT AND LONG SERIES.

This arrangement, first printed on p. 294 of the Proceedings for 1890, is here inserted, but with the new arrangement of inclined columns, to emphasize the progressive variation in acid and basic property.

The difficulties and incongruities referred to in the preceding discussion of the old arrangements are here almost entirely obviated. Thus, the halogens come by themselves at one end, as do also the oxygen group and the nitrogen group respectively, and manganese and chromium and vanadium are not thrown with groups to which they show but poor analogies, but stand alone. Also, on the other hand, the alkalies and alkaline earths stand alone, as also do the copper group, the zinc group, etc., respectively.

The disposition of magnesium and beryllium, as given in the "short and long series" arrangement, is, as said before, an affair of only approximate accuracy, because of the mathematical impossibility of making short series exactly match long ones.

But the arguments for locating magnesium and beryllium as they are here placed are clear and distinct; and, while the loca-

SHORT AND LONG SERIES PERIODIC ARRANGEMENT, TO SHOW PROGRESSIVE CHEMICAL VARIATION.

		BASIFEROUS or KALIDIC											OXIDIC - ACIDIFEROUS							Pre -F.	KNOWN ELEMENTS	PRESUMABLE ELEMENTS
HYDROGEN SERIES																				H	1	2
SHORT SERIES	Li											Be.	B.	C.	N.	O.	F.		Pre-F.		7	7
	Na.	Mg.												Al. Si	P	S	Cl				7	7
LONG SERIES	K.	Ca.	Sc.	Ti.	V	Cr.	Mn.	Fe.	Co.	Ni	Cu.	Zn.	Ga.	Ge.	As.	Se.	Br.			17	17
	Rb.	Sr.	Y.	Zr.	Cb.	Mo.	?	Ru.	Rh.	Pd.	Ag.	Cd.	In.	Sn.	Sb.	Te.	I			16	17
	Cs.	Ba.	La.	Ce.	Di	?	?	?	?	?	Au.	Hg.	Tl.	Pb.	Bi.	?	?			5	17
	?	?	Yb.	?	Ta.	W.	?	Os.	Ir.	Pt.	?	?	?	?	?	?	?			2	11
	?	?	?	Th.	?	Ur.	?	?	?	?	?	?	?	?	?	?	?			2	17
BASIFEROUS →																← ACIDIFEROUS			66	101	TOTAL

tion is not completely in accord with *all* facts, it certainly represents correctly the *balance* of evidence. But, strictly speaking, short series can be compared only with short series, and long with long.

The chief points indicating that on the whole magnesium is more closely related to the calcium group, and beryllium with the zinc group, are as follows: Magnesium oxide is slightly soluble in water, is slightly alkaline and is insoluble in potassium hydroxide; magnesium halides are non-volatile, and magnesium ethide is a white earthy solid. Beryllium oxide is insoluble in water, is not alkaline, is soluble in potassium hydroxide, and is precipitated on boiling; beryllium halides are volatile, and beryllium ethide is a volatile liquid.

Boron is evidently more acid than basic, and aluminium fairly acid, as its oxide is soluble in potassium hydroxide, and not precipitated by boiling.

The disposition of the rest of the short series is too obvious to require detailed comment. It may be well to observe again that the physical, chemical, and physico-chemical properties of the elements all favor this "short and long series" arrangement; and the latter set of properties is peculiarly valuable as evidence. For, notice that the curve of atomic gravities is calculated on the actual or supposed specific gravities of all the elements in the solid state. Now, this is also the free or uncombined state; and the relation of the elements in this state, considered as a whole, are probably more closely approximate to the relation of the elements in their early cosmic state, than the relations in any other condition; and moreover, although there is no intention of undervaluing the evidence from chemical compounds, yet it should be observed that the elements were produced *free* or *uncombined*, and that compounds are historically a second thought.

Happily, the general evidence from compounds is in favor of this "short and long series" arrangement, but the purpose of this paper is to show that the evidence from the writer's form of Meyer's curve is fundamental in determining the classification to be followed. Not only does this arrangement avoid many mistakes of the old method, and permit more elasticity where needed, but it

also possesses certain positive advantages in suggesting new expla-
nations for old problems.

Take, for example, the so-called "VIIIth Group" of the old
classification, the same as the eighth, ninth and tenth of the new.
The real facts concerning these metals are their ambiguous rela-
tions; in that, on the one hand, as a group, they show the highest
known value, as in the cases of OsO_4, $Ni(CO)_4$, etc,; and, on
the other, they all probably occur *free* to some extent, and are
reduced with great ease.

Now, what is the meaning of this double-sided nature of the
iron, ruthenium, and osmium groups, in that they can be either
oxidized to a high extreme, or reduced to the free state?

I do not recall any explanation for this in the old chemistry,
nor, indeed, any indication that there was any realizing sense of
the need of an explanation of this ambiguity.

But, notice the obvious explanation offered by the new classi-
fication, so far as the development of some related, physical con-
ceptions allows. These groups stand midway in long series, as far
as known. Counting *up* from the basiferous terminus, the increase
of valence for the passive chemistry is regular as far as manganese,
which shows a valence efficiency of seven; and the chemical
induction proceeding from the outer basiferous terminus or peri-
phery of the shell, should naturally weaken potentially, but
increase numerically in this mean group; hence its tendency to a
high valence.

On the other hand, the high valence of the passive chemistry
of the last half of the long series, proceeding from a normal of
series, in the per-bromater and per-iodater, by a decreasing chem-
ical induction reaches a minimum of one in the copper-silver
group. To go below this unit of valence into the nickel group
means a zero valence, or a tendency to be *uncombined* or *free;*
hence we see the form of an explation for this ambiguous group.

To be sure, we do not know the real meaning of valence, nor
of this induction process at present, but the general accuracy of
the intermediate location of this group between an *advancing*
passive valence beyond *seven* on the one hand, and a *retrograding*
passive valence below *one* on the other, no one can fail to observe.
To distinguish this as the "double induction" hypothesis, is only

a convenience of nomenclature which does not assume to tell more than it suggests. The full explanation can come only with the clearing up of the difficult problem of the valence structure. Another point wherein the new arrangement is valuable is in suggesting that the reason why the metals which best conduct heat and electricity are found at or about the middle of their series, is because their loci imply a fairly well balanced structure.

SOME OF THE PRINCIPLES OF THE NEW COMPARATIVE CHEMISTRY.

Having thus adopted the new classification as a basis, let us observe that, in the detailed consideration of the elements the latter have their independent chemical position, or locus, as regards, (1) the particular series in which an element occurs, and (2) the particular *locus* or position of the element in its series.

Regard for this point is necessary in considering the true relation of two distinct elements, or even considering the true meaning of some apparent anomalies in any one element. Thus, thallium has been called the "ornithorhynchus" among metals, but it is not remarkable in its normal valence action of three; and its basiferous tendencies are shown only in its reduced, monad valence conditions. Nitrogen is much more remarkable in ammonium nitrate, where it exhibits a double-sidedness that is amazing. Copper is but little understood because its normal monad or cuprous chemistry is characterized by insolubility; and the common action of dyad copper is really abnormal. This remark is of especial pertinence in determining the real relative electric potential of copper with other metals.

One considering the elements in these relations, will be at once reminded that the science of inorganic chemistry has suffered extreme neglect and inattention at the hands of chemists, and the true science of chemistry must be slowly accumulated on the indicated lines.

A detailed consideration of each series, and of each respective element in its physical and chemical relations would savor too much of the text book and would be out of place here. But enough has been indicated to show how rich is the harvest waiting

to be gathered, and incidentally there is emphasized the organic dependency of chemistry on the detailed study of physical property.*

APPLICATION OF THE PRINCIPLES OF EVOLUTION.

On applying the well known principles of evolution to the chemical elements and their relations, in the light of the "microcosmic hypothesis," we will observe that in general these principles find their application, with some modification, to suit the circumstances. We can at this time enumerate only a few of the more salient points.

Firstly. The progression from homogeneity to heterogeneity is fully illustrated in the production of sixty or one hundred kinds of matter from one protylic stuff.

Secondly. The conceptions of *types, genera, species*, etc., have peculiar significance; for the elements are not, presumably, descendants of each other, but the method of "fission" operated to bring forth each shell or series from the parent mole and again each element from the parent series or shell.

Whether the atoms of any elements are all alike, or whether they are only groups of matter of approximately identical characteristic, can not be said, but the latter view is the probable one.

Thirdly. The principles of Natural Selection and Survival of the Fittest undoubtedly operated in the process of atomic evolution. One fact that speaks volumes is the sequence of atomic weights by abrupt and irregular intervals, as though, for example, the mass 7 of lithium represents the mass conditions of mechanical stability in *that* locus, and the missing differences between 7 and 9 would represent unstable conditions until in 9—or there-

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* In brief, a detailed description of each series in general, of each element in particular, of the relations of each series to all other series, and of the relations of each element to all other elements would outline the complete treatment. Thus, the hydrogen series, as already indicated, must contain at least two members, viz.: hydrogen and pre-fluorine (Pre-F.). The form of the description of hydrogen is obvious. Of pre-fluorine it may be predicated that its atomic weight is about 4·4; that it is a slightly yellowish gas, with a molecular weight twice its atomic weight; that in its chemical properties it would be an *intensely corrosive* oxydizer, so active that it might be impossible to isolate it, even if we could isolate its compounds, etc., etc. The systematic literary and experimental treatment of the elements serially is obvious.

abouts—we find in the beryllium (glucinum) locus another maximum of mechanical stability, and so on through the series.

It is not in point here to fully analyze the subject and to ask what may have become of all the elements whose atoms, if existing, might appear in the gap between our known atomic weights, but only to emphasize the idea of the survival of the mechanically fittest and most stable under the land of internal motion and vibration implied in the atomic heat constant. .

CONCLUSION.

It is not assumed that in these papers a full description with full proof has been given, but only an outline of the great speculative and experimental possibilities of the science. Enough has been done by material drawn from the best source, that the question of the nature and evolution of the varieties of matter called elements, is not irrational nor unpromising.

It has been repeatedly necessary in the course of the discussion to criticise the views of one of the greatest chemists in all history, Meneléeff; and, before closing, a word of explanation is in order from one of his most genuine admirers. Mendeléeff does not encourage the conceptions advanced in the papers; yet his whole work leads in this direction. It may be the fallibility of nature; it may'be the eccentricity of genius, which has made many a brilliant investigation at times strangely conservative. However this may be, this greatest of modern inorganic chemists still has all the praise, for he has unmistakably indicated some of the open paths of progress and reform,

NOTES ON A DISCOVERY OF RADIOLITES AUSTINENSIS ROEMER.(?)

BY GEO. L. CANNON, JR.

At the October meeting, the attention of the Society was called to a peculiar specimen, recently obtained by Mr. Edwin Blackburn from a quarry of Niobrara limestone about half a mile north of Bear Creek; occurring with the familiar *Inoceramus deformis*, Meek, and the *Ostrea congesta*, Conrad. This locality has been frequently examined by large parties of students from the State School of Mines and from the Denver High School, without the discovery of similar fossils.

A cast of this specimen was submitted to Mr. T. W. Stanton, of the U. S. Geological Survey, and was identified as a species allied to *Radiolites Austinensis*, Roemer, of the equivalent of the Colorado Group of the Cretaceous of the Gulf States.

A crude idea of the appearance of these fossils may be obtained from the figures of Hippurites and Radiolites in Davis' Manual. One valve was of a rudely conical form, and was covered by the flattened hemispherical companion valve. This species must have been from six to eight inches in diameter, the shell having a thickness of two inches.

As various eminent anatomists have, in past times, differed widely as to the true position of the Rudistes (placing them in such widely separated groups as the Actinozoa, the Brachiopoda, the Annelida, the Crustacea, the Lamellibranchiata, the Ortheocerata and the Tunicata), great care must be taken to avoid mistaking fragmentary specimens of this species for various organic forms to which they bear considerable superficial resemblances.

A similar specimen was found in about the same horizon at Canon City, and large specimens of "Hippurites," probably belonging to this genus, have been reported from the Niobrara beds of Kansas.*

This specimen is of importance as constituting a new, but not an abundant member of our local Niobrara fauna.

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*The Colorado Formation and Its Invertebrate Fauna (Bulletin 106, U. S. Geo. Survey) pp. 96, 97.

REPORT OF THE COMMITTEE OF THE COLORADO SCIENTIFIC SOCIETY TO ADVISE ON THE NECESSITY FOR A UNIFORMITY IN TECHNICAL-CHEMICAL METHODS FOR THE DETERMINATION OF VARIOUS ELEMENTS, AND SOME IMPROVEMENTS IN THE CUSTOMARY METHODS NOW IN USE BY CHEMISTS AND ASSAYERS IN COLORADO.

Your Committee, in considering the needs of some uniformity in methods to be used by those chemists whose work is in technical lines, have found that the determination of silica is one of the first points worthy of discussion. The sale of silver and lead ores on a neutral basis, with respect to the total percentages of iron and manganese, as against silica, is now becoming so customary that this determination should be made more accurately than is now done. Many chemists report as silica an insoluble residue gained by evaporation with hydrochloric and nitric acids, and subsequent solution in hydrochloric acid, entirely without regard to the percentage of aluminous silicates that it may contain. In some ores of pyrite and galenite, as well as in silicious ores and the barytic ones of Aspen, the amount of these silicates is often large, and it seems that a method of evaporation with sulphuric acid, or a treatment of the ordinary insoluble residue with hydrofluoric acid, might well be considered.

The determination of zinc, even in the absence of manganese, is subject to some difference, but when manganese is present, the discrepancies in the results of methods used by those who ought to be prepared for such chemical work, are really astonishing. When, however, as is too often the case, such work is undertaken by those, who from lack of time, or other cause, neglect precau-

tions necessitated by the presence of various elements, the results prove positively, that unless some methods are recommended for use under all circumstances, we may not hope for any improvement.

The methods depending on the use of hydrogen per-oxide or potassic chlorate for the elimination of maganese, with uranic acetate as an indicator in the final titration, or some adaptation of the volumetric sulphide method, seem to offer a solution of `this difficulty.

To illustrate the question, we have only to recite a case which recently came under the notice of a member of your Committee.

The laboratory of one of the smelting works reported 14.10% Zn. in a lot of ore, which contained manganese in percentages from 3% to 7%. The chemist for the mine found 18.10% Zn., and on account of this lack of agreement a portion of the same sample was admitted to a third party for final arbitration. The result thus obtained was 10.10%! Comment on the necessities of some reform are clearly unnecessary.

The estimation of sulphur and antimony likewise need attention.

There are various methods, good or bad, in present use for the determination of sulphur, and several might well be selected as giving best results.

While it is true that the necessity of an analysis for antimony is of rare occurrence, still a consideration of the volumetric methods particularly, would be of service to busy chemists.

Bismuth is another element which seldom occasions any perplexity, but even its minute presence in test lead may cause great embarrassment. We have recently learned of a case in which the test lead used for assaying was found to contain 0.12% Bi., but not until assays made in this way were found to give greatly varying results. Even though in the case of test lead large amounts were used for assay, the fact that the lead only contained 0.12% Bi. would indicate that it is quite within the range of probability that an ore containing even a fraction of 1% Bi. may occasion much trouble.

The exact effect of bismuth on the assay of silver and gold ores has not been accurately determined, and there is a large field here for investigation.

Copper has long been a source of disagreement both to chemists and assayers.

Much has been written on the titration of copper by means of potassic cyanide in both hot and cold solutions; some little has been said of other volumetric methods, but outside of the books little has been proposed in the line of commercial work on the adaptation of gravimetric methods. These are of such an accurate nature that a consideration of them is necessary, as well as that excellent volumetric titration by potassic cyanide in hot solutions.

A paper writen by W. E. C. Eustis on "Methods for Copper Analysis," and read at the Colorado meeting of the American Institute of Mining Engineers, August, 1882, may furnish some food for reflection.

Assayers have found that the assay of lead on all classes of ores has not given such flattering results as to forbid a consideration of some rapid, or fairly rapid determination of lead by wet processes.

Many methods have been thought of and experimented upon. Among these is the well-known volumetric method based on the reaction of potassic bichromate on a solution of lead, with a silver salt as an indicatior, but thus far the end reaction has not been clear enough to give satisfaction. Something may yet be done towards discovering different means of securing the end reaction.

Other methods for the wet determination of lead by the use of potassic bichromate are somewhat known and greatly perfected, but they necessarily consume more time than would be allowed to substitute for the fire assay of lead.

A method recently proposed, which depends on the reaction of aluminum on an ammonic chloride solution of lead is well known to a number of chemists, and as soon as it is possible to obtain in Denver, aluminum made by the sodium process, exact experiments may be conducted on these lines. Aluminum made by the Cowles process of reduction contains considerable silicon, which vitiates the results.

The methods in use for the commercial estimation of iron, by potassic bichromate or potassic permanganate; of manganese, by potassic permanganate; of lime, by either weighing as a sulphate, or by titrating the oxalic acid in the precipitated calcic oxalate by

potassic permanganate in sulphuric acid solution; of magnesia by the usual process, and of arsenic by the well known excellent volumetric or gravimetric methods, are all of such standard character as to render improvement in the determination of these elements entirely unnecessary.

In the field of the assayer, the surprising differences which are frequently found on samples from ores carrying upwards of 0.30 ounces of gold per ton, indicate the necessity of improvement.

Some assayers add silver to a gold assay only when it is necessary in order to part the button properly, and of this number some add it to the flux, while others alloy the cupelled button with the silver necessary to allow parting.

This different usage will occasion varying results on the same samples of some ores, and the trouble often cannot be traced to its proper cause. Some assayers add silver to the flux of all assays for gold without regard to the silver contents, and these assert that they will get better assays by so doing; that is, more concordant results, because the silver added acts as a collector of the gold even more thoroughly than the silver contents of the ore.

By reason of this disagreement on so many questions, your Committee deem it best that they be authorized by the Society to put themselves in communication, through the Secretary, with the prominent chemists and assayers of Colorado, and elsewhere, if deemed necessary, so that the desirable uniformity of methods of technical analysis and assay may be obtained.

EDWIN N. HAWKINS, Sec'y,
FRANKLIN GUITERMAN,
F. C. KNIGHT,   } Committee.
L. J. W. JONES,
HENRY E. WOOD,

FORMATION OF ALLOYS OF TIN AND IRON.

DESCRIPTION OF SOME NEW ALLOYS.

BY WM. P. HEADDEN, PH. D.

Address of the Retiring President.

About three years ago I had occasion to investigate some tin buttons obtained by the potassic cyanide method, and observed that the alloy obtained by oxidizing the button with strong hydric nitrate and dissolving the metastannic acid in potassic hydrate was quite significant, varying from two and one-half to ten and one-half per cent of the button by weight; and, further, that the form of the alloy varied in buttons obtained under similar if not identical conditions.

I have been unable to find descriptions of any forms similar to those obtained from the buttons investigated—the information which I could find on this subject being meagre and not very satisfactory. The only references found, excluding such as are made to the alloys of tin and iron in works on metallurgy, are contained in Watts' Dictionary of Chemistry,* and in Gmelin-Kraut's Handbuch der Chemie.† These works contain the same references and essentially the same statements concerning the following alloys: $FeSn_{22}$, obtained by heating together iron and tin at a red heat. It is harder than tin and magnetic, and below this a compound of two parts of iron and one part of tin ($FeSn$ nearly) is formed which is white, very hard, slightly malleable, and difficultly fusible.

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* Vol. III., page 370.
† Vol. III.. page 427.

The next description of this alloy, FeSn, is given by Deville and Caron,[*] as obtained by crystallizing it, from its solution in excess of tin, as broad shining plates or laminæ; slightly soluble in hydric chlorid. $FeSn_2$; this alloy was obtained by Noellner[†] by dissolving Banca tin in hydric chlorid, in apparently quadratic needles having a specific gravity of 7·446. The alloy is almost insoluble in hydric nitrate, burns when strewn into the flame of a candle, and fuses at a white heat, whereby it becomes magnetic. When larger quantities of Banca tin are melted, and the tin allowed to separate, there remains a thick fluid, which, when cold, is permeated by needles which have a specific gravity of 7·341. Fe_3Sn was obtained by Lassaigne,[‡] and Fe_4Sn was described by Bergman. A. C. Oudemann, Jr., in an article on "The Impurities of Banca Tin."[||] describes the occurrence of FeSn in the dross obtained by liquating the Banca tin. According to Van Dyke, the alloy may make 15% of the dross, and as much as 17·9%, according to the writer of the article. It occurs in apparently tetragonal needles. Stoetzel[§] mentions, as occuring in the "Hærtlinge" from Schlaggenwald, two alloys, $FeSn_6$ and $FeSn_7$, in prismatic crystals, combinations of two tetragonal prisms.

This is, so far as I have been able to find, a complete enumeration of the alloys of tin and iron described up to the present time.

The original observations, made on alloys obtained from buttons resulting from the cyanide assay of stream tin, pointed strongly to two alloys as being the commonly occurring impurities in such buttons. The first alloy, obtained by oxidizing the button with hydric nitrate and dissolving the metastannic acid in potassic hydrate, was, as sometimes happens, of unmixed crystals, and these presenting but one form of aggregation, namely, a six-sided plate, were so arranged as to form hour-glass shaped masses, of which one branch was as a rule very short. The quantity of this alloy obtained was about 0·25 gram, and a determination of the iron showed the presence of 24·5% Fe, leaving 75·5% for Sn. I failed

*Compt. Rend., Vol. 46, page 764; also J. B., 1858, page 190.
†Ann. Pharm., Vol. 115, page 233; J. B. 1869, page 188.
‡Jour. Chem. Med., Vol. 6, page 609.
||Netherlands Jaarboek Mynwesen Nederlandsch Indien, 1890, No. 2.
§Metallurgie, 1863-66, page 840.

to detect the presence of other metals.   This indicated the presence of Fe_2Sn_3 in the button, of which it constituted about 7.0%. The second button, investigated in the same manner, yielded an altogether different alloy, corresponding to Fe_4Sn_5, while a third one gave an alloy crystallizing in six-sided prisms.   The quantity of the latter being very small, no analysis was made of it.   The alloy from the second button was magnetic, but those from the other two were not.

The supply of these alloys obtained from cyanide assays was insufficient for the purposes of this investigation, and recourse was had to old slags and dross resulting from the preparation of small lots of bar tin, to determine whether they could be used as a source for the preparative alloys already obtained in small quantities as well as those of others.   For this purpose some dross, termed dross A, was selected and melted under a borax cover; the regulus weighed about 250 grams, and yielded a quantity of a strongly magnetic alloy, as well as 0.2156 gram of a non-magnetic alloy.   This non-magnetic alloy consisted largely of six-sided prisms; but there were also other forms, among which was observed a very perfect tetrahedron or sphenoid.   This alloy is readily attacked by cold hydric chlorid; even dilution of the acid did not stop the action.   It was not wholly soluble in this menstruum, and aqua regia acted with extreme slowness on the residue, which consisted of a gray, crystalline substance with a metallic lustre. This portion gave, on analysis:

I.	At. Equiv.	Ratio.
Sn .... $70.16 = 74.70$	63·30	2·8 3 ⎱ nearly.
Fe. .... $23.76 = 25.30$	45·10	2· 2 ⎰
Insol...... 6.08 $\overline{}$ 100.00		
$\overline{}$ 100.00		

Assuming that there were no analytical errors, the alloy is probably a mixture in which the compound Fe_2Sn_3 predominates. The insoluble portion was separated and ignited, on which it changed its character in toto, turning from a gray, crystalline powder to an almost white and very bulky one.

The magnetic portion consisted of small, rounded grains, neither even nor regular, but resembling sintered masses which had been somewhat smoothed by being rolled.   Cold concentrated hydric chloride attacked this alloy readily, but did not completely dissolve it, nor was it perceptibly more soluble in aqua regia.   The residue resembled that from the non-magnetic portion, and gave on analysis the following results:

II.	At. Equiv.	Ratio.	Required.
Sn .. .... 60·36 = 69·38	58·80	1·05	67·82
Fe ..... . 26·64 = 30·62	54·67	1	32·18
Insol ... 12·66 _____ 100·00			_____ 100·00
99·66			

The second regulus, dross " B," was obtained by melting some dross, rich in tin prills, and rich slag, under borax for forty-five minutes in a Hoskins gasoline furnace.   As soon as the flame was removed, the fire pot was closed as tight as possible, the crucible remaining in it, and the latter allowed to stand until perfectly cold. The slag was easily removed, and the regulus was bright, but near the top, and in part adhering to the borax glass, were some hemispherical masses of an alloy which had not united to form a layer.   Whether the heat was not high enough, or was not sustained long enough, I do not know, but subsequent results indicate the latter hypothesis.   This alloy was crystalline and very strongly magnetic.   On the outside its color was gray, while the interior portion was brownish-gray with a bronzy reflex, being tarnished with faint pavonine lines.   The fracture was somewhat conchoidal, and the texture fine granular.   Strong hydric nitrate as well as an acid diluted 1 : 1 attacked it but slightly. Hydric chlorid, also aqua regia, dissolved it, leaving a gray crystalline residue, which persistently withstood the action of these agents.   The material used for analysis was re-treated with concentrated hydric nitrate, to which a little water was added, then washed with potassic hydrate, water, and finally with alcohol.

The analysis of this compound was:

III.	At. Equiv.	Ratio.
Sn...... 14·48 = 18·47	15·66	1
Fe...... 63·91 = 81·53	14·56	9·29
Insol..... 22·32		
——— 100·00		
100·71		

If this was a true chemical compound the results can probably be interpreted as indicating the formula Se_9Sn which requires Sn 18·97% and Fe 81·03%. The question, whether the original ratio of iron to tin had any influence upon the formation of this alloy, seems to be answered in the negative, by the fact, that only about five grams of this alloy was obtained, while the weight of the regulus was 1,000 grams, which would indicate an abundantly sufficient excess of tin to have favored the formation of an alloy poorer in iron. But we cannot answer the corresponding question in regard to temperature, as satisfactorily, though the temperature of the mass in the crucible must have been fully as high as the melting point of ordinary cast iron. This hard magnetic alloy was broken out of the mass of the regulus, after which the latter was granulated, then oxidized with hydric nitrate, sp. gr. 1·39, and the alloy separated as previously indicated, i. e. by potassic hydrate and subsequent washing. This was the general process in every instance. The alloy was divided by means of eighty, and a hundred-mesh sieves, into three portions, and each portion again divided into a magnetic and a non-magnetic part. The portion remaining on the eighty-mesh sieve was wholly magnetic and was mixed with a few grains of the preceding alloy, which was very much more strongly magnetic than the crystallized alloys. No definite crystal forms could be recognized under the microscope, only dendritic aggregations, and rods with projecting points. There were a few six sided prisms observed in the portion which remained on the hundred-mesh sieve—it did not otherwise differ from that which remained on the eighty-mesh sieve. The color of this alloy was light gray, with a strong metallic lustre. It was soluble in concentrated, also in dilute hydric chlorid. A few black

flakes remained suspended in the solution which disappeared upon
the addition of potassic chlorate or hydric nitrate.

Analysis of the material remaining on the hundred-mesh
sieve gave:

	IV.	V.	VI.	VII.	At. Equiv.	Ratio.	
Sn	72·50	72·43	71·86	71·89	61·44	2·46	5
Fe	27·61	27·69	27·79	27·79	49·3	1·97	4
Insol ...	·30	·32	·38	·32			
	100·41	100·44	100·03	100·00			

Fe_4Sn_5 requires Sn 72·52%.

The portion which passed through the hundred-mesh sieve
was strongly magnetic, and, in a general way, resembled the pre-
ceding, but the forms of the crystals and aggregations were not
all alike:

The results of analysis were:

	VIII.	At. Equiv.	Ratio.
Sn	73·00	61·86	1·30
Fe	26·58	47·50	1
Insol.....	·42		
	100·00		

This ratio approximates 3 : 4 and were it not that the micro-
scope showed it to be mixed, we would unhesitatingly attribute the
difference of 0·1 in the ratio to an error in the work and assign
Fe_3Sn_4 as the formula for the alloy. But the agreement of the
analytical result with the observation places it quite beyond
question that we have a mixture, composed probably of alloys
whose ratios are nearest, above and below the one found.

If we make this assumption and accept the ratio found as
the basis of our calculation, we obtain for the formula of the mix-
ture 8 Fe_4Sn_5 + 4 Fe_2Sn_3, which requires the ratio 1 : 3 and Sn
73·26%, Fe 26·74%.

The portions which passed through the respective sieves were

not wholly magnetic but gave a non-magnetic residue when sorted
with a magnet.   The non-magnetic portions, being small in quan-
tity and similar in form, were united and treated as one portion;
they consisted of six-sided prisms, needles, and grains of indefinite
forms, some of them appearing to have been centers from which
the needles had proceeded, but which had broken off in granula-
ting the regulus.   I could not recognize the form of these needles,
and it is altogether uncertain whether they were different in com-
position from the larger forms on the one hand, and the grains on
the other.   The inference from the diversity of form is that the
material was a mixture; the results of the analysis, however, indi-
cate that it was essentially a single alloy:

These results were:

	IX.	X.	At. Equiv.	Ratio.	
Sn....	75·19	75·28	63.72	1·47	3
Fe....	24·15	24·14	43.12	1	2
Insol..	·18	·58			
	99·52	100·00			

Fe_2Sn_3 requires Sn 75·96%, Fe 24·04%.

Owing to the brittleness of these alloys the granulation of
the regulus proved to be very ill advised.

The next regulus, dross " C," was obtained from similar ma-
terial, but more slag was used.   The regulus weighed 700 grams and
was composed of two distinct parts.   The line between them was
sharply defined and easily recognized by the difference in the
color and hardness of the parts.   The lower portion was removed
with the aid of a chisel.   It adhered tenaciously, but the separa-
tion when effected was fairly clean.   The lower portion, or bot-
tom, was a very strongly magnetic, hard, gray alloy, with con-
choidal fracture, and fine granular structure, and did not change
on exposure to the air.   The upper portion was not magnetic;
was somewhat malleable; had a coarse granular texture, and in the
mass was not readily acted on by hydric nitrate, sp. gr. 1·39, but
when granulated deported itself like granulated tin.   I endea-
vored to avoid the necessity of granulating this regulus by diluting

the acid and applying heat, which treatment was continued for two hours, but it then became evident that granulation would have to be resorted to and the regulus was removed, washed, and dried at a gentle heat. During the digestion there were frequent detonations, whereby portions of the contents of the dish were projected out of and several feet beyond it. The diameter of the dish was 18 inches. When the dried regulus was heated, preparatory to granulation, it gave out a succession of sharp reports accompanied by a reddish flame and a puff of smoke. These reports were distinctly heard in an adjoining room and the force of the explosions was sufficient in several instances to move the regulus. This phenomenon will be referred to again.

The hard, gray, magnetic alloy could not be cleaned by treating it with either hydric chlorid or nitrate as each of these agents attacked it; therefore it had to be broken and picked. It fused easily before the blowpipe and at an incipient white heat emitted sparks resembling those produced by burning steel; when finely powdered and strewn into the flame of an alcoholic lamp or candle it burned like reduced iron, but less readily.

The analysis of this alloy gave:

	XI.	At. Equiv.	Ratio.	
Sn..............	30·11 = 35·44	30·03	1	1
Fe..............	54·76 = 64·56	115·28	3·84	4
Insol..........	14·72 ——— 100·00			
	99·59			

Fe_4Sn requires Sn 35·51%, Fe 65·49%.

There were two errors in this analysis. First, there was a small amount of carbon which was not determined; second, the insoluble portion was not weighed in the same condition that it existed in the alloy. It changed upon ignition, absorbing oxygen and was consequently too high as recorded. The ratio, however, for the tin and iron appears to be correct.

The alloy obtained by treating the upper portion of this regulus, designated dross " C," with hydric nitrate was divided into two portions, one strongly, and the other very feebly magnetic. In

this case the division into magnetic and non-magnetic was quite unsatisfactory. There seemed to be a regular gradation from one extreme to the other with no break to mark any division.

The strongly magnetic portion was dendritic in form and gave upon analysis:

XII.	At. Equiv.	Ratio.	Required.
Sn..... 68·87	58·36	1·05	67·82
Fe..... 30·84	55·07	1	32·18
Insol... ·26			
			100·00
99·97			

This alloy was soluble in hydric chlorid and the analysis shows an excess of tin, probably free.

The feebly magnetic portion consisted of a mixture of forms. By a little careful manipulation, slides could be obtained on which other than six-sided prisms could scarcely be found; but if the finest portion was taken these crystals were found to be absent. There was one well defined form observed and easily interpreted, especially as it was seen end-on. It was a short ortho-rhombic prism with the basal pinacoid. One of the six-sided prisms was of unusual interest because of its size, its transversely-projecting plates, and shining but deeply-etched basal pinacoid. Another crystal presented a combination of a prism, a macropinacoid and a dome. I am inclined to hold the six-sided prisms to belong to the ortho-rhombic system and hope to be able to give a reasonable explanation of their formation. I regret that this small amount of material, rich in forms, was sacrificed for the analysis, the results of which were:

XIII.	At. Equiv.	Ratio.		Required.
Sn......... 71·42	60·52	1·21	6·05	71·66
Fe......... 27·88	49·98	1	5	28·34
Insol....... ·73				
				100·00
100·03				

The microscope showed that this material was mixed, and as this ratio, 1·21, had not been obtained before, it is dismissed until later.

In order to determine the influence of an increase in the ratio of the tin in the mass, a quantity of the regulus, dross " C," was fused with its own weight of bar tin and yielded mixed alloys, insoluble in hydric nitrate, amounting to 13·5% of its weight. The magnetic portion of this was made up of dendritic masses and fragments; its color was gray and it was soluble in hydric chlorid.

The analysis of this product gave:

XIV.	At. Equiv.	Ratio.		Required.
Sn......... .... 73·71	62·46	1·35	4·05	73·75
Fe......... 25·81	46·10	1	3	26·25
Insol....... ·20				
				100·00
99·72				

I obtained but 0·4239 grams of non-magnetic alloy, which was not at all clean. Analysis gave:

XV.	At. Equiv.	Ratio.		
Sn .... 72·92 = 75·23	63·76	1·44	2·88	3
Fe........ 23·88 = 24·77	44·20	1	2	2
Insol. .... 3·20	100·00			
100·00				

The alloy obtained by treating the granulated portion of the regulus, dross "C," with hydric nitrate, was made the basis of some subsequent experiments. This alloy was slightly mixed, but was essentially the alloy FeSn. One part of this alloy was fused with three parts of metallic tin. The whole regulus was treated with hydric nitrate, sp. gr. 1·39, which acted upon it violently; it was removed from the acid after a short time, and was found to have lost five grams and yielded 1·05 grams of alloy equal to 21·0% of the portion oxidized. This alloy was wholly and strongly magnetic; it was composed of rough, irregular grains, which under the

microscope were seen to be made up of still smaller grains. The aggregations had, in many instances, very small acicular crystals projecting from them. The alloy was dark-gray, almost black, with a strong metallic luster and shining. The dendritic forms were almost entirely absent. There were one or two bunches which appeared to be made up of plates, possibly needles, as there were many points projecting from them. Analysis gave:

XVI.	*At. Equiv.*	*Ratio.*
Sn .... 69·53	58·92	1·09
Fe .... 30·33	54·16	1
Insol........... ·18		
100·04		

The remaining part, about seven eights of the regulus, representing the interior portion, yielded 2·1082 grams of alloy equal to 7·81% of the mass. The alloy as obtained consisted of 78·23% or 1·6492 grams magnetic and 21·77% or 0·359 grams non-magnetic.

The magnetic portion was composed of grains and dendritic forms with projecting needles. The color of the mass was dull gray and its lustre was duller than that of the preceding alloy.

Analysis gave:

XVII.		*At. Equiv.*	*Ratio.*	
Sn ..... 73·31 =	74·05	62·7	1·35	4·05
Fe ..... 25·55 =	25·95	46·3	1	3
Insol ... 1·45	100·00			
100·31				

While this alloy was magnetic, it was very markedly less so than that from the outer portion of the regulus.

The non-magnetic portion was composed of very small irregular fragments and needles, with much crucible dust.

Analysis gave:

XVIII.		At. Equiv.	Ratio.	
Sn .... 71·63 = 76·03		64·42	1·5	3
Fe .... 22·59 = 23·97		42·80	1	2
Insol ...... 5·78	100·00			
100·00				

The next regulus was obtained by fusing one part of the crude alloy from dross " C," with ten parts of bar tin.   This crude alloy was mixed with metastannic acid; deducting this, the alloy corresponded approximately to the formula $FeSn$.   The regulus weighed 109·75 grams and yielded 1·8816 grams of alloy distributed as follows: The outer and largest portion gave 0·5369 grams, of which 0·2578 grams were non-magnetic; the middle portion gave 0·5181 grams, of which 0·0629 grams were non-magnetic; the innermost portion, weighing 18 grams, gave 0·8266 grams, of which 0·1587 grams were non-magnetic.   The alloy from the outer portion was divisible into three portions, a non-magnetic, a magnetic, and a strongly magnetic portion.   The strongly magnetic portion showed many dendritic forms, but these were much more abundant in the magnetic portion, while the non-magnetic portion was made up of many small and a few large six-sided crystals.

The mechanical separation by means of the magnet was found to be very difficult because only a small part of the magnetic portion could be taken up at a time without carrying some non-magnetic in its mass, and repeated separations were necessary even where the utmost care was exercised.   The magnetic part from the middle portion of the regulus was very strongly so, and consisted largely of dendritic forms with projecting ridges and re-entering angles, across which projected many fine glistening needles, whose form I could not make out.   The non-magnetic part from this portion showed many large and perfect six-sided prisms, while others were imperfect, being penetrated quite to the center by a longitudinal groove running down one or more of the prism faces·

The magnetic alloy from the innermost portion of the regulus was made up of light-gray, very irregular masses with needle-like

projections; while the non-magnetic portion was composed, for the most part, of six-sided crystals showing rough prismatic faces with a bright shining basal plane. Some of these crystals being wider than long, presented themselves end-on, and were observed to be hollow and to have a six-sided section, but the equality of the angles was very doubtful.

The magnetic portion was easily soluble in hydric chlorid with the separation of a few black flakes which dissolved upon addition of potassic chlorate or hydric nitrate.

Analysis gave:

XIX.		At. Equiv	Ratio.	
Sn	73·11*	61·95	1·326	4
Fe	26·13	46·71	1	3
Insol...........	·18			
	99·42			

*A slight loss occurred.

The non-magnetic portion was composed of mixed forms, some of them being comparatively large six-sided prisms, others were of doubtful form, and much of it was in the form of grains and rods rather than in crystals. Hydric chlorid dissolved it readily.

Analysis gave:

XX.		At. Equiv.	Ratio.	
Sn.............	71·16	60·26	1·21	6·05
Fe.............	27·88	49·78	1	5
Insol...........	1·32			
	100·36			

All of the six-sided crystals obtained from this regulus had rough prism surfaces and reflected as though those surfaces were made up of a series of transverse ridges like the surface of an ordinary washboard.

295 grams of the upper or non-magnetic portion of dross "C," as it was obtained by remelting of slags, etc., were melted

together with 360 grams of bar tin under potassic cyanide and kept at the highest temperature obtainable in the furnace for forty-five minutes. The crucible was allowed to cool in the tightly closed furnace. The cooling required, under these conditions, several hours, and the furnace was allowed to stand over night. The regulus was bright, its upper surface being full of cavities which were sparsely lined with crystals, so large as to be easily seen with the unaided eye. The microscope revealed a few very perfect six-sided prisms with rough prismatic surfaces. One group of crystals presented shining end surfaces, but they were marked with lines parallel to the edges. One individual in this group appeared to be modified by what would have been a pyramidal surface if the crystal had been hexagonal, and its basal plane was deeply pitted. This regulus was sawed transversely into four pieces and numbered from the top downward 1, 2, 3 and 4 respectively. No. 3, weighing 123 grams, yielded 11·85% or 14·5624 grams of mixed alloy insoluble in hydric nitrate, 9·0% of which, or 1·0194 grams, were non-magnetic and were made up of bright, shining needles with quadrangular sections and small fragments of indefinite form. The needles just mentioned can be very easily distinguished from the six-sided prisms, even when the latter are so thin as to be acicular. The former are bright, smooth, shining, and quadrangular and reflect the light very perfectly; the latter are rough and much duller in color. Even their smooth shining end surfaces are not comparable to the former in reflecting power and are, moreover, quite different in other respects. The magnetic grains removed from this portion were easily distinguished from the non-magnetic ones by the different character of their aggregations. This alloy was readily soluble in hydric chlorid, even when cold and somewhat dilute.

Analysis gave:

XXI.	At. Equiv.	Ratio.		Required.
Sn .... 77·25	65·47	4·92	5	77·84
Fe .... 22·37	39·95	3	5	22·16
Insol.... ..... ·26				
———				100·00
99·88				

The magnetic portion was composed of rough stick-like aggregates and dentritic forms, both of which had many projecting points or needle-like processes, suggesting that the fine needles of the preceding alloy might have been the broken off ends of these projections and that the magnetic portion was of a mixture and not a single alloy. This mixture or alloy was strongly magnetic and formed a comparatively loose powder; many of these rod-like aggregates are more or less curved. The most common form was such as would be produced by two short dendritic blades intersecting each other at right angles. It was readily attacked by hydric chlorid.

Analysis gave:

XXII. *

Sn	71·69
Fe	2·721
Insol.	·28
	99·18

*See Analyses IV to VII, inclusive.

The top piece, section No. 1, showing six-sided crystals in cavities, weighed 173 grams and yielded 8·94% or 15·3714 grams of alloy, of which only 7·16% or 1·1 grams were non-magnetic.

The magnetic portion was a gray, comparatively coarse and strongly magnetic powder made up of various indefinite forms, many of them mere grains; others appeared to be masses of crystals, packed side by side, forming many of the larger aggregates. A few of these masses appeared to have at the end of their branches, where these were present, a plate of definite form, that is six-sided. There were also many needles, but the dendritic form was the prevalent one in this sample. The material for analysis was re-sorted by means of the magnet and boiled with quite strong hydric nitrate, when the acid became slightly yellow. These alloys are not soluble in hydric nitrate, but are attacked to some extent when boiled with a slightly diluted acid. They are all soluble in hydric chloric, which I have uniformly used as the solvent, with the subsequent addition of hydric nitrate or postassic chlorate to dissolve the black flakes which separate. These were found to

consist of minute traces of copper and lead. This magnetic portion was the only sample in which I detected any appearance of rusting, even under the microscope, except in the case of the first sample where it was rather a tarnishing than a rusting. The projecting needles in this case were not the same as those in the former, at least, they differed from them in being magnetic. In the coarser part of this powder were observed some rudely tetragonal forms, but so imperfect and blurred that I regarded them as accidental.

The saw dust made in sawing the regulus was treated to obtain the alloy in it, but the alloy was so finely pulverized by the process that it remained suspended in the solution for several days.

Two analyses of the magnetic portion gave:

	XXIII.	*XXIV.*	*At. Equiv.*	*Ratio.*	
Sn	72·73	72·73	61·63	1·26	5·04
Fe	26·91	27·10	48·57	1	4
Insol	·36	·18			
	100·00	100·01			

The non-magnetic portion was composed of large six-sided forms with some rough and irregular pieces. I observed in this, what appeared to be a large tetragonal cyrstal with transverse striations, to which was attached a small, six-sided crystal. The lustre, color, and general appearance of these crystals were the same. The basal plane of the small crystal was pitted. I have no doubt as to the quadrangular section of the larger crystal, as several similar individuals were observed in this as well as in other samples; but I think that they, and the six-sided forms, are referable to the same system and are not different alloys. Many of the larger crystals had the appearance of having been deeply corroded and a few of them were hollow. Hydric chlorid dissolved them readily and completely; only the larger crystals resisted its action for a longer time.

Analysis gave:

XXV.	At Equiv.	Ratio.		
Sn .... 74·43	63·06	1·38	2·76	4·14
Fe .... 22·55	45·62	1	2	3
Insol.... .... ·22				
100·20				

This analysis does not satisfy either of the formulas Fe_2Sn_3 or Fe_3Sn_4, but it approaches the latter more nearly than the former, and indicates that the sample was a mixture in which the alloy Fe_3Sn_4 predominated. I obtain for this mixture, on the supposition that there were but two alloys present, and that these alloys were those whose ratios were nearest, respectively, above and below the one found—the formula $2\ Fe_3Sn_4 + Fe_2Sn_3$—requiring the ratio 1·375 with Sn 74·43% and Fe 25·51%.

The second section of the regulus (295 grams, dross "C"+ 360 grams bar tin) weighing 155 grams, was re-melted under borax with an equal weight of bar tin. As this regulus carried about ten per cent of alloy, there were 15·5 grams of it, or about 5·0% of the weight of tin and regulus taken. The resulting regulus was not distinguishable from pure tin, except that its upper surface was full of cavities lined with needles, some of which were recognizable as six-sided prisms under a magnifying power of twelve diameters. The crown of the regulus as removed weighed 76 grams and yielded 5·38% or 4·0896 grams of alloy, 14·55% of which were non-magnetic and composed of large, six-sided crystals with a few irregular grains. The six-sided crystals were perfectly non-magnetic, but some of them were attached to magnetic masses, and the whole could be picked up or not as the magnet was presented to the magnetic mass or the crystal. This material was very difficult to clean. Analysis gave:

XXVI.	At. Equiv.	Ratio.	
Sn .... 73·87	62·6	1·33	4
Fe ... . 26·34	47·00	1	3
Insol.......... ·51			
100·72			

The magnetic portion was gray, strongly magnetic, and composed of club-shaped masses, with many projecting, irregular portions. Only a few aggregations formed by intersecting planes were present. This alloy was readily soluble in hydric chlorid. Analysis gave:

XXVII.	At. Equiv.	Ratio.	
Sn .... 74·35	63·06	1·26	4·08
Fe .... 25·94	46·30	1	3
Insol... .... ·22			
Pb and Cu ......traces			
100·51			

This sample, though mixed, corresponded essentially to the formula Fe_3Sn_4.

Section No. 4, the bottom of the regulus, weighing 172 grams, was melted under borax with twice its weight of bar tin. The resulting regulus was treated with successive portions of 300 c.c. each, of hydric nitrate, sp. gr. 1·39. The regulus was removed, thoroughly washed, dried and weighed after each treatment. The assumption was made that all parts of the regulus would be equally acted upon by the acid, and that the effect of the successive treatments would be to remove successive envelopes of nearly equal weights and demonstrate how the alloy was distributed in the mass. The first, second, third and fourth portions of acid removed from the regulus 99·75, 104, 100 and 100 grams, respectively. The first portion, the outer envelope, yielded 3·18%; the second, 2·70%; the third, 2·57%; but this was too low, for a difficulty in its manipulation caused a loss; the fourth, 3·07%, and the fifth, 3·09%, of mixed alloy. These results are not in harmony with other observations,

for the distribution in this case was practically uniform throughout the mass; while in others it was quite irregular, the outer portion being far richer in alloy. The alloy obtained from each portion was divided into two parts, a magnetic and non magnetic, with the following results for the non-magnetic:

	Amount by weight.	Percentage of the total alloy.
(1)	1·1657	36·63
(2)	0·4742	17·03
(3)	0·3818	(rejected)
(4)	0·2908	9·47
(5)	0·2074	6·71

The amount of non-magnetic obtained equaled 0·52%, and the total alloy about 3·01% of the regulus, while the alloy added with section No. 4 equaled 3·33% of the mass. The pronounced decrease in the amount of non-magnetic alloy from the exterior of the regulus inward, the total amount remaining so near constant, suggests that either the rate of cooling or the duration of the higher temperature may have a determining influence upon the properties and possibly upon the composition of the alloys.

The magnetic alloy from portion No. 1 was separable into two portions, one much more strongly magnetic than the other; this was not the case with that from the other portions. The more magnetic could not be satisfactorily distinguished from the less magnetic portion by the form of its crystals or aggregations. There seemed, however, to be a difference, in this, that the less magnetic approached nearer to a definite, i. e,, a prismatic form, and the jagged aggregations were less conspicuous.

The properties and development of these alloys suggest that several of them may become magnetic or non-magnetic according as they are formed under one or another set of conditions. The distinction of magnetic and non-magnetic was much less satisfactory in this than in any preceding case. The result of the experiment gave three portions of alloy—a strongly, a feebly and a non-magnetic one.

The strongly magnetic portion had a light-gray color, a mild metallic lustre, and was made up of rods and combinations of such forms.

Analysis gave:

XXVIII.	At. Equiv.	Ratio.	
Sn................... 73·84	62·56	1·33	4
Fe................... 26·35	47·05	1	3
Insol .... ·30			
Pb and Cu ....traces			
100·49			

The less magnetic portion resembled the preceding except in the degree of its magnetic property, in the presence of dendritic forms which were almost entirely absent in the preceding, and in its composition. The analysis gave:

XXIX.	At. Equiv.	Ratio.
Sn ...·................ 74·61	63·14	1·41
Fe .... 25·15	44·91	1
Insol .... ·31		
100·06		

The mixture $3 Fe_3Sn_4 + 2 Fe_2Sn_3$ requires the ratio 1·385 with Sn 74·48% and Fe 25·52%.

The non-magnetic portion was made up of six-sided prisms with projecting plates, together with rod and club-shaped masses, simulating crystal forms. The analysis gave:

XXX.	At. Equiv.	Ratio.	
Sn .... 72·93	61·80	1·295	3·895
Fe .... 26·78	47·71	1	3
Insol.............. ·44			
100·15			

I am convinced that the explanation of these results is to be found in this, that there is formed at first an alloy richer in tin, but as the temperature is increased, or perhaps simply maintained for a longer time, a change analagous to that produced by heating

iron pyrites, takes place, whereby new alloys are formed. The alloy, $FeSn_2$, and probably others, having a high percentage of tin, are non-magnetic—possibly under all conditions under which they can be formed or exist—while those with a high percentage of iron may always be magnetic. But those with intermediate percentages of iron may or may not be magnetic according to the conditions under which they have been formed, and possibly the *time* during which they have been subjected to them.

Noellner makes the observation that $FeSn_2$ is non-magnetic, but acquires this property upon being fused; he does not, however, seemed to have observed or even looked for any other change in the alloy; nor have subsequent investigators, so far as I know, touched upon this point. Some of these alloys, as Fe_3Sn_4 and Fe_4Sn_5, may, and actually seem to be capable of sustaining for some time a temperature sufficient to fuse them without suffering any change in their composition, but I am doubtful whether the alloy $FeSn_2$ can be heated by itself to such a temperature as may be required to fuse it, for any length of time without its undergoing some decomposition.

The fact that the non-magnetic alloy in this regulus decreased from the exterior inward, while the total amount of the alloy remained about the same, together with the other fact, that the composition of the two portions, magnetic and non-magnetic, was practically the same, suggests the probability that these alloys may lose their magnetic property at a high temperature and acquire it again perfectly only upon cooling slowly. It is true, so far as my experiments go, that the outside portions of large reguli are richer in non-magnetic alloy than the interior portions, where the cooling takes place more slowly, and the small reguli are uniformly richer in non-magnetic alloy than the larger ones. But they are not quite comparable, because the ratio of tin to the alloy formed is not the same.

The non-magnetic portion was divided by sifting, into larger and smaller forms to facilitate the study of the crystals. The smaller ones were used for analysis, and the question arises whether the larger and smaller crystals in such a mixture are the same alloy or not? And another one in regard to the ratios, whether it is correct to assign the perfect ratio nearest to that found, as the

ratio for the alloy? My study of the crystals leads me to answer
the former in the affirmative; but in regard to the latter, in cases
where the differences between the perfect ratios, those correspond-
ing to simple molecules, is so small, that even a slight deviation is
significant, I believe that resort to calculation leads nearer to the
truth than the adoption of the next or nearest perfect ratio.

The ratio of the tin to the alloy added in this experiment was
29·5; and the iron in the alloy equaled 0.853% of the mass.

The next regulus was obtained, by fusing under borax, three
grams of alloy containing Sn 72·00% and Fe 24·65% with 150
grams of tin, or 1 : 50.   The iron amounted to 0 51% of the total
weight.   The regulus was dark, somewhat dull, and resisted the
action of hydric nitrate until the latter was heated, when its action
became violent.   The metastannic acid was quite pink but no
manganese was detected in the alloys.   The yield of alloy was
2·263% of the regulus, or 3·5082 grams, and was wholly non-mag-
netic.   Such of it as remained upon a hundred-mesh sieve was
preserved for the study of the forms, which proved to be exceed-
ingly interesting and a careful study of them will, doubtlessly,
throw some light upon the order in which these alloys are formed.
Some of the forms noted may properly be designated as cog-wheel
forms.   These had a sharply defined interior space, the sides of
which were regular and the angles sharp.   This space corresponded
to the mould of an orthorhombic combination of a prism and a ma-
cropinacoid.   Around this was apparently deposited a layer of an
alloy preserving the form of the enclosed space, respectively crys-
tal, until it had gained a greater or less thickness, when the uni-
form growth seemed to have ceased and been confined to the angles.
In some cases this manner of growth was continued to the end,
which was uniformly the case where the growth from the different
angles was unequal.   But where it was not there came a change in
the development, the radial changing to a lateral growth with a
re-establishment of the original angles, leaving a deep sulcation
corresponding to the face, whether prism or pinacoid.   This kind
of growth was in some cases symetrical, in others not.   These fur-
rows might, in some cases, have been partly filled, and this would
perfectly account for the furrowed faces which had been observed
in almost every instance where I had obtained any number of

these six-sided forms. Another form was a hollow one, the shell being single and uniform in thickness, with regular but uneven faces. In one instance I observed a double shell, the outer one projecting beyond the inner. These were the non-magnetic crystals, designated six-sided forms. The pitted basal pinacoids are accounted for in the same way, i. e., when the growth of the crystal closed the hollow form, the plane produced was seldom perfect and the apparent pits were openings into the interior of these crystals. This comports well with the observation that all, or nearly all, of the crystals not having a shining basal plane and seen end on, or such as were broken, were hollow. A few forms were observed which suggested, as their manner of formation, the envelopment of an original crystal with the obliteration of the basal plane, it being replaced by a shoulder with the extension of the enveloping material to a point beyond. Some further observations on these forms will be made, in connection with other material, corroborative of the view that these six-sided crystals, at first held to be hexagonal, were only imitative forms of original orthorhombic crystals.

The portion which passed through the hundred-mesh sieve consisted of forms similar to those just described, and bright acicular crystals. An ineffectual attempt was made to separate these by means of very dilute, warm hydric chlorid, but the two alloys were about equally soluble in this menstruum—at least, it failed as a means of separation and mechanical means had to be resorted to, by which the mixture was divided into five parts, numbered 1, 2, 3, 4 and 5, respectively.

No. 1 remained on 106-mesh bolting cloth, No. 2 on 124, No. 3 on 140, No. 4 on 156, and No. 5 passed through the last. The quantities of No. 1 and No. 2 were very small and composed exclusively of rough, six-sided forms. No. 3 and No. 4 differed only in the size of their individual crystals, and like the preceding were composed principally of six-sided forms. These together weighed a trifle over 0·5 grams. No. 5, on the other hand, was made up almost exclusively of the shining acicular, probably orthorhombic, crystals. I did not observe any satisfactory end surface on any crystal of this material. The differences between these two forms, the rough prisms and the acicular crystals, were, habit of crystal, color, lustre and structure. The faces of some of

these acicular crystals appeared to have been attacked by some agent, the hydric nitrate or some other, which acted on them in the mass of tin. One of these acicular crystals was observed projecting from and, for part of its length, penetrating one of the broken six-sided forms.

The portion which passed through the 124-mesh, but remained on the 156-mesh cloth was analyzed.

Analysis gave:

XXXI.	At. Equiv.	Ratio.	
Sn.............. 72·80	61·7	1·29	5·16
Fe.............. 26·71	47·7	1	4
Insol............ ·20			
99·71			

The portion which passed through the 156-mesh cloth gave:

XXXII.	At. Equiv.	Ratio.
Sn .... 78·17	66·26	1·75
Fe .... 21·31	38·06	1
Insol _____ .... ·22		
99·70		

The microscope revealed the fact that the last two analyses, were made on mixtures composed of only two forms, the rough, comparatively large six-sided crystals predominating in XXXI and the smaller shining acicular crystal in XXXII. The ratio given by analysis XXXI approaches 1·25, while that given by XXXII approaches 2. Using these as our limiting ratios in both cases we obtain for the former mixture the formula $9 Fe_4Sn_5 + 2 FeSn_2$, which requires the ratio found, 1·29, and for the latter, XXXII, the formula $8 FeSn_2 + Fe_4Sn_5$, which likewise requires the exact ratio found.

As we have to deal with only two forms in this case, it gives us the best basis so far presented upon which to form a judgment concerning the composition of these large, six-sided, rough and uniformly non-magnetic crystals. Analysis XXXII clearly indi-

cates that Fe_4Sn_5 was their composition in this instance.   But it is
certain that this is not always so; it would be the case were the
form in which the alloy, Fe_4Sn_5, crystallizes, unlike that of other
alloys near it in composition, but which crystallize in the same
system, and have the same habit and modifications.   Hence, the
form does not constitute a criterion by which to judge.   But, be
this as it may, this material had the formula Fe_4Sn_5; it occurred in
these forms and was non-magnetic, while the portions which served
for analyses IV–VIII, inclusive, XXII, XXIII and XXIV were mag-
netic and had a different form, but were also represented by the form-
ula Fe_4Sn_5.   From which it follows that this alloy may be magnetic
or non-magnetic, and a comparison of XXVII with XXV and XXX
indicates that the same is true of the alloy Fe_3Sn_4.   But in the case
of XXV, XXX and XXXI we had either a definite form, a six-sided
prism, or a mixture in which these were predominant; from which
we can conclude that while this form is not characteristic of a
definite chemical compound, there is a relation between it and the
absence of the magnetic property of the alloy.   The study of these
and other specimens leads me to hold these six-sided prisms in all
of their modifications to be imitative forms very probably after
$FeSn_2$, and that their composition may be either Fe_3Sn_4, Fe_4Sn_5 or
possibly that of some other alloy which may be formed under the
conditions obtaining, at that moment, in the molten mass.   This
view of the origin of these six-sided prisms, whether they are de-
rived from $FeSn_2$ or not, allows of a simple explanation of their
forms.   The hollow forms were cases where the original alloy was
wholly removed after the investment of the crystal had advanced
sufficiently to permit of their further growth without it.   The
irregular grains might have been either fragments from the broken
crystals, many of which were completely broken down, or
portions of such as were never perfect.   The original alloy proba-
bly could not exist under conditions favoring the formation of the
second, but itself suffered change, of which the second may have
been one of the products.   There is some evidence furnished that
this was the case by crystals from reguli which were fused only
for a short time, and also from such that were rich enough in tin to
admit of the separation of an upper portion of purer tin.

Three and one-half grams of alloy essentially FeSn were fused

with 225 grams of bar tin. The iron added in the form of alloy amounted to rather less than 0·4% of the regulus obtained, which was smooth and bright, but not readily acted on by hydric nitrate, sp. gr. 1·39. The metastannic acid was pure white. When about one-half of the regulus had been oxidized the remainder was removed, washed, dried and examined, and it was found to be rich in an alloy which appeared in crystals forming long and wide but thin plates traversing the regulus in all directions; some of these crystals were upwards of one-half an inch in length, while here and there throughout the mass appeared a small prismatic crystal. This regulus yielded only a very small amount of alloy insoluble in hydric nitrate—only 0·2820 grams, which was different in form and appearance from the alloys heretofore obtained, except the needles from the last experiment.

The quantity of alloy obtained being too small to operate with satisfactorily, the experiment was repeated under similar conditions and the regulus treated as before. It was however removed from the acid and examined twice in regard to its appearance. It showed, in both instances, an abundance of alloy in large plates which were evidently attacked by the acid. These crystals were as much as five-eighths of an inch long by one-fourth of an inch wide, but in no case did they exceed one-fiftieth of an inch in thickness

The yield of the crystallized alloy insoluble in hydric nitrate was 0·4471 grams, more than one-and-a-half times the quantity yielded by the other, and still amounting to less than 0·2% of the regulus. This alloy was perfectly non-magnetic. In the mass its color was dark gray, and when turned in the tube it showed a satiny lustre, and under the microscope presented a mass of acicular crystals. Those from the second were larger than those from the first regulus, but in each case many of the crystals were ` large enough to show their prismatic habit, and were probably orthorhombic crystals with the planes 110, 010, and 001.  On one of the largest crystals observed, the plane 001 was wanting, the form being completed by the dome 101.` A common combination was 010, 100, and 001, which gives a quadrangular prism, easily taken to be tetragonal. On a few of these latter I observed the plane 110. This combination was rare in my samples, but another observer has noted an alloy crystallizing in eight-sided prisms, which he re-

fers to the tetragonal system. The most favorable presentation of
these crystals was by the regulus after being removed from the
mass and carefully washed. The crystals then projected from the
mass, were readily removed, observed, and seemed to be orthorhom-
bic; but there is some doubt about their being the same as those
observed under the microscope. This alloy was clean, readily at-
tacked by cold hydric chlorid, in which it was completely soluble.
Analysis gave:

XXXIII.	*At. Equiv.*	*Ratio.*	*Required.*
Sn .... 81·01	68·67	2	80·82
Fe .... 19·14	34·20	1	19·17
100·15			100·00

In this connection I gladly avail myself of the results of two
analyses made by Prof. F. A. Genth, of Philadelphia, of an alloy
obtained from the skimmings (Abstrich) from Penang, India.
Prof. Genth, had the kindness to also send me such of his original
material as he had left:

XXXIV—Prof. Genth.	*At. Equiv.*	*Ratio.*	
Sand . ..... 9·27			
Sn .... 73·22 = 80·59	68·30	1·97	2
Fe .... 17·64 = 19·41	34·6	1	1
100·13 100·00			

XXXV—Prof. Genth.	*At. Equiv.*	*Ratio.*
Sn... ... ... 79·50	67.37	1·8
Fe... ... ... 20·70	37.44	1
100·29		

*4·02 per cent of insoluble matter deducted.

The latter analysis was made on a less pure material than the
former. That which he sent me, corresponding to analysis XXXV,

was soluble in hydric chlorid, and under the microscope was easily recognized as being composed of different forms. The predominating one was a six-sided, bright, shining, but very slender crystal. Many of these were invested with duller points, scattered more or less abundantly over their surfaces, and in some cases quite covering the crystals. There were also larger, rough, six-sided forms, some of them quite well developed, others more or less distorted; some of them were furrowed, others hollow, accompanied by a large number of rough, irregular grains having a metallic lustre. The powder was non-magnetic and had a bronzy reflex, due probably to tarnish, as this material was obtained in 1864. I have observed this sheen in but one instance in the course of my work. I hold the rough, six-sided forms in this sample to be the same as those associated with $FeSn_2$ in my own sample, and would offer the same explanation for form and appearance. The analyses also indicate that the material was mixed as Prof. Genth suggests. If we suppose the mixture contained the same alloys as mine, and base our calculation upon the ratios 1·25 and 2 as our limits, we obtain as the formula for the mixture $11 \ FeSn_2 + Fe_4Sn_5$, which requires the ratio 1·8 with Sn 79·14% and Fe 20·86%.

The next regulus was obtained from dross and rich slags. It weighed 503 grams and was divided into two portions. The upper one was dark-gray, feebly magnetic and slightly malleable with a granular and jagged fracture. The lower portion, amounting to rather more than one-third of the regulus by weight, was strongly magnetic, exceedingly hard and quite brittle; its hardness being such that it could scarcely be cut with a hack-saw. The difficulty in cutting this was likely due to small crystals occurring abundantly throughout the mass, rather than to the extreme hardness of the mass itself.

It was quite impossible to effect the complete disintegration of the upper portion by means of hydric nitrate even with the aid of heat. The action of the acid upon it was accompanied by sharp explosions so long as the heat was maintained, and though the material was thoroughly washed and dried, a succession of sharp detonations began to take place during the heating preparatory to granulation, even before the mass had attained a temperature of 100°C. Each detonation was accompanied by a red flame.

The iron in the upper portion of the regulus equaled 26·80%, and in the whole mass 11·92% of its weight.

The granulated regulus was completely soluble in hydric chlorid, and the hydrogen evolved contained hydric sulphid. The alloy insoluble in hydric nitrate amounted to 17·85%, and had the following composition:

XXXVI.			At. Equiv.	Ratio.
Sn .... 66·17	=	66·44	56·31	1
Fe .... 33·43	=	33·56	59·93	1·06
Insol..... .... ·41		100·00		
100·00				

The iron bottom, hard alloy, dross " D," was quite brittle, gray in color, and had a conchoidal fracture. The portion for analysis had to be selected, and taken as it occurred in the mass; for I could not purify it by the ordinary treatment with acids. It flattened under the pestle at first, but finally broke and could be pulverized. While it was readily attacked by each of the ordinary acids, hydric chlorid and nitrate, it was not completely dissolved by either of them or by both together. The residue was gray, shining, crystalline, and had a metallic lustre. An analysis of this material gave:

XXXVII.			At. Equiv.	Ratio.
Sn .... 38·66	=	39·42	33·4	1
Fe.................. 59·39	=	60·58	108·1	3·237
Insol .... 1·96		100·00		
100·01				

The portion analyzed was taken from near the top after a futile attempt had been made to obtain a sample by sawing the regulus into two pieces. The ratio obtained indicated that the mass consisted of the alloy Fe$_4$Sn with an excess of tin. It did not seem necessary to investigate this material further so far as the tin-iron compounds were concerned.

The next regulus, dross "E," was obtained from the same source

and in the same manner as "D." Its weight was 360 grams, but it was not divided into an upper and lower portion. One-half of the upper portion from dross "D" was added to it and the whole re-melted but without producing an iron bottom. The top of the re-sulting regulus was jagged and retained much slag, rendering it unfit for use; so one-half its weight in bar-tin was added to it, and the whole re-melted in a coke fire with a strong draft. The cru-cible was left in the fire for 28 minutes after it was judged to have at-tained its maximum temperature; when it was removed, it was placed in a strong draft of cold air, and as soon as feasible quenched in cold water. The object of this rapid cooling was to increase if possible the proportion of non-magnetic and determine the effect of the rate of cooling upon this point. The regulus was bright and arched over by a crust of a highly crystalline character, the greater portion of which was removed with the borax gloss. The upper portion of this crust was composed of a mass of fern-shaped crystals, while many orthorhombic crystals and needles projected from its under surface. The surface of the regulus under this was very jagged and slightly irridescent and rich in crystals, which were exclusively orthorhombic prisms and needles. These prisms were smooth, shining and even brilliant; the basal plane of some of them were apparently depressed at the centre and a few of them were pitted. These were not abundant, by far the greater portion of the crystals having their basal planes perfectly smooth and bright. The form of these crystals was unmistakably in harmony with the rhombic prism observed in and mentioned under XIII, and also with the fact, now observed for the second time, that a dome surface some-times occurred.

While it is possible that the different alloys crystallize in the different systems, the rhombic is the only one that I have recog-nized with reasonable certainty. It is true, however, that among the rarer forms observed was one whose face was apparently an equilateral triangle; but I have satisfied myself that this did not belong to the compounds which are dealt with in this paper.

The weight of the regulus was 733 grams. In order to obtain bright crystals, only the upper portion of the regulus was im-mersed in hydric nitrate, 50 c.c., sp. gr. 1·39. This was done twice, and the alloy obtained by each treatment was kept separate on ac-

count of the non-magnetic alloy, as well as on account of the crystals. The first treatment yielded 2·155 grams of alloy, of which 9·12%, or 0·2962 grams were non-magnetic; and the second, 2·2320 grams, of which 8·08%, or 0·1805 were non-magnetic. The alloy obtained by these two treatments equalled 10.44% of the mass removed, or 4·3874 grams.

The magnetic portions obtained by the first treatment were a coarse grained powder, made up of dendritic and very jagged rod-like forms. Some of the aggregations were composed of plates, some had many acicular crystals projecting from them, and to others were attached one or more of the rhombic prisms. The color of the powder was dark gray.

The magnetic alloy from the second treatment was much finer and had a much lighter color, but otherwise resembled that from the first treatment.

The non-magnetic alloy from the first portion was composed of rough, silvery-gray, six-sided forms, with transverse striations; there were also a few which were smooth, brilliant and much darker than the rough crystals. The corresponding portion from the second treatment were very small in quantity when freed from crucible dust and resembled that from the first portion. The six-sided prisms were separated from the dirt and acicular crystals by means of a glass plate, which had been rubbed with a cotton cloth and brought near the mixture, when the powder was attracted; but only the large forms were subsequently repelled. The susceptibility of these alloys to a charge of static electricity had been repeatedly noticed. The turning of a cork in a test tube from which a portion of the alloy was about to be poured often caused small but annoying losses. The film of crystals which formed the arch over the regulus was treated by itself, and yielded a comparatively large amount of alloy, composed of prisms and fern-shaped crystals, some of them still being joined together after the treatment with hydric nitrate.

The study of this non-magnetic portion (particularly the bright crystals) one end of which was, in some cases, completely invested in a gray material, similar in appearance to that forming the rough six-sided prisms, and which grew thinner until it became a single line of points or heads on the face of the crystal,

strongly tends to strengthen the view that the rough, and often if not always, hollow crystals are imitative forms.

Slightly diluted or gently warmed hydric nitrate attacked the regulus violently, accompanied by sharp detonations and flashes of light. The regulus was treated with successive portions of acid, of 300 c.c. each, and when the remaining regulus was washed and dried and heated to a temperature of 60 and 80 degrees, the detonations occurred. I observed that the depressions in the regulus from which the sharpest detonations proceeded were filled with a yellow compound upon whose presence they seemed to depend. On one occasion the explosions passed around the regulus, as though powder had been trained around it, but with a much sharper report. These explosions could be obtained after each treatment of the regulus with the acid. The puff of smoke accompanying the explosion was not always white, but when the explosions were less violent, and took place at a low temperature without emission of light, it was red and composed of lower oxides of nitrogen. There was a quantity of ammonic salts formed by the action of the acid on the regulus and these may play some part in the explanation of these explosions.

The successive portions of acid removed 190, 182, 177, and 161 grams, respectively, from the regulus, and yielded the following amounts of alloy:

Portion (1)—20·5413 grams, or 10·81%, all magnetic.
Portion (2)—18·2267 grams, or 10·01%, all magnetic.
Portion (3)—17·3594 grams, or 9·81%, all magnetic.
Portion (4)—17·1428 grams, or 10·71%, all magnetic.

This alloy was remarkably fine and strongly magnetic. The rapid cooling did not produce the desired results. The quantity of each portion which remained on a hundred-mesh sieve, was: portion No. (1), 1·6672; No. (2), 1·4192; No. (3), 4·1772; No. (4), 3·8077 grams, respectively. These coarser portions of the alloy, having the same form and physical properties, were united and passed through a sixty-mesh sieve to remove the coarser particles of alloy. The analysis gave:

XXXVIII.			*At. Equiv*	*Ratio.*	
Sn	67·80	= 71·67	60·73	1·2	6
Fe	26·80	28·33	50·60	1	5
Insol	5·40	———			
	———	100·00			
	100·80				

Cold concentrated hydric chlorid attacked the alloy readily, but the solution was not complete. Even upon the addition of the nitrate there remained a gray, crystalline residue, apparently unattacked, after digestion with aqua regia for an hour. A similar residue had been met with in the iron bottoms, · but this regulus was quite devoid of such, there being in its stead only a small mass of crystals. This residue was examined for tungstic acid, but only traces, at the most, could be found. Analyses XXXIX, XL and XLI of the fine from the respective portions only revealed the fact, that they were mixtures of the alloys Fe_3Sn_4 and Fe_4Sn_5. Analysis of portion No. 4, which was wholly magnetic, gave:

XXXIX.			*At. Equiv.*	*Ratio.*	
Sn	72·85	= 73·17	62·00	1·294	3·882
Fe	26·71	= 26·83	47·91	1	3
Insol	·44	———			
	———	100·00			
	100·00				

Compare analyses XXXIX with XXX, both of which correspond to the mixture $12Fe_3Sn_4 + 7Fe_4Sn_5$, requiring the ratio $1 : 1·296$.

A quantity of prills were picked out and fused by themselves under potassic cyanide. The regulus was quite black, had but little tenacity; was very feebly magnetic, and had a very coarse, granular fracture. To this were added two parts of tin, and the whole remelted under borax. The resulting regulus was bright, but the top was somewhat avernous. It weighed 182 grams. 151 grams of this yielded 5·73%, or 8·644 grams of alloy, which were all magnetic; the particles were very small, and under the microscope were seen to be of two classes; the predominant one, warty, in-

definite shaped rods, the other represented by masses with a somewhat broken reticulate structure and small projections, the ends of needles or portions of plates. The dendritic form was entirely wanting. The total amount of iron in this regulus was 2.13%. Analysis gave:

XL.	At. Equiv.	Ratio.		
Sn .... 74·60	63.22	1·47	2·94	3
Fe ... . 24·15	43.14	1	2	2
Insol .... ·30				
99·06				

This alloy was soluble in hydric chlorid, and is identical in composition with the first alloy obtained, which crystallized in plates aggregating themselves into hour-glass shaped forms, and with others which were non-magnetic. (See analyses IX, X, and XVIII).

We have so far obtained a series of alloys or stannides of iron, whose similarity to the series of sulphides of this metal, included between pyrite on the one hand, passing through the pyrrhotites to troilite on the other, is striking if not significant. Starting with FeS_2, Berzelius and also Rammelsberg have shown that the ratios Fe_7S_8 and Fe_8S_9 can be obtained by expelling sulphur, and that the ratio obtained depends upon the number of molecules of FeS_2 involved in the reaction. The series may be considered as an homologous series, with a constant difference of FeS, starting with FeS_2 as its fundamental molecule, which has never been eliminated from any member of the series, and so reducing it to FeS. But, on the other hand, artificial pyrites is sometimes met with, which is an interesting fact indicating the possibility of synthetically obtaining other members of the series under proper conditions.

The method used in this study has been to build up the molecules of the stannide from the lower to the higher ratios by the addition of tin, and not to break down the molecule with a higher ratio by the expulsion of one or more atoms, as Berzelius and Rammelsberg did in obtaining the members of the pyrite series

having a lower ratio—which reaction, or one similar to it, is the basis of Prof. Stoetzel's explanation of the formation of "Haertlinge."

There is but one series of the sulphides, and but one well developed series of stannides; though there is one of the analyses which indicates the existence of one compound based upon two molecules of $FeSn_2$, i. e., the compound $Fe_3Sn_5 = 2FeSn_2 + FeSn$. The series of sulphides is represented by the formulas FeS_2, Fe_2S_3, Fe_7S_8; that of the stannides by $FeSn_2$, Fe_2Sn_3, Fe_3Sn_4, Fe_4Sn_5, Fe_5Sn_6. It is not the object of this paper to even discuss the question as to whether the analogy between these series is a deeper one or not than is suggested by the similarity of their composition.

Some of these compounds have been described before, but there is in every case some respect in which the descriptions given in this paper vary from those given by others.   For instance, Noellner describes $FeSn_2$ as insoluble in hydric chlorid, while A. C. Oudemann, Jr., states that he prefers to use hydric nitrate in separating it from the excess of tin, leaving it to be inferred that he found it, at least, difficultly soluble in hydric chlorid.   Again, FeSn is described by Deville and Caron as insoluble in hydric chlorid and as crystallizing in plates.   The alloys which I have obtained giving this formula, analyses II, XII, XVI and XXXVI, do not agree with this description in either respect.   All writers on these alloys agree in giving aqua regia as their solvent, while I have uniformly used hydric chlorid as my solvent, and have found but a small amount of any of them insoluble in this agent.   The residue, whether it was composed of one or more alloys, was quite insoluble in aqua regia.   The descriptions of the forms in which the respective alloys occur are also quite at variance; but the fact that all of mine are in microscopic crystals may partially account for this; an explanation of the other differences may be, that these alloys vary greatly, both in form and properties, according to the conditions under which they are formed.

I have given the conditions under which my alloys were obtained, and the manner in which these conditions were varied. The compounds Fe_2Sn_3, Fe_3Sn_4 and Fe_4Sn_5 have been shown to vary in their magnetic properties.   I cannot be said to have

obtained more than one definite form, unless that designated as dendritic be considered such, and I have failed to establish, with even a reasonable degree of probability, that this form is characteristic of a given compound; for, while $FeSn_2$ crystallized in rhombic prisms, it is not proven that the large crystals occurring on the upper surface of several of the reguli, and having this form, are identical in this respect, or have the composition of $FeSn_2$. But, on the other hand, it is certain that the rough, six-sided imitative forms are not characteristic of any one of these compounds; nor is the property of being non-magnetic. Their deportment with hydric chlorid fails to differentiate them, while they are all slightly attacked by hydric nitrate.

The members of this series are all brittle; so much so that the crystallized alloys, as obtained by the method given, can be rubbed to a powder between the thumb and fingers. With some of them this is very easily done; with others it is more difficult. They all burn readily and quite brilliantly when strewn into the flame of an alcohol lamp, with the formation of a dense smoke and the emission of an intense odor of tin, best observed a short distance above the flame. This odor was so intense and similar to that of arsenic, that I could scarcely convince myself that arsenic was not present, but repeated efforts to detect it failed.

These alloys require so high a temperature to fuse them that I have only succeeded in imperfectly fusing small portions of them before the blowpipe. This applies to all with which I tried this experiment. Of some I had no material with which to make it, or so little that I did not wish to use it. Whether the compounds suffered any decomposition or not was not evident, but with soda on charcoal they were decomposed with emission of sparks, and the separation of malleable tin. Concentrated hydric sulphate acts upon them violently when heated, with copious evolution of sulphur dioxid.

That iron and tin readily unite with one another is well known; but the character of the iron and the temperature are important factors. When reduced iron, "*Ferrum reductum*," was used, the combination ensued quickly, and the solution, that is, the diffusion, of the iron throughout the mass was perfect. But when turnings of cast iron were used this was not the case.

The question arises, whether the alloys with which we have been dealing were the first products of the combination of the iron and tin, or may not have been changed in their composition by repeated melting.   It is possible they   may   change   in composition upon being remelted, but subsequent observations tend to establish the contrary—at least, within the limits of temperature under which the experiments were made.   But if the repeated meltings have any influence upon the composition of the alloys, it is very subordinate in comparison with that of the ratio of the tin to the iron.

The character of the material with which I started (prills, dross and slag) was approximately known, as it was obtained from the smelting of stream tin which had been carefully washed and smelted in graphite crucibles, with the addition of lime and fluorspar.   The usual impurities of this stream tin were principally columbite and magnetite, with occasionally a little wolfram and huebnerite.   The dross, which was the chief source of the alloys, had been repeatedly liquated, and was carefully pressed, to free it from tin; so, while it varied, it was in every case, rich in iron, sometimes containing as much as 12 or 15 and even a higher percentage of this metal.

It is probable that the alloy first formed during the reduction is not that with the highest ratio of tin, as is indicated by the results of the examination of the buttons from the cyanide assay. They underwent no subsequent treatment, and yielded the intermediate alloys, which were formed between wide limits in the ratio of tin and iron.

The analysis of the alloy from dross "A," which represents our nearest approach to the conditions existing in the original mass of tin, gave the ratio 1 : 1, and the regulus was scarcely distinguishable from pure tin.   In dross "B," which was fused for a longer time, and at a higher temperature, the principal part of the alloy had the ratio $1 : 1.25$; but in this case there was a small amount of a very rich iron alloy, with the approximate ratio 9 : 1 separated from the regulus.   It would seem probable that this might have some bearing upon the ratio of the $Fe : Sn$ in the alloy, especially if the iron bottom were produced by the decomposition of alloys previously existing in the mass of tin, which I hold to be doubtful.

The alloy obtained from dross "C" had the ratio 1 : 1, and there was a large iron bottom with the ratio 4 : 1; while dross "D," having in its upper or tinny portion 11·95% of iron, yielded an alloy with the ratio 1 : 1, and had an iron bottom equal to 33·76% of the weight of the regulus. Dross "E," with no iron bottom, yielded alloys represented by the ratios 5:6, 4:5 and 3:4. Dross "F," with no iron bottom, but carrying 2·13% of iron, yielded an alloy with the ratio 2 : 3. An examination of all the ratios for the alloys yielded by the different reguli will show that the presence of an iron bottom does not necessitate the lowest ratio for the tin, for we have in such cases the ratios 1, 1·20, 1·25, 1·33 and 1·5; nor does their absence indicate the highest ratio; for in these cases we have the same ratios as before, i. e., 1, 1·2, 1·25, 1·33 and .1·5. Still, in a general way, those reguli having an iron bottom yield alloys with lower ratios than those which have none; but the difference is neither decided enough, nor sufficiently constant to justify the conclusion that the bottoms are end products of a series of decompositions, with successive eliminations of tin and consequent enrichment of iron. The ratio of the Fe : Sn in the alloy depends upon the ratio of the iron to the tin in the mass, rather than upon any possible decompositions.

The experiments made with the crude alloy from dross "C," corresponding to the analyses from No. XVI to XXXIII inclusive, were made with the purpose of building up the series from the lowest to the highest ratio with the following results: A quantity of dross containing the alloy FeSn was fused with one and one-fourth times its weight of bar tin, with the effect of raising the ratio of the tin in the alloy from 1 to 1·25. The principal portion of the alloy found had the ratio given, but other changes were also taking place, as indicated by such ratios as 1·33 and 1·66, obtained for smaller portions. When the atomic ratio of the mixture was made 1 : 6, that of the alloy was changed from 1 : 1 to 1 : 1·33. When that of the mixture was increased to 1 : 18, that of the alloy was changed, as before, from 1 : 1 to 1 : 1·33. When the alloy Fe_4Sn_5 was used, and the ratio in the mixture was made 1 : 25, that of the alloy was changed from 1 : 1·25 to 1 : 1·33. Using the alloy FeSn, and making the atomic ratios of Fe : Sn in the mass 1 : 41 that of the alloy was changed to 1 : 1·33. When the ratio of the

mixture was made 1 : 98, a mixed result was óbtained, as shown by analyses XXXII and XXXIII, in which the ratios are 1 : 1·25 and 1 : 2; but when the ratio in the mixture was increased to 1 : 124, that of the alloy insoluble in hydric nitrate was raised from 1 : 1 to 1 : 2. Equally satisfactory results were obtained when I used reduced iron, instead of the alloy, so long as I observed the ratio in the mixture, showing that the use of the alloy had no influence upon the result of the reaction. It is evident that the ratio of the iron to the tin in the mass has a determining influence upon the alloy formed; also, that this ratio may vary within comparatively wide limits for some of the alloys, especially Fe_3Sn_4 and Fe_3Sn_5; while the formation of others is confined to narrow limits or peculiar conditions, as Fe_2Sn_3, which was found to be the chief alloy formed in only one instance, i. e., where the atomic ratio in the mass was 1 : 22; and this is singular, for in other instances where the ratio of iron to tin was 1 : 25 and 1 : 41, a lower ratio, i. e,, 1·33, was obtained. Moreover, 1 : 22 is the ratio given in Watt's Dictionary of Chemistry for a definite alloy. This would not be correct for the regulus which I prepared having this ratio; for the iron was not in perfect solution in the tin and evenly diffused through it, but existed in it partly in the form of a definite chemical compound having another ratio. There is often a large quantity of iron present which is not obtained in the form of these alloys, but it may exist in chemical combination, forming alloys with definite atomic ratios; at least one having a definite form has been mentioned in this paper as associated with the alloy $FeSn_2$.

The influence of temperature within the range used in these experiments is not evident, nor does the rate of cooling seem to have much influence upon the nature and condition, magnetic or non-magnetic, of the alloys obtained; unless the very marked differences in quantity, composition and magnetic properties of the alloys from the exterior and interior portions of some of the reguli be attributed to one or the other of these causes. But if we offer these observations as proof that either temperature or rate of cooling affect the character or composition of the alloys, we will have to explain how it happens that in those cases where we have urged the one or hastened the other to the extent of our

ability, the distribution and character of the alloy were remarkably uniform.

The term "iron bottom" has been used to designate, in every instance a hard, gray, and strongly magnetic mass forming the lower portion of the regulus, and constituting, in one case, a little more than one-third of it by weight. The analyses of these bottoms, as given in III, XI, and XXXVII, contain, as previously pointed out, two errors, but which, being in contrary direction, about neutralize each other. Only one of them, however, would affect the ratio obtained for the iron to tin when the percentages are calculated to one hundred, namely, the carbon, for it is partly, if not largely in combination with the iron, and as neither its quantity nor manner of combination is known, the ratios obtained lose a part of their significance, and it is a question whether these bottoms are other than gray cast iron with varying quantities of tin. If the analyses be examined, it will appear that only one of them gives even an approximate ratio. The fact that the material analyzed had to be used as it was taken from the crucible, may partly account for this. If these bottoms were products of a series of decompositions of alloys richer in tin than the compounds Fe_9Sn, Fe_4Sn, and Fe_3Sn, they ought to be considered as alloys, and the variations in the ratios would have to be attributed to impurities in the material. But the excess in the ratios is in favor of the iron and not of the tin, as one would expect in case they were formed by the expulsion of tin from two or more molecules of another alloy.

It is probable that iron and tin in combination with each other can be dissociated, but whether this can take place in a regulus rich in tin and at a temperature scarcely exceeding an incipient white heat, is doubtful. Some of the reguli containing less than 12% of iron produced these bottoms, but no regulus which had produced one bottom produced a second upon subsequent fusion.

I made some experiments under known conditions to determine whether the alloys of iron and tin might have been the products of decomposition. I used bar tin and reduced iron, beginning with, tin 92%, iron 0%, and increased the latter until it amounted to 15%. Some of the reguli showed a separation of the mass into strata of harder and softer tin, but no bottom was

obtained in this manner; though the heat was intense—sufficient to melt an ounce of cast iron, placed in an almost cold crucible in less than six minutes. The combination of tin with the reduced iron took place readily, but scarcely any combination took place when cast iron in the form of turnings was used; when the whole was fused for an hour, a bottom was formed, but whether it was other than the cast iron which had been added and simply fused was uncertain. Having failed to satisfactorily obtain the bottoms in this way, the reguli, to which reduced iron had been added, were liquated, and the dross and alloy were pressed as free from tin as possible and remelted. The resulting regulus was hard and brittle, and had a crown of softer tin, which was thickly beset with orthorhombic crystals. The liquations and meltings were repeated six times, the temperature at which the liquation was effected being higher each succeeding time, but no bottom was obtained.

Being satisfied that I was not likely to obtain my object in this way, I took a portion of one of the alloys, Fe_4Sn_5, and fused it in a double crucible for a little less than one hour. The alloy fused, but showed no signs of decomposition. The fused mass was homogeneous, and had the same composition after, as before the fusion.

These experiments indicate that some other condition than the presence of a large percentage of iron is necessary to the production of the bottoms. The experiment in which cast iron was added suggests that during the continued heating of the original tin charge, in which were magnetite and other iron bearing minerals, and an excess of anthracite, a portion of the iron was reduced and carbonized. But the temperature was not sufficient to make the mass liquid enough to permit of its fusion and separation as cast iron, though it was retained in the slag and dross upon the liquation of the tin. In my experiments, however, the slag formed was more fusible and liquid when melted, and the total mass, including the crucible, was smaller, so that the temperature necessary to fuse it, together with conditions favoring its separation, were attained — resulting in the formation of these bottoms.

The direct proof of the correctness of these views rests upon

a single but conclusive experiment. The final regulus obtained by repeated liquations and meltings of the dross was fused in a charcoal lined crucible, with the addition of charcoal to the coarsely granulated regulus, for one hour; when, upon cooling and breaking, there was a bottom adhering to the regulus. An examination of the regulus before its fusion with carbon gave the following data: Total iron in the regulus equaled 12·41%; alloy insoluble in hydric nitrate, 28·2%; composition of same, Fe 31·96, Sn 68·04, corresponding to the alloy FeSn. This bottom weighed 4·8 grams; had a light-gray color; was much harder than tin; very strongly magnetic, and soluble in hydric chlorid with separation of graphitic carbon, and with the characteristic odor of hydrocarbons given off by cast iron. The iron determinations show that rather less than two-thirds of the iron in the regulus was present in the form of an alloy insoluble in hydric nitrate.

These bottoms with a high iron ratio do not lose any of their interest because they are related to cast iron; for, though containing a considerable percentage of tin, they have, with this substance the property of collecting some other alloys, either mechanically or, possibly, by dissolving them, and subsequently permitting them to crystallize out. They will be the subjects of future study. The alloys so far obtained are:

		Previously Described.
Fe_8Sn	Fe_4Sn_5	Fe_4Sn—Bergman
Fe_4Sn	Fe_3Sn_4	Fe_3Sn—Lassaigne
Fe_3Sn	Fe_2Sn_3	FeSn —Deville-Caron
FeSn	Fe_2Sn_6	$FeSn_2$—Noellner.
Fe_6Sn_6	$FeSn_2$	

THE PRESENT LIMITATIONS OF ELECTRIC POWER IN MINING.

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Few achievements of science have been received with more enthusiasm or discussed with greater appreciation of the possibilities involved than the transmission of power by means of electricity, and the peculiar fitness of electric power for mining operations, has been generally recognized.   In fact there has been a decided inclination towards exaggeration, and the subject has offered temptations too strong to be resisted by those who delight in flights of the imagination and startling prophecies.

No cause can be benefitted by extravagant praise and claims not based on facts, and it behooves those interested in electrical development and in the mining industry to face the question squarely, discuss the situation candidly, and determine as nearly as possible the present limits of electric power and the probable extension of those limits by future developments.   There has been a tendency, not only on the part of the general public, but also among electrical engineers, to look at this question from the scientific rather than from the financial standpoint.   The engineer is as dependent on the capitalist as an army on its base of supplies, and the question that every engineer must answer is not whether a certain enterprise is practicable, regarded simply as a feat of engineering, but whether it will pay sufficient dividends to enlist the necessary capital.

It requires no very deep investigation to discover that at present, electric transmission of power has limits that will be considered by many as disappointingly narrow, and a more thorough study of the question shows that although these limits will be ex-

tended by improvements that may reasonably be expected during the present generation, still there are quite well defined secondary limits beyond which they can hardly go without some very radical change in the whole process and apparatus employed.

It is not intended to speak discouragingly of electric transmission of power. On the contrary, it will be shown that it has at the present time a wide and profitable field, and that the next few years will see enormous developments in this department of engineering. But it is not probable that any of us will live to see the coal market of New York City affected by the power of Niagara Falls, nor is it likely (unless the price of coal is considerably increased), that we will enjoy the spectacle of the factories of Denver run by power transmitted from our mountain streams. Nevertheless, a glance at the remarkable progress in practical electricity in the past ten years, will serve as a warning to the pessimist and a hint that he who desires to pose as a successful prophet should avoid in his predictions the word "impossible." And whatever the future may or may not bring forth, it is certain that at the present time electric transmission of power applied to mining is a successful and highly profitable reality.

Up to date, the actual use of electricity in mines has been comparatively small. This has been due to two causes:

First, mine managers are cautious about spending the funds of their companies in doubtful experiments, and are unwilling to put in expensive electric plants, unless some reliable electric company will assume the responsibility and absolutely guarantee their work.

Second, the electric companies have been so occupied with other work, principally the street railway business, that while appreciating the importance of the mining field, they have been rather slow in occupying it.

Now that some of the leading companies are prepared to build and install, on full guarantees, almost every kind of mining machinery, progress in this department will undoubtedly be rapid.

The subject can best be treated under two heads:

I. The generation and transmission of the power.

II. The utilization of the power for hoisting, pumping, hauling, drilling and milling.

GENERATION AND TRANSMISSION OF ELECTRIC POWER.

Under the first head the problem is generally to design a plant that will deliver the required power and make the total operating expenses, including depreciation, repairs, taxes, insurance, and interest on investment, a minimum. Since the largest part of the operating expense is made up of the above named items, which vary directly with the cost of plant, and since the other items of labor, superintendence, oil and incidentals are practically independent of the cost of plant (for a given amount of power delivered), the minimum operating expenses will generally be secured by making the original cost a minimum.

It will frequently happen that, owing to scarcity of water or other conditions, it may be desirable to allow a smaller line loss than would give a minimum cost of plant. These special conditions must be given proper weight. Still, in most mountain districts there is an abundance of water during high water season, the shortage occurring during a few months in winter and early spring, and as the power generated at that time will be much less than the maximum power for which the plant is designed, the line loss will be correspondingly reduced, and will not be a very important item. This discussion is therefore based on minimum total cost of plant, it being borne in mind, however, that all such special conditions must be given due consideration.

The question of minimum cost of plant has been investigated heretofore and expressions have been deduced, giving line loss corresponding to minimum total cost for various distances. It is the object of this paper to carry the investigation a little further and deduce equations and curves that will show in a convenient manner the minimum total cost of plant, the operating expenses, the relative economy as compared with steam under varying circumstances, the distance at which double conversion becomes cheaper than direct transmission, and other points of practical interest. The conditions as to cost of supplies, labor, freight, etc., are assumed to be the average conditions existing in the mining districts of the Rocky Mountain regions, and as nearly all these regions are reached by railroads, these conditions will not vary enough to materially affect the general results.

In a transmission of power problem, the known quantities are the amount of power desired, the amount of water power available, and the distance.   The principal questions to be decided are:

(1)   What voltage shall be used?

(2)   Shall bare or insulated wire be employed?

(3)   Shall a ground return or complete metallic circuit be used?

(4)   What line loss will give best general economy?

VOLTAGE.

If the dynamos can be located at or near the mine, 220 volts at motor is generally the most convenient voltage.   It is absolutely safe, is easy to insulate and is applicable to all purposes, including lighting by connecting two lamps in series.

When distance from dynamo to motor exceeds about half a mile, the wire for 220 volts becomes a serious item, especially as a large portion of this distance is frequently underground, where rubber-covered wire must be used.   From this distance up to about two miles, 440 volts at motor (500-volt railway generators) will generally be most desirable.   This voltage possesses the same advantages as 220 volts in a less degree; it is not dangerous to life, although the shock is painful; it is not very difficult to insulate it, unless the mine is very wet; incandescent lights, in a series of five, will generally meet every requirement in a mine.   At Aspen, Colorado, where more electric mining machinery is in use than in any other camp, this voltage is used exclusively under ground for hoisting and drilling, and in some places for lighting, and no troubles of any consequence have been experienced.   A lower voltage (220) is undoubtedly preferable when practicable, but it is better to use 500 volts than to be forced to use double conversion at short distances.

Considerations of safety and insulation of line and motors, make 500 volts the highest voltage that should be used in mines, except in certain particular cases where mine is dry and where wires can be permanently placed and thoroughly protected, and where motors are in a dry chamber and isolated from the general mine.   Consequently when the distance becomes so great as to make the wire for 500 volts so expensive as to render double conversion

cheaper, it will generally be necessary to transmit at a very high voltage, converting at mine to 220 volts. The distance at which this conversion becomes desirable will be indicated in the following discussion. The primary voltage to be used in this case may as well be as high as can be successfully managed; it is mainly a question as to how high voltage machines the electric companies are willing to make and guarantee, due allowance being made for the fact that beyond a certain point increase in voltage must mean increased cost of manufacture, and greater liability to break-downs and increased repairs. In the present state of the art, it may be the best plan where the power can be used or converted to a lower voltage in sufficiently large units, to employ several. dynamos in series, the armature shafts being connected by flexible couplings, and to connect a number of motors in the same way, thus keeping the voltage in each machine within a moderate limit. Generally, however, the power will be scattered among numerous mines, too far apart to permit them to be supplied from the same converting plant, and each using too small an amount of power to admit of using a number of motors connected as described. In such cases single motors must be used, wound for as high a voltage as may be found desirable in actual practice.

BARE OR INSULATED WIRE.

With moderate voltages, in localities free from trees, and where lightning is not troublesome, bare wire gives good results. Even with high voltages, the other conditions being favorable, special insulators at points of support can probably be made to give sufficiently high insulation. Through wooded districts, and where lightning is troublesome, bare wire would be poor economy. If a grounded circuit is used, covered wire would seem to be almost a necessity to secure reliability.

METALLIC OR GROUNDED CIRCUIT.

This is an important question and one that merits careful investigation.

The principal difficulties with the grounded circuit are:

Increased danger of shocks.

Greater difficulty of insulation and liability to grounds, especially in a wooded country.

Greater danger from lightning.

Trouble from electrolysis of ground plates.

As it will be very seldom advisable to use a grounded circuit inside the mine, no matter what the voltage, the use of the grounded circuit will be limited to the primary circuit in cases where double conversion is used, the voltage of which circuit will be high; and even where power is used on surface for running mills, etc., there will be no object in using the grounded circuit, unless the distance is so great as to make the saving in copper outweigh the disadvantages. In other words the grounded circuit would be required only in cases where a high voltage would also be necessary, and a high voltage greatly increases the first two difficulties mentioned; consequently, the more necessary the grounded circuit becomes for reasons of economy in first cost, the more objectionable it becomes. Of course, the grounded circuit will permit the use of a lower voltage at the same cost for copper, but on the other hand, it is a question whether there will not be less difficulties with higher voltage and metallic circuit, than with lower voltage and grounded circuit, at least until we reach the highest voltage for which machines can be wound with guaranteed reliability. For all these reasons it is believed that the use of the ground return will be limited, and that in most cases sufficiently moderate cost can be secured without it.

LOSS IN LINE.

The above points having been decided to meet the requirements of the case, the question remains to determine the loss in line that will give the best general economy. For reasons previously stated, it is assumed that this will generally be secured by making the initial cost of the whole plant a minimum.

The cost of water power is a rather indefinite item, varying with length of pipe line to get required fall, difficulty of laying this line, and other local conditions. Moveover, the assumption that the cost of water power is proportional to its amount, is not strictly correct, as an increase of ten per cent in amount of power would not, as a rule, add ten per cent to cost of power plant, although in some cases it would add much more than this; for example, where water is limited and there is a rapid fall for a certain

distance, but a gentle fall on each side, so that a great increase in length of pipe would be required to get a little additional head. However, as no law can be laid down for variation in cost of water power, it is assumed to be directly proportional to amount of power, and to cost on an average $40 per horse power on pulley of water wheel, including dam, pipe-line, water wheel and power house. This is probably a fair average for large powers. In considering the results of this discussion it should be borne in mind that when water power costs more than this, the best line loss will be less than shown by formula, and vice versa.

In this discussion the following notation will be used:

e = voltage at motor.

V = loss in line.   D = distance.

P = percentage of loss of line in terms of e.

P' = percentage of loss in line in terms of e + V (dynamo voltage).

As large dynamos will be used, their efficiency is assumed to be 90%, while 80% is assumed to be a fair average efficiency for the motors, which will be of all sizes.

Motors, including freight and setting, will cost (averaging the various sizes) about $52 per mechanical H. P. on motor pulley.

Dynamos of large size, including freight and setting, will cost about $40 per electrical H. P. at brushes, or since one mechanical H. P. on motor pulley requires $(1 \div \cdot 80) \times (\frac{e+V}{e})$ electrical H. P. at dynamo terminals, dynamos will cost $\$40 \times 1 \cdot 25 \times \frac{e+V}{e} = \$50 \frac{e+V}{e}$ per mechanical H. P. on motor pulley. The necessary power on pulley of water wheel will be $1 \cdot 25 (\frac{e+V}{e}) \div \cdot 90 = 1 \cdot 4 \frac{e+V}{e}$ (approximately), costing, at $40 per H. P., $\$56 \frac{e+V}{e}$.

Pole line, including cross-arms, pegs, insulators, braces, guying and labor of stringing wire will cost, under average conditions in mountains, about $100 per 1,000 feet, or $\frac{\cdot 1 \, D}{H. P.}$ per H. P. on motor pulley. Weather-proof wire delivered at the poles will cost at present prices of copper about $180 per 100,000 C. M. (circular mils) per 1,000 feet of line (2,000 feet wire). Using the usual formula for determining size of wire and assuming efficiency of motor to be 80%, we have C. M. $= \frac{20000 \times H. P. \times D.}{e \times V}$, from which the cost of wire is found to be $\frac{\cdot 036 \, D^2}{e \, V}$ per H. P. delivered on motor pulley.

The general expenses, such as railroad fare and expenses, superintendent's salary and other incidentals, will be made up of two parts, one independent of size of plant, and the other dependent on it. A fair average allowance will be $300 for the former, and $1 per H. P. for the latter, making the cost per H. P., $\frac{300}{\text{H. P.}} + 1$.

The expression for total cost of plant per H. P. delivered on motor pulley will, therefore, be:

Motor.　　Dynamo.　　Power.　　Wire.　　Pole-line.　Gen. Expense.

$$C = 52 + 50\frac{e+V}{e} + 56\frac{e+V}{e} + \frac{\cdot 036\, D^2}{e\, V} + \frac{\cdot 1\, D}{\text{H. P.}} + \frac{300}{\text{H. P.}} + 1 \quad (A).$$

Differentiating this equation and placing first differential coefficient equal to zero, we deduce the condition of minimum total cost.

$$V = \cdot 0184\, D \dots\dots\dots\dots\dots\dots (B), \text{ or}$$

$$P = \frac{V}{e} \times 100 = \frac{1\cdot 84\, D}{e} \dots\dots\dots\dots (C)$$

$$P' = \frac{V}{e+V} \times 100 = \frac{1\cdot 84\, D}{e + \cdot 0184\, D} \dots\dots\dots (C')$$

These equations show that the drop *in volts*, to get minimum cost of plant, is independent of size of plant and of voltage employed, and depends only on the distance; but that the *percentage* of loss is dependent on the voltage used, being for a given distance inversely proportional to the voltage. When it is necessary to use low voltage at comparatively great distance, the application of Equations (B) and (C) may give such a high percentage of loss in line as to be impracticable. For example, at 15,000 feet the line drop corresponding to minimum cost of plant would be 276 volts, no matter what voltage is used. If 1,000-volt motors are used this would be allowable, but if 440-volt motors are required, they would be subjected to a range in voltage between full load and light load of nearly 276 volts, or over 50%,—a variation too great for satisfactory service.

In such cases it would be necessary to sacrifice minimum cost of plant in order to keep the variation within reasonable limits, say 30% of voltage at motor, which would be 23% of voltage at dynamo.

The equation $\frac{1\cdot 84\, D}{e} = 30$, or $D = 16\cdot 3\, e \dots\dots (D)$

expresses the relation between D and e, when a drop in line of

30% of voltage at motor, or 23% of voltage at dynamo will give minimum cost of plant, and gives the limiting value of D, beyond which minimum cost of plant must be sacrificed in order to keep line loss within the above limits.

Substituting the value $V = \cdot 0184\,D$ (B) in Equation (A,) and combining and reducing second and third terms, we have for minimum cost of plant per H. P. on motor pulley,

$$C = 52 + 106 + \frac{1\cdot95\,D}{e} + \frac{1\cdot95\,D}{e} + \frac{\cdot1\,D}{\text{H. P.}} + \frac{300}{\text{H. P.}} + 1 \ldots (1).$$

Beyond the distance determined by Equation (D), it will be necessary to abandon minimum cost of plant, and compute copper on the basis of the assumed greatest allowable line loss, 30% of voltage at motor. Making $V = \cdot 3e$, Equation (A) becomes,

$$C = 52 + 138 + \frac{\cdot12\,D^2}{e^2} + \frac{\cdot1\,D}{\text{H. P.}} + \frac{300}{\text{H. P.}} + 1 \ldots \ldots (1\,a)$$

It may be observed that in Equation (1), the second term represents cost of dynamo and power if there were no loss in line, and the third term represents cost of the excess of capacity of dynamo and power plant required to generate the energy wasted in line, and that the third term is equal to the fourth, which represents cost of wire. In other words, minimum cost is obtained when these two terms, one of which increases as the other decreases, become equal.

Figure B C' is drawn from Equations (B) and (C'). Equation (B) gives a straight line, same for all voltages. Equation (C)' gives a separate curve for each voltage. The horizontal 23% line cuts these curves at points beyond which minimum cost must be sacrificed and the line drop maintained at 23% of dynamo voltage. It takes the place of a curve plotted from Equation (D).

The curves at top of Figure B C show total efficiency of "minimum cost" plants using various voltages, and at all distances up to 100,000 feet. Each of these curves is plotted from the corresponding curve C' (line loss) by multiplying product of dynamo and motor efficiencies ($\cdot 90 \times \cdot 80$) by unity less line loss for the distance considered. The total efficiency corresponding to the assumed maximum line loss, 23%, is $\cdot 90 \times \cdot 80 \times \cdot 77 = 55\cdot4\%$. Beyond this point the efficiency curve for "minimum cost" is broken, while the full horizontal line at 55·4% becomes the efficiency curve of the plant having "lowest practicable cost."

The total efficiency curves for double conversion plants might be plotted on same figure, for comparison of the efficiencies obtained with the two methods, but as this would cause considerable confusion it has not been done. As will be shown hereafter, the efficiency with double conversion is much lower than with direct transmission.

The curves in Figure 1 are plotted from Equations (1) and (1 a), assuming various sizes of plants and voltages, a separate figure being drawn for each size of plant to avoid confusion. Equation (1), "minimum cost of plant," gives a straight line which is drawn full up to the point determined by Equation (D), beyond which, minimum cost must be abandoned in order to keep the line loss within practicable limits; beyond this point the line is broken. At this point begins the curve plotted from Equation (1 a) and representing "lowest practicable cost of plant."

The lowest curve in the 1,000 H. P. diagram shows cost of plant exclusive of wire, and assuming dynamos to be of same size as motors (line loss zero). It represents the limit which may be approached by increasing the voltage, but which can never be reached, no matter how high a voltage may be employed. The only hope of decreasing cost below this, lies in cheapening the machinery itself.

<div align="center">OPERATING EXPENSES.</div>

The operating expenses of an electric plant may be divided into two parts; the first, consisting of labor, superintendence, oil and incidentals, will be practically independent of cost of the plant for a fixed amount of power delivered. The second, consisting of depreciation and repairs, taxes, insurance and interest on investment, will be nearly proportional to cost.

In the following estimate interest is placed at 20% per annum. This is not too high, partly for the reason that interest rates are high in mining districts, but principally because mining is an uncertain and fluctuating business, and a company putting in an expensive plant of machinery can never tell how much use can be obtained from it before a change in the outlook makes it necessary to shut it down, or move it, or replace it by other machinery better adapted to the changing conditions. For these reasons no mining

man would think of investing in machinery unless it would pay for itself in five years, and many would not touch it even with that guarantee. For similar reasons, and also because mining machinery is operated under trying conditions, the item of depreciation and repairs is made a little higher than the amount usually allowed.

In plants of 100-H. P. and 200-H. P. capacity, no provision is made for superintendence or general expenses, as it is assumed that a plant of that size would be run by a mining company for its own use, and be in charge of its regular superintendent. Plants of 500-H. P. and upwards are assumed to be run by an independent company for rental of power, and to require superintendent, electrician, and other general expenses.

This accounts for the fact that the operating expense per H. P. for a 500-H. P. plant, running ten hours a day, is a little greater than for a 200-H. P. plant.

In case of plants renting power to consumers, the motors and men to run them would generally be furnished by the user of power, but these expenses are included in order to make a comparison with steam. In making this comparison it is assumed that power is used in units of 100 H. P. This assumption favors steam, because usually the power would be used in smaller units, in which case the increased cost of attendance and labor would be greater with steam than with electricity, as small motors can frequently be given the required attention by men engaged at other work.

ANNUAL OPERATING EXPENSES OF ELECTRIC PLANT.

100-H. P. Plant.	*10 hours per day.*	*24 hours per day.*
Dynamo tender	$1,500	
Chief dynamo tender and two assistants		$ 3,900
Lineman and general assistant	1,200	1,200
Motor tender (proportional part of wages of man engaged in other work)	600	1,800
Oil, waste, incidentals	200	400
Expenses independent of cost	$3,500	$7,300

Per H. P..	$35	$73
Depreciation and repairs.............................	6%	10%
Insurance and taxes..................................	1%	1%
Interest..	20%	20%
Expenses depending on cost	27%	31%

200-H. P. Plant.

Dynamo tenders ....(1)	$1,500	(3)	$3,900
Lineman and general assistant.........................	1,200		1,200
Oil, waste and incidentals.............................	300		600
Motor tenders (motors in different places and requiring part of time of two men)...................... ...	1,200		3,600
Expenses independent of cost....................	$4,200		$9,300

Per H. P.	$21	$46.50
Depreciation, repairs, taxes, interest and insurance.....	27%	31%

500-H. P. Plant.

Superintendent and electrician	$3,000		$3,000
Bookkeeper	1,500		1,500
Armature winder and mechanic........................	1,500		1,500
Lineman..	1,200		1,200
Dynamo tenders ....(1)	1,500	(3)	3,900
Motor tender (supposing five 100-H. P. motors in different places, requiring partial services of five men)........	3,000		9,000
Oil, waste and incidentals.............................	600		1,200
Expenses independent of cost....................	$12,300		$21,300

Per H. P..	$24 60	$42 60
Depreciation, repairs, taxes, insurance and interest.....	25%	38%

The allowance for repairs and depreciation is somewhat de-creased, because Company makes its own repairs, and wages of mechanic are included in regular expenses.

1,000-H. P. Plant.

Superintendent and electrician	$3,600		$3,600
Bookkeeper	1,500		1,500
Armature winder and mechanic........................	1,800		1,800
Two linemen and general assistants....................	2,400		2,400
Dynamo tenders.....................................(1)	1,800	(3)	4,800
Motor tenders (part services of ten men)...............	6,000		18,000
Oil, waste and incidentals.............................	1,000		2,000
Expenses independent of cost....................	$18,100		$34,100
Per H. P.	18·10		34·10
Depreciation, repairs, taxes, insurance and interest.....	25%		28%

As the operating expenses per H. P. of a plant of certain size consists of two parts, one independent of, and the other directly proportional to the cost of the plant, the curve of expense can be drawn by laying off on the axis of expense a distance representing the part independent of cost, and drawing a straight line, making with the axis of cost an angle whose tangent is equal to the amount of depreciation, repairs, taxes, insurance and interest, expressed as a fractional part of cost. The curves in Figure 2, are plotted in this manner. For example, the total annual operating expenses per H. P. of a 500-H. P. plant costing $220 per H. P., would be $79 if run ten hours per day, and $105 if run twenty-four hours per day. By joining Figure 2 and Figure 1 so as to make the axis of cost of plant the same for each, the two figures can be conveniently used together.

OPERATING EXPENSES OF 100-H. P. STEAM PLANT.

As stated before, in order to make the comparison as favorable as possible to steam it is assumed that the power, whether steam or electric, is used in units of 100 H. P.

In mining plants the consumption of coal per H. P. hour, actually developed, will vary from two or three pounds for high-duty compound condensing pumps, to six or seven pounds for ordinary engines and air compressors, and ten to fifteen pounds for small hoists and sinking pumps. For most mining plants an average of seven pounds per actual H. P. hour would be a moderate estimate.

Estimates are made with coal at various prices from \$1 to \$20 per ton. In most mining districts on railroads coal will cost from \$4 to \$8 per ton. At many mines in high altitudes, where it has to be packed up on jacks, it will cost from \$15 to \$20 per ton.

The item of depreciation and repairs will be high, especially for boilers, the latter ranging from 10% to 20% according to quality of water, and even higher in many cases. Depreciation and repairs will be higher for steam plants than for electric, and the allowance in the following estimate is probably too low rather than too high. The average cost of complete steam plant, including engines, boilers, pump, heater, piping, etc., set up in running order is assumed to be \$50 per H. P.,—a moderate estimate for most localities.

ANNUAL EXPENSE.

	10 hours per day.		24 hours per day.
Coal at \$1 per ton	\$ 1,277	\$	3,066
Engineer	1,800		5,400
Fireman	1,200		3,600
Oil, waste and incidentals	400		800
Depreciation and repairs, 7%.	350	12%	600
Interest, 20%	1,000		1,000
Insurance and taxes, 1%	50		50
Total	\$ 6,077		\$14,516

	10 hours	24 hours
Per H. P.	\$ 60.77	\$145.16
Coal at \$1.50 per ton	67.16	160.49
Coal at \$2 per ton	73.55	175.82
Coal at \$4 per ton	99.10	237.14
Coal at \$6 per ton	124.65	298.46
Coal at \$8 per ton	150.20	359.78
Coal at \$10 per ton	175.75	421.10
Coal at \$15 per ton	239.62	574.40
Coal at \$20 per ton	303.50	727.70

From the above estimate the vertical lines in Figure 2, representing Annual Operating Expenses per H. P. for steam power in 100-H. P. units, are plotted; the broken lines represent ten hours per day, the full lines twenty-four hours per day.

APPLICATION OF CURVES.

Assume that it is proposed to transmit 200 H. P., a distance of 4,500 feet, and that as part of the power is to be used underground, it is desirable to limit the E. M. F. at motor to 440 volts. Power is used twenty-four hours per day. Coal costs $6 per ton. Water-power plant costs $40 per H. P. on pulley of wheel. Equation (B) shows that minimum cost will be obtained by allowing a drop in line of 83 volts, which is 19% of motor voltage (16% of dynamo voltage) and within the assumed limit of 30% of motor (23% of dynamo) voltage.

In Figure 1 (for 200 H. P.) follow the ordinate 4,500 feet until it intersects curve for 440 volts, then follow the abscissa horizontally until it intersects axis of minimum cost of plant at $203; showing this to be the minimum cost per H. P. Continue horizontally into Figure 2 to curve of Annual Operating Expenses twenty-four hours a day, thence on vertical ordinate to axis of Operating Expenses; showing Annual Operating Expenses per H. P. (including depreciation, repairs, taxes, insurance and 20% interest) to be $110. The operating expence for steam power, twenty-four hours per day, coal $6 per ton, is shown in same figure to be $298. The saving is $188 or 92% profit on $203, cost of plant, in addition to the 20% interest included in expenses.

If power is used only ten hours per day, the same process shows an annual saving of $44 per H. P., or a profit of 21% above the 20% interest.

Assuming that 1,000 H. P. are to be used ten hours per day, coal $4 per ton, and reversing the process by starting at the intersection of expense curve for electricity (ten hours per day) with expense line for steam (ten hours per day), coal $4 per ton, and passing along the horizontal abscissa to the cost curve, 440 volts, and thence down the ordinate to the axis of distance, we find that 14,600 feet is the greatest distance at which electric power at 440 volts can compete with steam when coal is $4 per ton, and yield 20% interest on the investment. With 1,000 volts the limiting distance would be 33,000 feet. If 2,000 volts can be used, and coal cost $6 per ton, the limiting distance would be 87,500 feet. If coal costs only $1.50 per ton, and granting that 6,000 volts at motor can be successfully employed, it will pay to transmit power

56,000 feet (10ˑ6 miles) if used ten hours per day, or 265,000 feet (50ˑ2 miles) if it can be utilized twenty-four hours per day. The curves are not sufficiently extended to show the latter distance, which is obtained by calculation from Equation 1 a.

The lowest line in Figure 1, as previously explained, shows the limit of cheapness which can be approached but not reached, except by a decrease in the cost of manufacture of the machines themselves. The alternating and "three-phase" systems, which are regarded as a possible solution of the problem of long distance transmission, require converters at the generating station to raise the voltage to the enormous amount desired, and another set at the motors to lower it again, and although it is quite probable that the "three-phase" generators and motors can be made considerably cheaper than continuous current machines, the cost of converters will probably more than offset this difference, so that the cost of plant can hardly fall below that shown in the curve just referred to. It is not intended to disparage the possibilities of the "three-phase" system, or to deny that it may render practicable transmission to distances far beyond what may be attained by continuous currents, provided always that the price of coal is high enough to give sufficient margin to pay interest on the cost.

It is simply intended to show that even if this system fulfills the most sanguine hopes, it can hardly reduce the cost of plant below that shown in the curve described, in which copper and line loss are entirely eliminated, a condition that can never be attained by any system of which we have any conception, although the "three-phase" system may approximate more closely to it than the continuous current method. Consequently by comparing the operating expenses of this ideal plant of 1,000 H. P. used in a single unit with those of a 1,000-H. P. steam plant, also used in a single unit, comprising the best boilers and triple-expansion engines, and consuming per H. P. hour two to three pounds of coal, costing $1.50 per ton, we can get at least an approximate idea of the distance beyond which electricity, with all the improvements that can reasonably be expected, cannot compete with steam power where coal is very cheap. From the corresponding curves of Figure 2, applying the same process as before, we see that the

expense curves for steam and electricity, used ten hours per day, intersect at 122, or considerably lower than any point of curve of cost of plant "without copper," showing that the saving will not pay 20% on cost of water power plant, dynamos and motors without any line, unless this is reduced below $122 per H. P. delivered on motor pulley. If, however, the power is used twenty-four hours per day, electricity can compete with steam at a distance of about nineteen miles, and pay 20% on the investment.

This has little bearing on the mining question, as coal is never cheap in metal mining districts, but it is interesting from a general standpoint, and gives some idea of what Denver may hope for from the mountain streams.

DOUBLE CONVERSION.

To determine at what point double conversion would become preferable to direct transmission, an equation and curve showing minimum cost of double conversion plant should be deduced, and the intersection of this curve with corresponding curve for direct transmission would indicate the distance within which the latter would cost least, and beyond which the double transmission plant would be least in first cost. It must be remembered, however, that the latter should be considerably cheaper to make it preferable, as the total efficiency is lower while it is more complicated, requires more men to run it, and would probably cost more for repairs. How much cheaper it should be to make it preferable is a question to be carefully studied in each particular case, as the additional complication and cost of attendance would depend greatly on circumstances.

As the secondary distance will vary as well as the primary, there could be an indefinite number of combinations requiring different solutions, so that it is impracticable to deduce any general equation on the subject. As the secondary distance would usually be rather small, it would seldom be necessary or desirable to lose more than 10% in secondary line; on the other hand, as this distance would generally be underground, requiring low voltage and best water-proof wire, a reduction of the loss very much below 10% would rapidly increase the cost of wiring while not effecting any very great gain in economy. It is fair to assume,

therefore, that the loss in secondary would generally not vary much from 10%. With 220 volts and an average distance of 1,000 feet underground, and 10% loss, the cost of wiring (including labor) would be in the vicinity of $20 per H. P. To get a rough idea of the relative advantages of direct transmission and double. conversion, we will make the following assumptions, which will represent fair average conditions:

Secondary motors, efficiency 80%; cost in place $42 per H. P. on pulley. Loss in secondary line 10%.

Secondary generators, efficiency 85%, cost in place $40 per E. H. P. at brushes.

Primary motors, larger than secondary, efficiency 85%, cost in place $40 per H. P. at brushes ($47 per H. P. on pulley).

Primary generators, efficiency 90%, cost in place $40 per E. H. P. at brushes.

Primary line, loss to be determined to give minimum total cost.

Water power, cost $40 per H. P. on pulley of wheel.

Then 1 H. P. on pulley of secondary motor $= 1\cdot25$ H. P. at brushes of same $= 1\cdot39$ H. P. at brushes of secondary generators $= 1\cdot64$ H. P. on pulley of primary motors, $= 1\cdot93$ H. P. at brushes of same, $= 1\cdot93 \frac{e'+V'}{e'}$ H. P. at brushes of primary generator $= 2\cdot14 \frac{e'+V'}{e'}$ H. P. on pulley of wheel.

The total efficiency will be $\cdot467 \frac{e'}{e'+V'}$. If drop in primary line is 20% of voltage at dynamo, total efficiency will be 37%; with 10% primary drop, it will be 42%; and however small the primary drop is made, the efficiency can never exceed 46·7%, provided 10% drop is allowed in secondary line as assumed in above discussion. With no loss in secondary or primary line, total efficiency cannot exceed 52%.

The curves for direct transmission are drawn under the assumed condition that line drop must never exceed 30% of motor voltage $= 23\%$ of dynamo voltage, and within the straight portions of these curves the loss is less than this; consequently the total efficiency never falls below $\cdot90\times\cdot77\times\cdot80 = \cdot55$, which is higher than the highest attainable efficiency with double conversion when line loss is reduced to zero, and from one-third to one-half higher than any efficiency that can actually be attained by

double conversion, allowing reasonable line losses, as dictated by minimum cost or lowest practicable cost.

The expression for total cost of a double conversion plant becomes on the above assumptions,

$$
\underset{\substack{\text{Sec.} \\ \text{motor.}}}{C=52} + \underset{\substack{\text{Sec.} \\ \text{line.}}}{20} + \underset{\substack{\text{Sec.} \\ \text{dyn.}}}{56} + \underset{\substack{\text{Prim.} \\ \text{motor.}}}{77} + \underset{\substack{\text{Prim.} \\ \text{dyn.}}}{77 \frac{e'+V'}{e'}} +
$$

$$
\underset{\text{Power.}}{86 \frac{e'+V'}{e'}} + \underset{\substack{\text{Prim.} \\ \text{line.}}}{\frac{\cdot 055 \ D^2}{e' \ V}} + \underset{\substack{\text{Pole-} \\ \text{line.}}}{\frac{\cdot 1 \ D}{\text{H. P.}}} + \underset{\substack{\text{Gen'l} \\ \text{exp.}}}{\frac{300}{\text{H. P.}}} + 2 \dots \text{(E)}.
$$

The condition for minimum cost is same as in case of direct transmission, $V = \cdot 0184 \ D$ as the only variables are the primary line, primary dynamo, and power, same as before. Substituting and reducing,

$$
C = 370 + \left(\frac{6}{e'} + \frac{\cdot 1}{\text{H. P.}} \right) D + \frac{300}{\text{H. P.}} \dots (2).
$$

Curves are plotted from this equation in the diagram for 1,000 H. P., using 2,000, 4,000 and 6,000 volts in the primary circuit, and afford a comparison with the direct transmission method. For same reasons given in case of direct transmission, the drop in primary circuit should be limited to 30% of voltage at motor (23% of dynamo voltage), and beyond the distance where minimum cost demands greater drop than this, the minimum cost line is broken, and the curve for "least practicable cost," based on the above drop throughout, is drawn full.

The equation from which this curve is plotted is obtained by substituting $V' = \cdot 3e'$ in Equation (E), which becomes,

$$
C = 419 + \frac{\cdot 183 \ D^2}{e'^2} + \frac{\cdot 1 \ D}{\text{H. P.}} + \frac{300}{\text{H. P.}} \dots (2 \ \text{a}).
$$

These curves show that a double conversion plant using 6,000 volts in primary, costs less than a direct transmission plant using 220 volts beyond 8,700 feet, and costs less than a 440 volt direct plant beyond 17,600 feet. With 2,000 volts in primary, these distances are 9,100 feet and 19,200 feet respectively. It does not follow, however, that double conversion should be used beyond these distances.

The total efficiency of the double conversion plant (6,000 volts) at 17,600 feet is 44%, and the efficiency of direct plant

(440 volts) at the same distance, (23% loss in line) 55·4%, while the efficiency of the double transmission plant (2,000 volts) and the direct plant (440 volts) at 19,200 feet, where they cost the same, are 39·6% and 55·4% respectively. If there is more water power all the year round than can be utilized (a rare case), the low efficiency of the double conversion method would have little weight, but in most cases there is use for more power than can be obtained throughout the year.

On account of its inferior efficiency, greater number of machines, greater depreciation and repairs, and greater cost of attendance, it is plain that double conversion should not be used until a distance is reached where it is very much cheaper than direct transmission; exactly how much, depends altogether on circumstances. As 440 volts can be used almost universally in mining (except in such special cases as percussion drills requiring a peculiar pulsating current, or house lighting where connection of lamps in series would be inconvenient), it is safe to say that double conversion should seldom be used below five miles.

This discussion is of course not intended as an accurate guide in considering problems in transmission of power. It simply presents graphically and correctly enough for ordinary purposes, the general conditions and limitations of electric transmission of power under average conditions in mining districts, and enables one to determine at a glance whether a proposed enterprise has sufficient merit and promises sufficient profit to make it worthy of careful consideration.

If the plant is to be actually installed, the engineer will apply the actual conditions in all their details, and make accurate estimates in accordance with the various plans that may suggest themselves, and thus determine the best and most economical plant for that particular case.

The general conclusion to be drawn from the equations and curves presented, is that as in a great part of the mining districts of the State coal costs over $4 per ton, and water power is available within from one to five miles, the installation of electric power transmission plant presents a very attractive investment for capital, provided it is practicable to successfully apply this power to the various operations of mining.

This brings us to the second part of the subject:

APPLICATION OF ELECTRIC POWER.

The generation and transmission of electric energy is no longer an experiment, and presents few difficulties, provided the distance is within limits that can be economically covered at practicable voltages. The utilization of this power for mining purposes requires machinery of special design, operated under trying conditions, and it is in the design of this machinery that the principal difficulties arise. These difficulties are principally of a mechanical nature, and are by no means formidable, but considerable study and practical experiment will be required to bring electric mining machinery to the same state of perfection as steam machinery. At the present time, however, electricity is being used successfully for every application of power required in mining, and in spite of the comparatively small amount of attention that has been given to the subject, electric mining machinery has reached a degree of perfection that will justify any mining company in adopting it without fear as to its success wherever the conditions are such that its use will give financial profit or superior convenience.

Mills.—The running of stamp mills, crushers, rolls, concentrators, and machinery of this class, is a very simple problem, as the electric motor can be belted to the machinery as easily as a steam engine. As thousands of horse-power of electric motors are employed for similar purposes throughout this country, this branch of the subject requires no special discussion.

Ventilating Fans.—The operation of fans and blowers is still simpler, and the same remarks apply.

Hoists.—The application of electric power to hoisting presents no great difficulties. The rotary motion of the motor especially adapts it to this purpose, and requires only the necessary gearing to reduce the speed, and a controlling device to start, stop, and regulate the speed.

The requisites of a satisfactory mining hoist are:

First, simplicity and durability.

Second, ease of handling.

Third, ability to start gradually under either light or heavy loads.

Fourth, perfect regulation of speed.

Fifth, safe brakes easily applied.

The first, second and fifth conditions are as easily fulfilled in electric as in steam hoists. Under the second head multiplicity of levers should be avoided, but this is as easily accomplished with electricity as with steam, as the levers operating clutch and brake may be the same in both, while the lever that turns on steam in one case can throw on the current in the other.

The third and fourth requirements are admirably fulfilled by the series-wound street-car type of motor, controlled either by commutated field and switch, as in the Edison-Sprague system, or by a rheostat, as in the Thomson-Houston system. Electric hoists have been made, using a shunt wound constant speed motor, the motor being allowed to run at full speed, and the drum being thrown in gear by a friction clutch or flat friction pulley. Such hoists give fair results where only materials are handled, but are not suitable in cases where the hoist is used by the miners, and a variable and perfectly controlled speed is required, as this cannot be obtained by any kind of friction clutch or pulley now in use.

Electric hoists have been in use at Aspen for several years, and although most of them are improvised affairs, made by attaching street car motors to hoists made in Colorado, the practical knowledge of the improvisors made them perfect successes, and they have been in constant use with the most satisfactory results. Aspen is entitled to the name of the pioneer camp in the use of electricity for hoisting, but electric hoists are now in use at other places, and are everywhere successful and popular. A hoist recently placed at the Virginius mine near Ouray, consisting of an Edison motor of the standard pattern, but with street car winding and switch attached to the same base as the drum, and geared to it with spur gearing and friction clutch, is a good example of the more recent types of electric hoists, and embodies all the features required to make a complete and thoroughly satisfactory machine.

Pumps.—The conversion of the rapid rotary motion of the electric motor into the slow reciprocating motion of the pump presents more mechanical difficulties than the preceding cases

but duplex power pumps have been satisfactorily operated by electric motors by means of belts, spur gear, and worm gear, while more recent designs of triplex pumps, which more effectually equalize the strains during the entire revolution of the crank shaft of the pump, have increased the smoothness of operation by motors connected by any one of the three methods mentioned. At the Virginius mine there are two electric pumps, both operated by worm gear. The larger of the two is a Knowles duplex pump operated by an Edison 60-H. P. motor by means of a double worm (one left-hand and the other right-hand) on the armature shaft, working into two gears which mesh into each other and drive the pump. The object of the two opposite worms is to neutralize the longitudinal thrust. Some difficulty was experienced at first from heating of the gear, but this was soon overcome, and for several months this pump has been working steadily and satisfactorily, raising water 700 feet, and is pronounced as perfect a piece of machinery as can be found in that region. A smaller pump has recently been placed in this same mine, working with a single worm gear, the armature being vertical, and its weight counteracting the thrust of the worm; it is giving equally good satisfaction.

Concerning the economy of electric pumping, an interesting question arises that merits careful investigation. When water power is available to run the dynamo, the saving by electricity is evident. But even if steam must be used to drive the dynamo, it is an open question whether it would not be better to place a high economy steam engine on the surface to run the dynamo which supplies current for the pump, than to carry the steam direct to a steam pump in the mine. The best compound condensing steam pumps have a high efficiency, but the average sinking pump and simple station pump are very wasteful machines, and cannot compare in efficiency with a good engine. Moreover in carrying steam several hundred or thousand feet through a mine, there is great loss from condensation, while the heat from the pipes is frequently almost unbearable, and the air often saturated with escaping steam. Taking all these points into consideration, it is certainly not unreasonable to say there are many places where an electric pump would be preferable in every way to a steam

pump, even if water power is not available. The same argument applies to hoists and other machinery placed below the surface.

Locomotives.—The application of electricity to hauling in tunnels is identical with the operation of street cars, and presents no difficulties except the necessity of placing the requisite power in the limited space afforded by the narrow gauges ordinarily used in mines. Numerous electric locomotives are in successful operation in eastern coal mines, where the tracks are usually as wide as street car tracks, and permit the use of regular street car motors or specially designed motors of equal or greater power. A 10-H. P. 18 inch gauge locomotive has also been designed and manufactured which will meet the requirements of metal mines where this gauge is usually employed.

For tunnel haulage a single trolley wire with rail return may be used as in street railways; or a double trolley wire (positive and negative) may be employed with a trolley carriage riding upon them, and connected with the locomotive by a flexible conductor, enabling the wires to be placed at one side of roof of tunnel, out of the way. As tunnels are usually comparatively straight, with few branches and turn-outs, the double trolley system would be much less objectionable here than in street railways, where the numerous curves, turn-outs, switches and crossings introduce complications that are almost prohibitory; and it has some decided advantages, such as less liability to grounds, less danger of shocks, greater certainty of a good return, which would not always be insured when rails are used, as the bond wires would frequently be broken and the rails in many places would be poorly grounded. In regard to danger from shocks, it should be stated that in the bare trolly wires for an electric locomotive a sufficiently low voltage would be used to remove all risk of injury, but a frequently repeated shock of even 200 volts would not tend to increase the friendship of the miner for "the deadly fluid" and it is therefore just as well to so place the wires as to prevent, as far as possible, the occurrence of even this mild reminder of the fluid's disagreeable qualities.

Diamond Drills.—The electric motor, with its rapid rotary motion, is the ideal power for the diamond drill, obviating to a great extent the cumbersome gearing required to convert the recip-

rocating motion of the steam or air engine into the high rotary speed of the drill, and the fly wheel that is necessary to prevent the jerky motion that would be communicated by the pistons to the drill. An electric drill with its supply wires can be moved from place to place with much greater ease and rapidity than an air drill and its pipes; and this means not only greater convenience, but much saving of time, which means saving of money and the accomplishment of more work with one machine. Several electric diamond drills are used at Aspen, and have done good work.

Percussion Drills.—To produce by electricity in a simple and practical manner the rapid reciprocating motion of the percussion drill, has been the most serious problem encountered in the application of electricity to mining. Various combinations of cams, cranks and springs have been tried in the endeavor to obtain this movement from the ordinary motor, but with indifferent success, and the desired object has been accomplished by utilizing the principle of the solenoid and its power to draw an iron bar within its coils—the principal that was used in the construction of the earliest types of electric motors, but abandoned upon the invention of the more efficient dynamo and motor of to-day. But while the motion produced by the solenoid was badly adapted to its use as a motor, both on account of its reciprocating nature and low efficiency, it is exactly what is required for a percussion drill, and its lack of efficiency is no serious defect in this case, as its only competitor is the air drill, which as a waster of power stands unrivalled. If (as is the case) an electric drill will cut at a given rate with the expenditure of about half the power required by an air drill, it will be pronounced very satifactory so far as economy of power is concerned, even if it is not the ideal of efficiency, and the only questions asked will be whether it will do steady, reliable work, stand the hard knocks, and cost no more for repairs than its compressed air rival.

The limits of this paper do not permit an extended description of the Electric Percussion Drill, but it may be stated briefly that the drill consists essentially of two solenoids or spools of wire enclosed in water-tight cases, which draw the plunger backward and forward as the current is sent through them alternately

by the specially designed commutator of the dynamos, a spring at the back end of the drill taking up the backward blow and aiding in forcing the plunger forward. The bit, chuck, feed, general adjustment and mechanism for giving the bit the necessary twist at each stroke are similar to the corresponding parts of an air drill, the main difference between the two being that the cylinder of the air drill, with its piston, packing, and moving valves, is replaced by two simple coils with an iron plunger moving loosely within them.

The principal advantages of this drill over the air drill are:

First—Simplicity and small number of parts.•

Second—Ease with which it can be repaired by simply replacing the broken part without sending the entire drill to the repair shop.

Third—Ability to regulate the force of the blow by feeding the drill more or less rapidly.

Fourth—The peculiar action of the drill in automatically reducing the stroke to a mere tremble when not fed up against the rock, thus obviating all danger of injury by pounding in case it is carelessly handled and improperly fed.

Fifth—The superior convenience of wires as compared with pipes.

Sixth—The small amount of power required. Actual tests show that the electric drill requires less than half the power used by an air drill doing the same work. This means a saving, that in many places where coal is expensive would pay for the entire plant every year.

These drills have been in practical use in several mines, quarries and railroad cuts, under conditions varying from favorable to exceptionally severe, and with more or less success according to circumstances; but they are giving good satisfaction at several places, and while the short experience to date has shown that the drill, like every other new machine, has imperfections that must be remedied, it has proved that its essential features are good, that the defects, which are principally of a mechanical nature, can be remedied; that the advantages of the drill as enumerated above are numerous and important, and that the electric drill will supersede the air drill as certainly and probably as rapidly as the electric street railway has superseded the cable.

Probably the best example of the application of electric power to mining at the present time, is the large plant operated by the Caroline Mining Co. at the Virginius group of mines near Ouray, Colo. It is one of the largest, if not the largest purely mining plant in the world, comprising at the present time three dynamos having a total output of 290 H. P., with sufficient water power for considerable increase. It encounters every difficulty that is likely to be met in work of this nature, as the pipe line is constructed along the side of a rocky canyon; the wires are strung partly through dense timber where they are exposed to falling trees, and partly above timber line over rocks and snow banks, where the poles and wires may be carried away by snowslides, and where lightning storms are frequent and violent; the line is as long (nearly four miles) as will be required in the majority of cases. The voltage (800) is higher than will usually be employed in mines, and the mine is wet. It illustrates the relative advantages of the ground return and complete metallic circuit, as switches are arranged so that either may be employed (the metallic circuit is used at present). It includes a variety of machinery, comprising two pumps, one hoist, one blower, and two motors running mills—everything except locomotives and drills, and these will probably be added in the future; and lastly, it forcibly illustrates the enormous saving that can be effected in many places by the utilization and transmission of water power by means of electricity, as coal is worth $15 per ton at the mines, and cost, for the power they were using, over $100 per day or nearly $40,000 per annum, which is saved by the use of electric power,—and it also affords an instance of unprofitable mines made profitable by the use of cheaper power; for while some of the mines of this group are rich enough to be worked under the most adverse conditions, there are others of lower grade which the management stated would have to be shut down if the electric plant should prove a failure, but which, with the plant, will yield a satisfactory profit.

The situation may be summarized by saying that enough has been already done to prove that electric power is practicable for all mining purposes, and now that the electric companies are taking hold of the question in earnest, the next few years will surely witness great developments. While it would be extravagant to state that in the near future all machinery in the mining districts

will be operated by electricity transmitted from neighboring water powers, it is not a wild prophecy to predict five years from now thousands of horse power of electric plants will be in operation; that the capital invested in these plants will be figured in millions; that the annual saving effected by them will represent hundreds of thousands of dollars; that numerous, otherwise unprofitable mines, will be worked at a profit, giving employment to many additional men, and materially increasing the output; and that directly or indirectly great benefit will result to the entire State.

ON THE ORE-DEPOSITS OF NEWMAN HILL.

NEAR RICO, COLORADO.

BY JOHN B. FARISH, DENVER, COLORADO.

The following communication on the ore-deposits of Newman Hill, near Rico, is an endeavor to describe certain peculiar and somewhat complex features brought to light during the development of the important systems of mineral veins in that locality. It should be understood, however, that the conclusions do not apply to all the ore-deposits of that region, but only to those of the locality specified.

Rico, the county seat of Dolores County, is situated on the East Fork of the Dolores River, about twelve miles from its source in the San Miguel Mountains. The general course of the river is southwesterly, through a deep canyon extending from the head of the stream to its junction with the West Fork.

GEOLOGY OF THE DISTRICT.

The general geology of the Rico region, as shown by numerous exposures in the main canyon and its tributaries, is quite simple. The mountains surrounding the town are composed of sedimentary beds, apparently conformable, whose geological age ranges from the lower Carboniferous to the Colorado Cretaceous inclusive. The elevation of the mountains was associated in its origin with the intrusion of a laccolitic mass of porphyritic diorite, which may be seen a short distance above the town. The amount of upheaval at the center of the uplift was several thousand feet; its longer axis is at right angles to the course of the river, and is co-incident with the corresponding axis of the laccolite. From

the center of the uplift the strata, resting on the flank of the intruded body, dip in all directions, the angle of inclination varying from a few degrees to a maximum of twenty-five.

Owing to the vast erosion that has taken place in the higher parts of the uplift (making itself manifest in the canyons with their tributary gulches and ravines) the mountain sides are covered by deep deposits of debris, which often conceal the beds entirely.

The geological disturbances have also caused numerous faults; a surprising number of these often occurring within a comparatively small area.

The ore-bodies of the Rico district are in the main confined to the horizons of the Lower Carboniferous and Carboniferous proper; they are found in the mountains on both sides of the Dolores River, the total area within which the mineral deposition has taken place having not yet been accurately determined.

With this brief review of the general geology of the Rico district, in which I have only attempted to sketch its salient features, I will pass on to the special characteristics of Newman Hill.

Geology of the Ore–Deposits.

Newman Hill is situated a short distance from Rico, rising from the eastern edge of the town, and forms a bench-like extension of the western portion of the base of Dolores Mountain into which it merges without any intervening depression. On the southern and western slopes of this bench the greater part of the mining has been done; the numerous shafts, tunnels and up-raises, afford a most excellent means for obtaining a geological section of the mountain.

The lowest exposures which are to be found at the foot of the hill, visible along the banks of the river, consist of a stratum of limestone (magnesian) largely impregnated with chloritic products. In this stratum large bodies of ore have been found, consisting of pyrite, chalcopyrite and sphalerite. The silver contents in these ores have been, as a rule, quite low; although some bunches of rich ore have been encountered occasionally.

But little mining has been done up to date in this zone, owing on the one hand, to lack of inducement offered to capital by the low-grade and refractory nature of the mineral product, and on

the other, by the difficulties encountered in mining, the question of ventilation of the workings being a most serious feature.   On account of the exhalations of carbonic acid gas from circulating, subterranean, carbonated waters—which when reaching the surface form the soda-springs near the town—the limestone itself seems fairly charged with the free gas.   Even the shallow excavations made in the ore-deposits of this zone are quickly filled with gas, making the workings, without forced ventilation, unfit to sustain life.   Small animals and birds that unwittingly venture into the openings are quickly overcome and perish.   The gas also permeates the overlying strata, although to a more limited degree; sufficiently so, however, to vitiate the air of the mine workings in the upper levels, if proper means of ventilation are neglected.

While the age of the lowest exposure is somewhat doubtful, all fossil remains having been destroyed by metamorphism, it has been assumed from the stratigraphical position of this zone that the limestone is Carboniferous.

Resting upon this formation follow alternating strata of sandstones and argillaceous shales, referable to the Carboniferous, to a height of 500 feet, when a band of limestone appears, which is again followed by alternating beds of shales and sandstones—the total thickness of the section being about 1,000 feet.   The shales found below the limestone bed are much harder and more silicious than those above it.

Fifty feet above the magnesian limestone a tongue of the laccolite, to which allusion has been made in the earlier part of this paper, has been intruded between the argillaceous shale and superincumbent sandstone strata.   The thickness of the intruded body has been approximately determined on Newman Hill by the "Skeptical Shaft," which was sunk in it to a depth of about 250 feet before penetrating the underlying shale.   The laccolite and its sheet-like ramifications appear to be intimately connected with the origin of the ore-bodies of the Rico district, being in a number of instances almost replaced by pyritiferous mineral itself.   I am indebted to Mr. R. C. Hills for the following remarks, which describe the rock more closely:

"The rock is grayish in color, shows phenocrysts of a white, opaque feldspar, and small, partly altered, green hornblendes. Apatites are occasionally visible in stout prisms.

"Under the microscope the feldspars are seen to be much kaolinized; though, so far as determined, they are plagioclases. The hornblendes are largely altered to chlorite. Small, pale green augites and stout, relatively large apatites are somewhat numerous. The groundmass, also partly kaolinized, gives undulatory extinction. Abundantly distributed through it are small crystals and grains of kaolinized feldspar, together with ore-particles (magnetite?). The rock is probably hornblende-augite-porphyrite (a porphyritic diorite); though, as only one thin section was available for examination, other varieties may occur in the mass from which the specimen was taken."

Attention has been called to a band of limestone that occurs midway in the series of alternating shales and sandstone strata. It is a grayish deposit, varying in thickness from 18 to 30 inches, and occupies throughout Newman Hill the same stratigraphical position with reference to the other beds. From its close relation to the ore-deposits, this band is locally known as the "contact-limestone." It is enclosed between two layers of argillaceous shale, which are, however, quite different in appearance. The overlying stratum is a soft, comminuted, drab-colored shale, varying in thickness from 6 to 20 feet. This layer forms an impervious shed to the surface waters circulating above it, thus leaving the mine workings below, comparatively dry. The underlying bed is a black, finely laminated shale, from 7 to 12 feet in thickness, which rests upon the series of alternating gray sandstones and drab and greenish shales. The geological section is shown in Fig. 1.

The top of the bench forming Newman Hill is covered by 100 to 300 feet of debris. The cliffs rising above the summit of the hill, and which are part of Dolores Mountain, are composed of alternate bands of limestone, shale, quartzitic conglomerate and sandstone. These are followed by the well known Red Beds, the section being topped (except where removed by erosion) by exposures of Cretaceous age.

The dip of the strata in that portion of Newman Hill which we are now considering is generally about 15 deg. to the southeast, although it varies somewhat, locally.

THE ORE-DEPOSITS.

The mineral deposits which on Newman Hill have proven of the greatest economic importance, occur (1) in a series of almost vertical fissures, more or less parallel, having a strike from a few degrees to as much as 45 deg. east of north, and a dip varying but a few degrees from the perpendicular, either to the north of west or south of east; (2) in another series of fissures which have a strike of 30 to 50 deg. north of west, and a varying dip of from 30 to 45 deg. north of east, crossing the nearly vertical fissures at almost all angles; and (3) along the contact plane between the "contact-limestone" and the overlying shale.

The vertical fissures having proven the most prolific and richest in ore, are locally called "vertical pay-veins," while those of the second system, which intersect the first, are termed ."cross-veins;" these latter are uniformly characterized by ore-bodies lesser in extent and lower in grade than those in the former.

The "vertical pay-veins," as well as the "cross-veins" are fault-fissures, the vertical displacement of the walls in the former ranging from a few inches to a maximum of 6 feet, and in the latter to a trifle over 25 feet. These fissures vary in width from a few inches to several feet. They possess all the characteristics usually ascribed to so-called "true fissure-veins," slickensides and selvages often occurring; where, however, the veins pass through the sandstone strata, these peculiarities do not appear, the mineral or vein-filling being usually closely adherent to the walls, or frozen to them.

The banded or comb-structure of the ore in the veins is a marked feature. In Fig. 2, I have illustrated a typical case.

In longitudinal extent the fissures show great strength; the "vertical pay-veins" which have been subjected to the greatest development have, in some cases, been followed for a linear distance of 4,000 feet.

Thus far, about one dozen "vertical-pay-veins" have been opened on Newman Hill; a number of these have, however, proven of little economic importance, the mineral deposits in them, while often of high grade, being on the whole so slight as to make their exploitation commercially unprofitable. Others again, seemingly

. disappear entirely, or unite with the larger and stronger veins as they extend to the northeast.

Altogether some five veins, owing to their mineral production, have proven of great importance, namely, the "Swansea," "Enterprise," "Hiawatha," "Jumbo" and "Eureka." Some confusion is apt to be caused on account of the names of the mining claims being applied also to the "vertical pay-veins" which they cover, as the same fissure at times extends from one claim to another. The heavy development work which, however, has been done on all of the foregoing claims amply serves to establish the identity of the respective veins which they embrace. In Fig. 3, I have given a ground plan of the most prominent "vertical pay-veins" and the claims covering them, which will illustrate the preceding remarks.

The lowest workings on these veins are 200 feet below the "contact-limestone," as shown in Fig. 4, which represents a section along the "Enterprise" vein. The veins show great strength and regularity until the black shale, lying below the "contact-limestone," is reached. In passing through this band they split into numerous small seams, ranging in width from one-sixteenth to rarely over one inch. These veinlets irregularly traverse the black shale and the following thin layer of limestone—which is occasionally replaced with ore to a limited extent—until the super-incumbent drab-colored argillaceous shale is reached. The maximum ore deposition, as already stated, has taken place along the contact-plane, the horizontal ore-bodies taking the form of a pipe. These horizontal ore-bodies vary in width from 2 to 30 feet, and in thickness from a few inches to a maximum of two feet, following in longitudinal extent the course of the veins with which they are connected. The pipes lie directly over the vertical fissures, as illustrated in Fig. 5. It is rarely the case that the pipes are found so regular in outline as depicted in the sketch, the regularity seeming to have been affected by disturbing movements, subsequent to the ore deposition.

The fissures do not, apparently, extend beyond the "contact-limestone," for drifts and tunnels, which have been run in the overlying shale and sandstones, have failed to disclose any sign of vein-structure or ore, even immediately over those points where strong and well defined veins are being worked below. The fault-

ing which caused the original fissures doubtless extends through the formations overlying the "contact-limestone," but such fault-crevices are tight and barren.

It has been observed in following the "Hiawatha" vein, that it will occasionally narrow down, and finally pinch out; where this occurs, however, a cross-cut to the east or west, driven for a short distance, has always disclosed a parallel vein beginning at the point where the original disappeared. Such breaks are characteristic of the "Hiawatha" vein, and where they occur the horizontal ore-pipe on the contact exhibits the same features. The close relation existing between the contact ore-pipes and the underlying veins is, furthermore, shown by the fact that where the veins narrow, the horizontal ore-pipe is also contracted; and where the veins widen, the overlying pipe is correspondingly enlarged.

The physical characteristics of the "cross-veins," of which over twenty-five have been disclosed in drifting along the "vertical pay-veins," do not materially differ from those described as pertaining to the first system. They vary considerably, however, in their strike, which is from north to N. 60 deg. west; and also in their dip, which is from 30 to 50 deg. north of east. In the southern portion of Newman Hill, in the "Jumbo," "New Discovery" and "Swansea" group of mines, several "cross-veins" have been opened that show a strike almost north-and-south, and a dip of 45 deg. to the east. The "cross-veins" are, on the whole, perhaps narrower than the "vertical pay-veins," being not often more than a mere seam, and attaining a maximum width of not more than three feet. The vertical displacement of the walls varies from a few inches to rarely over five feet. In one of the recently opened "cross-veins" in the "Enterprise" workings, this displacement, however, exceeds 25 feet—the greatest thus far observed.

The veins of the system as they enter the shale underlying the "contact-limestone," also separate into smaller veins, although the ramifications are less numerous than is the case with the "vertical pay-veins." The ore-pipes, which in this case again form along the contact-plane, do not, however, cover the underlying veins, as is the case in the vertical fissures, but invariably make to one side of them. This I have illustrated in Fig. 6.

The horizontal ore bodies connected with the "cross-veins" vary in width from 20 to 40 feet, and in thickness from a few inches to a maximum of three feet. They follow continuously, although on one side, as has been noted, the veins with which they are associated.

Faults.—The juncture of the "cross-veins" with the "vertical pay-veins" is uniformly characterized by a disturbance of the latter, the former continuing along their course without much deviation from their average individual strike. The irregularities so produced in the "vertical pay-veins" manifest themselves (1) in absolute faults, the break in the vein being sharp and usually to the southeast. The throw in such instances varies from a few inches to as much as 15 feet; (2) in a deviation of the vein from its normal course to one parallel with the intersecting "cross-vein." Such parallelism extends over distances from 15 to 80 feet, although in one observed instance it measures over 200 feet before the original strike of the vein is resumed; (3) in a bend of the "vertical pay-vein" as it approaches an intersecting "cross-vein," a reverse curve taking place at the departure. In instances of this nature, the "vertical pay-vein" usually cuts across the intersecting "cross-vein" on a diagonal line.

Figures 7, 8 and 9 will illustrate some of the more marked irregularities occurring in the "vertical pay-veins" within the territory studied by me, and I may say that when such disturbances are noted in the lower workings, the ore-pipes at the contact show similar features.

Fig. 7 shows the "Enterprise," together with a parallel one called "Vein No. 1," the distance separating them being about 180 feet. Where these veins are intersected by the "cross-vein," they merge into it, and pursue their course *within the "cross-vein" walls* for a distance of about 80 feet before departing from the intersecting fissure. They then continue in a trend parallel to the original course of the veins before the intersection. In all cases of this kind, the "vertical-pay-veins" are easily distinguished from the "cross-veins," the veins being separated, and each system marked by its characteristic matrix. The "vertical-pay-veins" show signs of disturbance as they enter and depart from the

"cross-veins," a disintegration into seams and stringers taking place. Such disintegration, however, does not obtain for any great distance from the cross-fissure.

Before these peculiar occurrences were known and recognized, much useless work was often done to discover the continuation of the apparently lost vein.

Sketch No. 8 illustrates the occurrence of a fault in the "Enterprise" vein, and the deflection of the "Hiawatha" vein by the same cross-fissure. The break in the "Enterprise" vein is seen to be sharp, while the "Hiawatha" vein is not faulted, but makes along the "cross-vein" for nearly 100 feet before emerging from its walls and resuming the original course.

In Fig. 9, I have shown the intersection of a "cross-vein" with the "Jumbo" vein, an instance of the third class of disturbances. The "Jumbo" vein, as it approaches and departs from the cross-fissure is considerably disintegrated, the numerous seams and stringers striking diagonally through the "cross-vein."

Where the "vertical-pay-veins" consort with the "cross-veins" after joining same, the trend is usually to the north. A noted exception occurs, however, in the case of the "Chestnut vein," which at the junction with the "cross-vein" follows the latter for a distance of 200 feet to the south, as far as has been observed. Beyond this point the veins pass into foreign territory, and were not subject to any examination.

The absolute faulting of the "vertical-pay-veins," as well as the swerving of the same from their normal course, in the manner indicated, often occurs in comparatively close proximity, no single area being characterized by any special feature of vein disturbance.

A consideration of these irregularities naturally suggests a speculation concerning the relative age of the two vein-systems. In this connection I must confess that from the complexity of the problem, I have not been able to arrive at positive conclusions. Reasoning from the occurrence of the sharp faults in the "vertical-pay-veins"—the disconnection being absolute—and the unbroken trend of the "cross-veins," the inference would be drawn that the latter are, relatively, the younger. Whatever mistrust arises from

such a deduction is occasioned by the observed deviation of the
"vertical-pay-veins" from their normal course for considerable
distances to a parallelism with the intersecting "cross-veins"
within the walls of the latter.

On the assumption, however, that all of the "vertical-pay-
veins" when disturbed by intersecting "cross-veins" were origin-
ally faulted, and that the faulting fissure in some instances—pre-
scribed by local influences—furnished a connecting channel for
the mineral solutions circulating in the faulted vein, these phe-
nomena are susceptible of reasonable interpretation.   I am, at
least, strongly inclined to favor this view.   As the developments
on the Newman Hill mines progress, there will be opportunities
for further investigation on this interesting question, the results
of which I shall take pleasure· in transmitting to the Society as
they are reached.

Minor Veins.—In addition to the two main systems of veins
described, there have been encountered a number of white quartz
veins entirely barren, which are almost perpendicular, their strike
being parallel, or nearly so, to the "cross-veins."   They seem to
be without influence on the veins of either system, producing no
disturbances,.and not being associated in any way with the ore-
deposits.

Disturbing Influences.—In none of the openings in any of the
mines have eruptive rocks been encountered, with the exception
of the tongue-like intrusion in which the "Skeptical Shaft" has
been sunk, and which is at least 100 feet below the lowest levels
in the "Enterprise" and adjoining mines; and a small porphyry
dyke, from four to five feet in width, which is very much decom-
posed.   This dyke seems to be of comparatively recent origin.   It
stands almost perpendicular, and is nearly parallel in its course to
the "Eureka" vein, from which it is removed only a few feet.
On reaching the "contact," the dyke cuts through the horizontal
ore-body connected with the "Eureka" vein, and then spreads out
in the soft shale immediately over the ore, as shown in Fig. 10.
This intrusion aptly illustrates the disturbing influences to which
the mass of the mountain has been subjected since the deposition
of the ore.

MINERAL CHARACTERISTICS OF THE VEINS.

It has been stated that the deepest workings on the veins in the territory under consideration, are 200 feet below the "contact-limestone." At this depth, on the "vertical-pay-veins," the vein-filling is a glassy, white quartz. The quartz contains numerous vugs, some of which are of considerable size. These cavities are usually lined with handsome quartz crystals. The metallic minerals are not plentiful, and consist of pyrite (in cubes) associated with some chalcopyrite. Raising on the vein, the quartz becomes less glassy, fewer vugs are found, and rhodochrosite appears. The pyrite is more abundant and becomes finer grained and sphalerite, galena and massive tetrahedrite appear. Continuing upward toward the "contact," the proportion of metallic minerals steadily increases, and with such increase the gold and silver contents become, in a marked degree, greater. The principal argentiferous minerals which are associated with the sphalerite and galena are argentite, polybasite and stephanite. Irregular nuggets, and even sheets of these, are often found in the vein cavities. Occasionally pyrargyrite and proustite, as well as native silver, make their appearance. As the black shale underlying the "contact-limestone" is reached, and the vein disintegrates into veinlets, a still larger proportion of the metallic mineral abounds. The veinlets are so narrow, as a rule, that they are not mined. Not infrequently, however, is the "contact-limestone" replaced with ore to such an extent to permit of its extraction to a good profit. When the "contact" zone is entered, the ore-deposits attain their maximum development. Here the ore is nearly a solid mass of pyrite, galena, sphalerite and tetrahedrite, carrying its maximum contents of silver and gold—the silver minerals being of the nature described. The silica contents of the ore reach their minimum, being at times less than 10 per cent. Rhodochrosite, which forms a large percentage of the gangue of the vein, immediately below the black shale, is rarely found with the ore in the "contact" zone; in fact, its presence there is considered somewhat of a curiosity. The silver contents of these horizontal ore-bodies range from 300 to 800 ounces and the gold from two to nine ounces per ton, the deposits being remarkably uniform in value throughout their whole

extent. In the "cross-veins," the matrix consists of white quartz enclosing a large proportion of more or less altered country rock. I account for this phenomenon on the theory that the dip of these veins being quite flat, a greater fracturing of the shales and sandstones forming the hanging wall was effected, the seams thus produced permitting the mineral solutions to freely circulate around, and finally enclose, the loosened pieces of wall rock as the mineral deposition progressed. Rhodochrosite, which is a prominent feature of the gangue of the "vertical-pay-veins," is totally absent in the "cross-veins." The metallic minerals associated with the quartz are found in very small quantities. The gold and silver contents of these veins are very small indeed, average samples rarely showing a combined value of $12 per ton. Contrary to the experience met with in the "vertical-pay-veins," there is no improvement in values as the "contact" is approached. At the "contact," however, a radical change often occurs. Many of the horizontal ore-bodies associated with the "cross-veins" are extremely rich in gold and silver. The ore is a white quartz carrying from 20 to 40 per cent. of galena, sphalerite, pyrite and chalcopyrite, associated with the same silver minerals found in the "vertical-pay-veins" and the "contact" ore-deposits connected with them. The ore mined and shipped in large quantities from the horizontal ore-bodies associated with the "cross-veins" has shown silver contents ranging from 200 to 500 ounces of silver and from two to nine ounces of gold, per ton.

A peculiar feature that has been observed in connection with the horizontal ore-bodies of the cross-system veins, is that on working along their longitudinal extent their richness is subject to great variation; a body may yield rich ore for a long distance, and then become gradually impoverished, or the reverse may occur, without any apparent cause for the change.

OTHER DEPOSITS.

It has been explained that no evidences of vein-structure have, as yet, been found beyond the argillaceous shale overlying the "contact-limestone." A number of fissure-veins are reported to have been found in the cliffs on the slope of Dolores Mountain, immediately above the summit of Newman Hill. These veins have

not come under my personal observation, but are said to have the same strike and dip as the "cross-veins" in Newman Hill. Accepting this statement as correct, it would demonstrate that the faulting, which resulted in the formation of the veins of Newman Hill also extended through the superincumbent strata of the main mountain. In explanation of the limitation of the mineral deposits to an area not extending upward beyond the "contact" zone, it may not unreasonably be assumed that after the production of the fault-fissures, subsequent movements in the mountain mass closed the fissures extending through the soft argillaceous shale overlying the "contact-limestone," thus preventing the circulation of the mineral solutions beyond the plane of contact. If such were the case, it is probable that the mineral solutions were retarded in their flow along this plane, the final result being the maximum deposition of ore in the "contact" zone, with the attendant increased richness of the ore. Assuming these premises, the conclusion must naturally follow that the vein-filling of the fissures found in the higher cliffs of Dolores Mountain owes its origin to other sources than produced the deposits of Newman Hill. It may be said that the mineral-deposits of the veins in the cliffs of Dolores Mountain are essentially different in character from the ores in the Newman Hill fissures, those of the former being essentially a galena, with low silver contents.

If the question is asked, what correlation, if any, there exists between the mineral-deposits of Newman Hill, those of the main laccolite and its spurs—which are essentially pyritiferous—and those of the other prominent mineral zones of the Rico district— consisting in the main of carbonate of lead and oxidized iron ores, —I must answer that lack of time forbade the attempt on my part of any such extended investigation. To establish such correlation, or to differentiate the various periods of mineral-deposition, will be a work of great magnitude, involving detailed geological research; but it is, nevertheless, one which ought to be undertaken, and which is fully warranted by the economic importance of the region.

In conclusion, I beg to acknowledge my indebtedness to Mr. J. W. Edwards, of Rico, for aid rendered in the collecting of certain rock specimens; to Mr. R. C. Hills, of Denver, for petro-

graphical work; to Mr. P. H. van Diest, of Der
paration of the map and sketches; and to Mr. .̄
of Denver, who, owing to the limited time at
undertook the arrangement of my extende
of the paper.*

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* The paper was accompanied by a large and h⁵
specimens, which are now in possession of the Soci

THE NATURE OF THE CHEMICAL ELEMENTS.

(FIFTH PAPER.)

BY CHARLES SKEELE PALMER, PH. D.

Professor of Chemistry, University of Colorado.

Read at Meeting, May 2d, 1892.

This paper will be devoted to a brief consideration of some mechanical details of the microcosmic hypothesis so far as this side of the problem may be open for chemical consideration.

I.

In a preceding paper of this series, it has been anticipated that the apparent paradox between a regular progression of increase in specific gravity, on the one hand, which must have been an original condition of things in the protyl mole, and of a variable progression in specific gravity in the members of successive series, on the other hand, may be explained by supposing that the two kinds of progression of specific gravity are not really opposed to each other, but that they represent conditions at different stages of atomic evolution; so that the condition of regular increase of specific gravity represents a relatively earlier stage as contrasted with the condition of varying progression of specific gravity, which latter, therefore, represents a relatively later stage of evolution.

Hence, these apparently contrasted conditions are by no means inconsistent with each other, but like many other apparent paradoxes, serve as starting points for new lines of investigation.

In this particular case, our apparent paradox between the hypothetical, original, regular progression in specific gravity, and the subsequent variable progression in specific gravity, (ch

latter form of progression represents approximately the present condition of things as we know them), will prove a very valuable pointer, both in tracing the subsequent stages of evolution and in offering an explanation of the probable nature of chemical affinity.

In detail it will be noticed, that while each series, as a whole, has a greater specific gravity than the preceding, yet that (a) the alkali termini do not show any remarkable increase in specific gravity, and that (b) the elements congregated toward the halogen ends do show a very remarkable decrease in specific gravity as compared with their respective median elements: i. e., that lithium, sodium, potassium, rubidium caesium, successively show only a comparatively slight increase in specific gravity, (and irregular at that); while fluorine, chlorine, bromine and iodine exhibit an enormous decrease in specific gravity as contrasted respectively with their median elements, carbon, silicon, iron and ruthenium.

These two facts, in most obvious interpretation, can have but one meaning, viz., *expansion: i. e.*, as the successive series or shells were cast off from the protyl mole, each shell for itself expanded, both as a whole, and also locally, in particular at the termini. This expansion, general and local, was probably due to inherent elasticity, by reason of enormous condensation while a part of the protyl mole, and this expansion probably took place after each shell was separated successively from the protyl mole, and before the chemical characteristics of the individual members had become fixed.

Thus, we see clearly that as long as each shell was a part of the protyl mole, it was condensed enormously; but as each shell was detached from the protyl nucleus it expanded as a whole and also locally.

Furthermore, as similar termini of different series resemble each other, yet each terminus of any series or shell is relatively different chemically and physically from the opposite terminus of the same series; so all of the series or shells must have expanded according to the same general law and under similar conditions. Thus we see, again, that the similar termini of distinct series, though formed at different successive periods, resemble each other because they were subject to similar mechanical conditions.

II.

Let us now observe the probable mechanical result of the expansion of the shells as they were separated from the protyl mole.

Each series at first we suppose to have been a shell of approximately the same thickness or depth in all parts; it is presumable, however, that quite early in the process of throwing off shells, there would arise a rotation of the mass and hence a differentiation of the protyl mole with its encircling shells, as regards polar and equatorial position. As a result of this the shells would thin out at the poles and thicken at the equator, resulting in an equatorial ring.

In this change of the form of the shells it is not necessary to suppose that there would be a mixing of atoms of different atomic weights, for they would still preserve their relative positions in the ring as in the shell; the heavier atomic weights remaining near the interior of the ring, and the lighter on the exterior of the ring, and the intermediate ones in regular graded order.

Thus, the development of centrifugal force, in the change from the shell structure to the ring structure, would not change the regular gradation of the elements in any series, in respect to the progression of their atomic weights; but as each shell changed to the ring form by reason of the centrifugal force, there would be opportunity for expansion of the ring, both as a whole and in parts.

Now, let us notice that the expansion of the ring as a whole must be *outward;* but that while this takes place, the inner parts of the ring may after a time expand *inward* toward the protyl nucleus, from which the ring has been separated by centrifugal force; thus in this general and local expansion, the outer portions of each ring would expand mostly outward, the inner parts would expand considerably inward, while the middle part of each ring would expand least.

And thus we would have the resulting conditions as we actually observe them in the varying gradations of specific gravity of the elements of each series; the outer or basiferous (kalidic) members showing low specific gravity; the inner or acidiferous (oxidic) members showing a greater specific gravity; and the

maximum specific gravity being found in the median members of each series.

The expansion of the outer part of each ring being outward, and of the inner part inward, and the whole being under centrifugal action, would probably result in a twisting motion and structure within the atoms; and the atomic twist of the outer members would be relatively different and opposite from the atomic twist of the inner members; and thus we find a difference in kind which is also different in degree for the structure of the kalidic elements, as distinguished from the structure of the oxidic elements.

But little can be surmised at this stage, of the mechanical details and of the possibilities of harmonic combinations of the motions of the sub-atoms; but it certainly is reasonable to suppose that in the process of atomic evolution as above outlined, there is a basis for the fundamental difference in nature between the kalidic and oxidic elements, in an inherent mechanical twist-structure.

The simplest illustration of this contrasted structure is that of two conical helices or coils of opposite twists; but it is not the business or the privilege of the chemist to go into these mathematical and mechanical details.   What we would emphasize is that the microcosmic hypothesis clearly points out the probability of a similar but contrasted mechanical structure of the kalidic elements as distinguished from the oxidic elements.

The value of this similarity and difference of mechanical structure will be observed both as an illustration of the differences between the extremes of the active and passive chemistry (noted in the third paper), and also an illustration of the possible electrical nature of chemical affinity, to be noted under our next heading, viz.:

III.

Some of the arguments in favor of the view that the nature of chemical affinity is essentially electrical have been given in a preceding paper; but at the present, surely no one need apologize for holding this view.   The general tendency of modern chemical physics seems to be closely in accord with Tesla's view of "bound

ether;" or of the views of the Ostwald school of physical chem-
istry, viz.: that free atoms have no electrical charge, but that com-
bined atoms have, and that in the electrolytic separation of com-
pounds the ions move to the electrodes and there give up their
charges. [See Walker's Translation of Ostwald's General Chem-
istry, p. 275.]

According to this view no free atoms of *any* element have
inherent electrical charges; yet it must follow that free kalidic
atoms must have inherent receptivities or capacities for positive
charges.

Here it will be observed that the fundamental difference
in mechanical twist structure offers an explanation for the inher-
ent difference of receptivity or capacity of kalidic and oxidic ele-
ments for positive and negative charges respectively; and also that
this inherent capacity of kalidic and oxidic elements for the differ-
ent electricities by reason of their structure, involves a similar
difference in structure in the electricities themselves, and this
brings us to the consideration of our next point, viz.:

IV.

THE POSSIBLE NATURE AND DIFFERENTIATION OF THE ELECTRICAL ETHER FROM A CHEMICAL POINT OF VIEW.

The so-called luminiferous ether, the conception of which
since the days of Huyghens, has been a scientific necessity, has in
recent times come to be regarded as a real substantial variety of
matter, probably having definite weight, and genuine extension,
but a variety of elasticity and a manifestation of inertia almost
paradoxical.

This luminiferous ether may be called also the thermiferous
ether or the electriferous ether, in view of the fact that it appears
to be the common medium for the transmission of heat and elec-
trical waves.

But, however important the nature of the ether may be for
the pure physicist, it is equally important for the pure chemist;
since it is a genuine variety of matter.

To say that it is imponderable does not mean that it is abso-

lutely so; but that it eludes detection by our common chemical balances. If it is a genuine variety of matter, it must have a chemistry of its own.

If it is a genuine variety of matter, it must have had its own process of evolution.

We will observe that it is possible to include the process of the evolution of the ether within the limits of our microcosmic hypothesis.

Thus, the ether (and there may be as many kinds of ether as there are kinds of elements) may have been the result of condensation on the outside of the old protyl mole and may have been developed from shells thrown off long before the hydrogen shell.

This pre-hydrogen etherial shell or shells, would probably evolve, differentiate and disintegrate in a manner similar to that indicated above for the other shells; and the expansion noted in the later cases may partially account for the extreme levity of the ether.

But of much more importance is the inference that the ether shell or shells must have had their kalidic and oxidic extremes, and therefore, their kalidic and oxidic chemical atoms, with the implied oxidic and kalidic structure and functions.

This would mean that there were formed ethereal atoms of opposite chemical nature; and moreover, following the analogy of the chemistry of our known elements, the opposite or unlike kalidic and oxidic ethereal atoms would unite with each other, forming molecules which would be analagous to salts. Therefore, according to this view the ether would consist of molecular groups of unlike ethereal atoms, in the same way that lithium fluoride, sodium chloride, and potassium bromide are composed of the extreme members of their respective series; or in the same way that lithium fluoride, beryllium oxide, and boron nitride are composed of the opposite balanced members of their series.

To the best of the author's knowledge and belief, this inference, viz.: that the luminiferous ether consists of molecules which are composed of, and can be separated into dissimilar, kalidic and oxidic ethereal atoms, was an entirely independent deduction based on the argument and analogy given above. This view was first presented in a paper read before the University Scientific

Society of the University of Colorado, on January 30, 1892. Afterwards, however, it occurred to the writer that he had sometime before seen mention of a similar view. Such a view is found on page 220 of Modern Views of Electricity, by O. J. Lodge, and elsewhere. I quote from loc. cit.:

"That the doubleness of constitution of the medium—it being composed of two precisely opposite entities—is suggested by the facts of electrolysis, by the absence of mechanical momentum in currents and magnets, and by the difficulty of otherwise conceiving a medium endowed with rigidity which yet is perfectly fluid to masses of matter moving through it."

Thus it will be observed that there is no direct connection between the line of inference followed by Prof. Lodge and that of the writer; yet on the other hand, that the inferences as to the duality of the ether are entirely in harmony with each other, and from their entire independence are strongly corroborative of each other.

I will not at this time go into any detail regarding the applications of the compound nature of the ether, but will only observe that it is part and parcel of the following points which have been emphasized in these papers, viz: (1) The fact that there are two and only two chemical extremes of the series of the periodic arrangement. (2) The inference of two implied ingredients, viz.: kalidium and oxidium. (3) The inference that kalidium and oxidium must represent opposite properties of structure rather than unlike concrete varieties of matter. (4) The inference of two unlike and opposite structures of mechanical twist, developed respectively in the outer and inner parts of the expanding and revolving shells. (5) The well known doubleness in the manifestation of electrical phenomena; and, (6) The inference that the ether itself is a double substance when at rest composed of two opposite and unlike ingredients which are separated in electrical action.

This duality of substance, structure and function of the known chemical elements, and of the hypothecated ethereal elements, must be more than accidental. It suggests a wide field for legitimate speculation, patient investigation, and abundant results.

In closing it will be well to enumerate briefly a few of the suc-

cessive stages in the evolution of the chemical atoms, which can be fairly recognized at present, viz.:

First. An early (but not necessarily original) state of matter in which the essential condition was that of the "atomicule," involving at least one grade of subdivision below the atom.

Second. A period when these atomicules agglomerated into the protyl mole, or moles.

Third. A period of regular condensation within the protyl mole resulting in a regular progression in specific gravity; the relative figures of the atomic weights, probably represent the originals of these specific gravities, though these were probably subject to much modification in the subsequent evolution.

Fourth. A period when each shell successively weathered off or was thrown off, from the nucleus of the protyl mole. This period was probably a continuous one for the protyl mole and successive shells would evidently be in different stages of their evolution at any particular time.

This period was probably for each shell the time during which the permanent conditions for its so called *passive chemistry* were established.

Fifth. A period of the differentiation of each shell occassioned by the combined action of the centrifugal force of rotation and the tendency to local expansion, resulting in the inferred *twist structures.* This period was probably the time of the establishing of the permanent conditions for the *active chemistry* of each series.

Sixth. A period of the disintegration and separation of the atoms of each series. The condition of all the periods thus far enumerated must have been one of intense heat in application to which our ordinary expressions and standards can have but little meaning.

Seventh. A period or series of periods of cooling. The conditions were probably still far too hot to allow of chemical union in the case of our common elements.

The hottest stars in our sidereal universe are probably cold compared with these earlier conditions.

Eighth. A period of increased cooling when the elements could be condensed, at least, into physical union.

Ninth. A period when the refrigeration allowed all sorts of chemical union between the elements.

Thus it will be observed that in general, the present conditions of the universe represent only the very latest stages of atomic evolution.

There are many questions which cannot be considered at present, viz.: as to the number of necessary grades of subdivision below the atom; the number of protyl moles; the exactness or the average nature of the atomic weights; the nature of the valence structure, etc., which are legitimate chemical problems.

The subject is barely introduced, but its unfinished condition is only one of the many indications of the brilliant development which awaits the grand science of Boyle and Lavoisier, of Dalton and Berzelius, of Liebig and Wohler, of Mendeléeff and of Ostwald, and that throng of workers who constitute the army of chemists.

NOTES ON MONTANA SAPPHIRES.

BY A. S. Dwight, Pueblo, Colo.

At a distance of twelve or fourteen miles from Helena, and near the headwaters of the Missouri River, are found the now famous sapphire fields of Montana. The presence of gems in this locality has been a matter of local notoriety since 1870, though public attention has only recently been called to it by the sale of some of this land to the omnivorous English syndicate, a few months ago, at a figure so fabulous as to be entirely in keeping with its usual transactions. The deposits have been described by Prof. J. Lawrence Smith (Am. J. Sci. III, Vol. 6, page 185, Sept. 1873,) and by George F. Kunz (Gems and Precious Stones of North America), and possibly by others.

The sapphires and rubies are found in bars of placer gravel, associated with garnets of a remarkably fine hue, and placer gold, and were first noticed in the sluice boxes of the gold washers. American Bar, Spokane Bar, El Dorado Bar and Frence Bar are the most important of these deposits. The gravel lies on bed-rock in a layer about five feet thick, with the corundum pebbles scattered through it. The rough pebbles resemble irregular pieces of water-worn bottle-glass, though it is usually possible to trace some crystallographic faces, more or less distinct. The predominating form seems to be a peculiar combination of holohedral and hemihedral forms, or more specifically, a plate-like hexagonal prism modified by the scalenohedron. The faces of the prism are usually somewhat obscure, but the triangular faces of the scalenohedron stand out in bold relief above the basal pinnacoids of the prism. This is clearly shown in the specimens of rough stones which I have the honor to present to the cabinet of the Society herewith.

In hardness these stones are next to the diamond (9) and are said to be even harder than the oriental corundum. In color, the cut stones are more commonly of a light-green, greenish-blue, steel-blue, bluish-red, amethystine, light-red and red. Compared to the oriental sapphires and rubies, the Montana stones are character-istically lighter in shade, and may even be entirely colorless. But few are found of the true oriental blue or pigeon's blood red, and these naturally command a high price, but the reddest of these, when placed by the side of an oriental stone, will look amethyst-ine. They are usually dichroitic, blue in one direction, and red in another, and tend to turn red in artificial light. Fine stones have an almost diamond-like brilliancy, a maximum size of about six carats, and command prices up to one hundred dollars per carat. Asterias, or crystals showing a pearly star when viewed along the major axis, are found, but perfect specimens are almost unknown. A few beautiful gems have been found showing a ruby center in a matrix of blue sapphire.

As to the probable genesis and original home of these stones, there is a short distance above Frence Bar, a vein or dyke of eruptive rock, of a brownish-gray color, and about five feet in thickness, in which well-defined crystals of corundum and garnet are imbedded, though it must be confessed, in very imperfect con-dition. A specimen of this rock is presented to the Society here-with. There can be but little doubt that the placer deposits have been formed by the sorting and classification of the debris from this dyke, and though a few sapphires are found higher up the stream, these can be accounted for by assuming the existence of another such dyke, of the same kind, trace of which is now oblit-erated.

An occurrence of corundum near Calumet, about twelve or fourteen miles from Salida, in this State, was once described by Mr. William B. Smith before this Society. He describes it as a sort of corundum schist, with flat hexagonal plates of small size, and with a bluish tinge.

To Mr. August Raht, the writer is under obligations for being able to present to the Society these specimens, which exhibit with such remarkable clearness, the curious crystalline forms, as well as the specimen of the eruptive dyke.

REPORT ON THE TECHNICAL DETERMINATION OF ZINC.

To the Society:

In accordance with the plan outlined some time since, your committee appointed for the purpose, has undertaken the work of attempting to establish a uniformity in the technical methods of analyses in the West, and as the result of its first effort it herewith presents to your body the work of a number of our best known western chemists on zinc determination.

It may be remarked that the samples of ore, on which the work was done, were such as seemed to offer the greatest difficulty in the correct determination of the metal in question.

The ores so submitted were from a number of mines of widely separated localities; they were mixtures of galenite, pyrite and sphalerite, accompanied by greater or less percentages of manganese in the form of rhodochrosite, associated with a quartzose gangue.

That a standard of comparison might be had by which the various results could be judged, the assistance of the chemical laboratory of the U. S. Geological Survey at Washington, D. C. was invoked. Mr. F. W. Clarke, Chief Chemist of the Survey, notwithstanding the fact that his department is always busily engaged with work correlated to the geological investigation of the Survey, met our request for the co-operation of his laboratory in the work to be undertaken with the greatest willingness, and your committee takes this occasion to express its deep appreciation of the valued assistance thus afforded.

The analyses were made by Mr. L. G. Eakins, one of the ablest of Mr. Clarke's corps of chemists, and your committee doubts not that the results furnished by him will unhesitatingly be ac-

cepted as standard by all the technical chemists who assisted in the investigations.

The samples of ore distributed came from the following mines:

Enterprise Mine at Rico, Colo.

Mary Murphy Mine, near St. Elmo, Colo.

Robinson Mine, Robinson, Colo.

New York Mine, near Park, Colo.

Moyer Mine, Leadville, Colo., the ore from this property being a concentrate product.

These were designated respectively, Nos. 5, 9, 11, 13 and 20, great care being taken in the mixing of each separate large sample, so that uniformity in the material subsequently distributed might be assured.

The analytical methods employed by the different chemists are given, together with the results obtained. In one instance, that of Dr. H. C. Hahn, in conjunction with the zinc determination, that of manganese is also furnished, thus happily affording a knowledge of the extent to which the latter element was present.

METHOD OF L. G. EAKINS.

Chemist U. S. Geological Survey, Washington, D. C.

"About 1 gram of ore was treated with 25 c.c. of dilute hydrochloric acid (1 HCl : 1 H$_2$O) and after digestion on the water bath, 3 c.c. nitric acid were added, the whole being then evaporated to dryness. The dried mass was digested with dilute hydrochloric acid and water, and the insoluble residue filtered off. The filtrate was precipitated with sulphuretted hydrogen, filtered, and the precipitate redissolved in nitrohydrochloric acid, evaporated nearly to dryness, and water and hydrochloric acid added.

"This solution was once more precipitated with sulphuretted hydrogen, the precipitate filtered off, washed, and the filtrate combined with the first. The solution was now oxidized with nitric acid, and a basic acetate precipitation made. The resulting precipitate was filtered off, dissolved in dilute hydrochloric acid, and reprecipitated as basic acetate, filtered, and this precipitate again dissolved. This solution was evaporated to expel excess of acid,

and then poured with constant stirring into an excess of strong, cold ammonia, the precipitate allowed to stand for some time after which it was filtered off and washed.

"The solution from the last ammonia precipitation was found in every case to still contain zinc which had not been removed by the two previous basic acetate precipitations, the amount so held varying from 0·30% to 2%.

"The filtrates from the basic acetate precipitations were combined, evaporated to a convenient bulk, about 5 grams of acetate of sodium and 5 c.c. of glacial acetic acid added, the solution heated to boiling, and the zinc precipitated with sulphuretted hydrogen. The precipitated sulphide was allowed to settle, the solution filtered, and the precipitate washed with sulphuretted hydrogen water containing acetate of sodium.

"The filtrate obtained from the ammonia precipitate was now evaporated to expel excess of ammonia, acetate of sodium and glacial acetic acid added, and the zinc precipitated as sulphide in the same way as has just been described.

"The zinc sulphide precipitates were combined and digested with dilute hydrochloric acid containing sulphuretted hydrogen. All arsenic and traces of nickel (if present) were left undissolved, the zinc and any cadmium that might be present passing into solution. This solution was filtered, the filtrate evaporated to expel the sulphuretted hydrogen, and the zinc precipitated as carbonate with carbonate of sodium in the usual way, being finally weighed as oxide of zinc.

"This was dissolved in dilute hydrochloric acid, the small amount of silica which may have contaminated the precipitate filtered off, washed and weighed.

"To the filtrate an excess of tartaric acid was added, then an excess of caustic soda, and after the solution was diluted to a large bulk it was boiled in a platinum dish to precipitate any cadmium which might have been associated with the oxide of zinc. The precipitate so obtained was filtered off, washed and weighed, and correction made for such amount, together with what silica had previously been found. The results were as follows:

No. 5................14·64% zinc. Cd 0·60%.
" 9................24·11% "   " 0·15%.
" 11................10·71% "
" 13................ 6·31% "
" 20................16·09% "

Note. "Sample No. 5 contained appreciable quantities of cadmium, sample No. 9 very small quantities, and the other samples only traces of this element."

METHOD OF MESSRS. VON SCHULZ & LOW,
Chemists and Assayers. Denver, Colo.

"Prepare a solution of ferrocyanide of potassium by dissolving 44 grams of the pure salt in distilled water and diluting to 1 litre. Standardize as follows:

"Dissolve exactly 200 milligrams of pure oxide of zinc in a beaker in 10 c.c. of strong pure hydrochloric acid. Now add 7 grams of C.P. chloride of ammonium, (the commercial article frequently contains a little copper), and about 100 c.c. of boiling hot water. Titrate the clear liquid with the ferrocyanide solution until a drop, when tested on a porcelain plate with a drop of strong aqueous solution of acetate of uranium, shows a brown tinge. About 16 c.c. of ferrocyanide will be required, and according nearly this amount may be run in rapidly before making a test, and then the titration finished carefully by testing after each additional drop of ferrocyanide. As soon as a brown tinge is obtained note the reading of the burette, and then wait a minute or two and observe if one or more of the previous tests have not also developed a brown tinge. Usually the end point will be found to have been passed by a test or two and the proper correction must then be applied to the burette reading. Finally make a further deduction from the burette reading of the amount of ferrocyanide required to produce a brown tinge under the same conditions when no zinc is present. This correction is about 2 drops, or 0·14 c.c.

"200 m.g. of oxide of zinc contain 160·4 m.g. of zinc, and 1 c.c. of the above standardized solution will equal about 0·01 gram of zinc, or about 1% when 1 gram of ore is taken for assay.

"Prepare the following solutions for the assay of ores:

"A saturated solution of chlorate of potassium in nitric acid, made by shaking an excess of the crystals with the strong pure acid in a flask. Keep the solution in an open flask.

"A dilute solution of chloride of ammonium containing about 10 grams to the litre. For use, heat to boiling in a wash-bottle.

"A wash-bottle of hot water.

"Take exactly 1 gram of the ore and treat in a $3\frac{1}{2}$ inch casserole with 25 c.c. of the above chlorate solution. Do not cover the casserole at first, but warm gently until any violent action is over and greenish vapors have ceased to come off. Then cover with a watch-glass and boil rapidly to complete dryness, but avoid overheating and baking. A drop of nitric acid adhering to the cover does no harm. Cool sufficiently and add 7 grams of chloride of ammonium, 15 c.c. of strong ammonia water and 25 c.c. of hot water. Boil the covered mixture one minute and then, with a rubber-tipped glass rod, see that all solid matter on the cover, sides and bottom of casserole is either dissolved or disintegrated. Filter into a beaker and wash several times with the hot chloride of ammonium solution. A blue-colored filtrate indicates the presence of copper. In that case add 25 c.c. of strong pure hydrochloric acid and about 40 grams of granulated test-lead. Stir the lead about in the beaker until the liquid has become perfectly colorless and then a little longer to make sure that the copper is all precipitated. The solution, which should still be quite hot, is now ready for titration. In the absence of copper the lead is omitted and only the acid added. About one-third of the solution is now set aside, and the main portion is titrated rapidly with the ferrocyanide until the end-point is passed, using the uranium indicator as in the standardization. The greater part of the reserved portion is now added, and the titration continued with more caution until the end-point is again passed. Then add the remainder of the reserved portion and finish the titration carefully, ordinarily by additions of two drops of ferrocyanide at a time. Make corrections of the final reading of the burette precisely as in the standardization.

"Gold, silver, lead, copper, iron, manganese and the ordinary constituents of ores do not interfere with the above scheme. Cad-

mium behaves like zinc. When known to be present it may be
removed, together with the copper, by the proper treatment with
sulphuretted hydrogen, and the titration for zinc may be made
upon the properly acidified filtrate without the removal of the ex-
cess of gas. There seems to be no simpler way to remove cad-
mium.

"The following results were obtained on the samples of ore
sent us by the Colorado Scientific Society. Each sample was
assayed only once. The weighing was done on the ordinary ore-
scale and the burette used had not been corrected. It was in-
tended to show just what would be obtained by the method in
ordinary technical work.

<div style="text-align:center">

Sample No. 5............15·31% zinc.
"   "   9............24·34%   "
"   "   11............10·76%   "
"   "   13............ 6·42%   "
"   "   20............16·14%   "

</div>

Notes on the Above Scheme.—"Acids destroy the delicacy of
the uranium test, and for this reason a strong aqueous solution of
uranium acetate is used. By having the zinc solution only faintly
acid the production of the brown color in the end-test becomes
almost instantaneous and no previous test will develop a color.
Under these conditions, however, lead is apt to seriously interfere
and the excess of acid recommended above is found to be a neces-
sity. When a strong solution of uranium acetate, not acidified, is
used as indicator, the error caused by the excess of acid in the
zinc solution amounts to only two drops of ferrocyanide, which
may be allowed for, and the brown tinge develops so rapidly that
the end-point is seldom passed by more than one test.

"When an ore contains but little copper, the granulated lead
used frequently coheres in lumps that may hold zinc solution.
These lumps are most easily broken up after a little of the ferro-
cyanide has been added. They appear to cause no appreciable
error in the work. Of course lead shot or thin sheet lead may be
used if preferred, and it may be cleaned with strong nitric acid
and used repeatedly. It seems simpler and more satisfactory,
however, to use the granulated lead and throw it away after use.

"As regards the effect of nitric acid, it is found that the addi-

tion of 1 c.c. of the strong acid to the boiling hot zinc solution during the standardization of the ferrocyanide makes no appreciable difference."

METHOD OF MR. L. J. W. JONES,
Chemist Pueblo Smelting and Refining Co.. Pueblo, Colo.

"The method used was that published some time since by Messrs. von Schulz & Low, Chemists and Assayers, Denver, Colo., which consists in effecting a decomposition of the ore by means of conc. nitric acid saturated with chlorate of potassium, evaporating to dryness, and bringing the zinc into solution by means of water, ammonia water and chloride of ammonium; heating the solution to boiling, filtering off the insoluble residue and washing.   If the filtrate shows the presence of copper, this metal is precipitated after acidifying the solution with hydrochloric acid by means of granulated lead.

"To the hot solution a few grams of sulphite of sodium are now added to counteract any effects due to the possible presence of free chlorine from the action of the hydrochloric acid on any chlorate that might not have been decomposed, and the zinc is titrated with a standardized solution of ferrocyanide of potassium, using acetate of uranium as an indicator.

"The readings of the burette were corrected by an amount of ferrocyanide necessary to produce a reaction with acetate of uranium in a blank test, the standardization having been made under like conditions.   The results obtained on the samples submitted were:

No.   5.............15·39% zinc.
"   9.............24·53% "
"   11.............10·83% "
"   13............. 6·58% "
"   20.............16·46% "

METHOD OF MR. E. N. HAWKINS,
Sup't Holden Smelting and Refining Company, Leadville, Colo.

"1 gram of ore is treated in a 3½ inch casserole with 5 to 10 c.c. of conc. nitric acid, evaporated to dryness on a hot plate and baked for several minutes.   After cooling 20 to 30 c.c. of water are

added, and about 7 grams of chloride of ammonium and 15 c.c. of strong ammonia water.

"If the ore is free from manganese proceed as follows:

"Boil for several minutes, filter and wash with warm water, taking the precaution to add a few drops of ammonia water to the first wash-water on filter to keep the zinc in solution. It is more convenient to operate in this way than to use ammoniacal wash-water.

"Neutralize the filtrate with hydrochloric acid, then add an excess of 10 c.c. of the acid. If copper is present precipitate it with granulated lead.

"The solution is now ready for titration with ferrocyanide of potassium, uranium acetate being used as an indicator.

"If manganese is present, after addition of chloride of ammonium and ammonia water as stated above, add to the solution 5 c.c. of peroxide of hydrogen and boil. The manganese will all be precipitated as the hydrated dioxide together with such iron and alumina as may be present. Filter, using the regular precautions.

"Now dissolve the precipitate in a small quantity of hydrochloric acid, dilute with water, add an excess of ammonia water and again 5 c.c. of peroxide of hydrogen, boil for several minutes, filter and wash, and combine filtrate with the one previously obtained.

"The solution is now made acid with an excess of hydrochloric acid, and the titration of the zinc effected, after removal of any copper that may be present, as previously specified.

"In ordinary practice it has been found that the amount of zinc which is carried down with the manganese in its first precipitation by means of peroxide of hydrogen, in the ores which carry from 3 to 10% of that element, is equal to about 5% of the total quantity of zinc present, although this does and will vary somewhat with different practice and the amounts of reagents employed. The results obtained were as follows:

No. 5..............15·66% zinc.
 "   9..............24·23%   "
 " 11..............11·88%   "
 " 13.............. 8·73%   "
 " 20.......... ...15·86%   "

METHOD OF MR. F. C. KNIGHT,

Chemist Boston & Colorado Smelting Co., Argo, Colo.

"1 gram of ore is taken and mixed in a 3½ inch casserole with 10 grams of nitrate of ammonium and 10 c.c. of conc. nitric acid added. The casserole is covered with a watch-glass and the mixture evaporated to complete dryness on a hot plate. The mass usually deflagrates just before becoming completely dry.

"After cooling, about 20 c.c. water and 5 grams of chloride of ammonium are added.

"If manganese is present, of which previous indications will have been afforded, add to the solution 5 c.c. peroxide of hydrogen and 10 c.c. strong ammonia water, heat to boiling for two or three minutes, filter and wash with water containing ammonia water.

"As the precipitate of iron and manganese carries zinc, it is redissolved in a small quantity of hydrochloric acid, water and chloride of ammonium added, then 5 c.c. peroxide of hydrogen and 10 c.c. ammonia water as before. Boil, filter and wash with hot water rendered ammoniacal, and combine the two filtrates. The second precipitation of the iron and manganese practically brings all zinc into solution.

"The filtrate should now measure from 250 to 300 c.c. It is slightly acidified with hydrochloric acid and if copper is present it is precipitated with granulated lead.

"To the solution now add an excess of 10 c.c. hydrochloric acid and titrate the zinc with a standardized solution of ferrocyanide of potassium, 1 c.c. of which is equal to about 5 m.g. or 0·50% zinc. Acetate of uranium is used as an indicator of final reaction.

"As about 5 to 6 drops of the ferrocyanide solution will be absorbed in a blank test before the reaction with acetate of uranium manifests itself, due allowance must be made for this error in the standardization of the solution. It is almost needless to remark that a similar precaution must be observed in taking the reading of the burette in the actual titration of the zinc solution of the ore. Results obtained were as follows:

No. 5...............15·08% zinc.
"   9...............23·80% "
"   11...............10·69% "
"   13............... 6·85% "
"   20...............15·90% "

METHOD OF MR. MANN PAGE,

Chemist Omaha & Grant Smelting Company, Denver, Colo.

"The ore is decomposed by boiling in a casserole with a mixture of conc. hydrochloric, nitric and sulphuric acids, added separately in the order given, the amounts of acid varying according to the demands of the character of the ore under treatment to insure complete decomposition. The boiling is continued until the fumes of sulphuric acid appear distinctly.

"The casserole is then removed from the hot plate, contents allowed to cool and the sulphuric acid solution diluted with water to three or four times its bulk, and chlorate of potassium added whether manganese be present or not.

"If the manganese is present the chlorate must be added in quantity sufficient to insure complete precipitation, an additional quantity of this reagent being added during the boiling if it appears necessary. This can be easily determined by the appearance of the solution. The precipitated manganese dioxide and the insoluble residue are now filtered off and well washed with boiling water.

"To the filtrate ammonia water is added *in slight excess,* the precipitate well stirred and immediately filtered off, the filtrate passing into a graduated flask of 250 c.c. capacity.

"After the iron and alumina precipitate has been transferred to the filter—which should be a sufficiently capacious one—it is allowed to drain thoroughly, and then washed three or four times with water which has been rendered distinctly ammoniacal, and which should not be more than *tolerably* warm. In washing the precipitate care should be taken to thoroughly disintegrate it by the stream of wash-water.

"After a thorough washing the filtrate is acidified by hydrochloric acid, the flask filled to the mark, its contents well mixed,

and a number of aliquot portions of the solution taken for the zinc determination, which is accomplished by a standardized solution of ferrocyanide of potassium, acetate of uranium being used as indicator.

"If copper is present it must be removed previous to titration by means of granulated lead. The titration is always made in hot solutions. Results were as follows:

No. 5..............14·62% zinc.
" 9..............22·00% "
" 11..............10·50% "
" 13.............. 6·30% "
" 20..............15·37% "

"*Notes on the Above Method.*—Attention has been called to the advisability of washing the iron precipitate with water which is not more than tolerably warm, it having been the writer's experience that a partial precipitation of the hydrated oxide of zinc takes place more easily from solutions which, while yet distinctly ammoniacal, approach more nearly the boiling temperature. The precipitation of the hydrated zinc oxide is furthermore influenced by the precipitation of the hydrated sesquioxide of iron, especially so when the solutions are very hot.

"To prevent this occurrence the precautions previously indicated must be observed, in addition to which as a further safeguard, wash-water, which has been rendered ammoniacal, or has been impregnated with chloride of ammonium is used.

METHOD OF MR. F. MENTZEL,

Sup't San Juan Smelting and Mining Company, Durango, Colo.

"The method about to be described is based on the principle, that in an almost neutral solution of sulphates or chlorides, the separation of zinc from iron, manganese, cobalt and nickel can practically be effected by means of sulphuretted hydrogen, while if the solution contains about one-tenth of its volume of sulphuric acid the separation of zinc from copper is equally complete, provided the solution is heated almost to the boiling point before the precipitated sulphides are filtered off.

"The *modus operandi* is as follows:

"1 gram of ore is decomposed in an eight ounce flask with 5 c.c. conc. hydrochloric and 5 c.c. conc. nitric acid; after the red fumes have ceased to be evolved, 5 c.c. conc. sulphuric acid are added, and the whole evaporated until the fumes of sulphuric acid appear. It is absolutely essential at this point that all traces of nitric acid shall have been expelled as otherwise correct results will be vitiated.

"On the appearance of the sulphuric acid fumes the flask is removed from the hot plate, allowed to cool, about 50 c.c. water added and a brisk current of sulphuretted hydrogen passed through the solution. In a few minutes the precipitation of the copper, etc., will have taken place. The precipitation is complete when the precipitated sulphides are seen to settle rapidly at the bottom of the flask.

"Now heat the solution as rapidly as possible almost to the boiling point, by which most of the absorbed sulphuretted hydrogen will be expelled; any zinc which may have been precipitated will by this means be redissolved. Filter into a sixteen ounce flask, wash the precipitate with cold water three or four times, allowing the filter to run dry each time before renewing the wash-water.

"After washing neutralize the filtrate with ammonia water, care being taken not to let the ammonia run down the sides of the flask, but to drop it directly into the liquid, the solution being constantly agitated while being neutralized. It is advisable to add a slight excess of ammonia, the ferrous hydrate precipitate being again redissolved by a few drops of dilute sulphuric acid (1 H_2SO_4 : 4 H_2O). A slight permanent turbidity is of no consequence.

"Now add an excess of 4 to 6 drops of dilute sulphuric acid, fill up the flask with water, and again introduce a brisk current of sulphuretted hydrogen into the solution. Within 5 to 10 minutes a heavy sandy or powdery precipitate of whitish or yellowish zinc sulphide will appear, the rapid settling of which, and the clear supernatant liquid being an indication of complete precipitation. The precipitate filters rapidly and is indifferent to the influence of air, either during filtering or washing. It is filtered off and thoroughly washed, about five washings being usually sufficient unless the solution contained much iron.

"The zinc sulphide which has adhered to the flask and the glass tube is now dissolved in 3 to 5 c.c. of hydrochloric acid, the solution diluted with an equal amount of water and then poured on the filter containing the precipitate, which should immediately thereafter be covered with a watch-glass. The greater part of the precipitate dissolves easily, the solution of any undissolved portion being effected with a few drops of conc. hydrochloric acid.

"The bulk of free acid in the solution is now neutralized with ammonia water, and the zinc determined by titrating with stand-ardized solution of ferrocyanide of potassium, using acetate of uranium as an indicator. The following are the percentages of zinc obtained:

	No. 9	No. 11	No. 13	No. 20
	23·63	11·17	6·94	16·15
	23·56	11·13	7·05	16·05
	23·56	10·99	6·76	16·10
	23·73	10·99	6·81	16·02
Average,	23·62	11·07	6·89	16·08

METHOD OF DR. H. C. HAHN,

Chemist Colorado Smelting Company, Pueblo, Colo.

"The following method is one in which the determination of manganese as well as zinc is effected in the same solution.

"0·50 gram of ore is treated in a porcelain casserole with 2 c.c. conc. nitric, 3 c.c. dilute sulphuric $(1\ H_2SO_4 : 2\ H_2O)$, and 6 c.c. conc. hydrochloric acid, evaporated to dryness, or until the fumes of sulphuric acid appear. The casserole is then removed from the hot plate and allowed to cool, when 20 c.c. water are added and the solution heated to boiling for about one minute.

"The contents of casserole are now transferred to an eight ounce beaker, and the solution nearly neutralized with a saturated solution of carbonate of sodium. In case too much of the latter should have been used, acidify with a few drops of dilute sul-phuric acid.

"Now add to the solution an excess of basic carbonate of lead suspended in water, until after vigorous stirring the precipitated

hydroxide of iron settles quickly to the bottom of the beaker, leaving the liquid clear.

"The solution should measure now about 80 c.c. It is heated to boiling without previous filtration, and the manganese determined with a standardized solution of permanganate of potassium. (4·86 grams of $KMnO_4$: 1 litre of H_2O, whence 1 c.c.=0·50% Mn.)

"After each addition of the permanganate the solution should be briskly stirred as it facilitates the settling of the precipitate. Should the solution appear yellow or turbid, the stirring must be continued until it is clear. When the rose tint appears, indicating the complete precipitation of the manganese, a few grams of chloride of ammonium and 5 c.c. ammonia water are added, and the solution is filtered without previous heating, the precipitate being washed with water containing about one-fifteenth of its bulk of strong ammonia water.

"The precipitate is well washed, and to the filtrate, which should measure about 140 c.c., 12½ c.c. of hydrochloric acid are added. If copper is present it is removed by means of granulated lead, after which the zinc is determined by titrating with a standardized solution of ferrocyanide of potassium, an uranium salt being used as indicator.

"The manganese determination is quite exact, but the zinc determination not so good. The percentage results on samples of ore submitted are:

Zinc.

	No. 5	No. 9	No. 11	No. 13	No. 20
	14·38	22·95	8·58	5·24	13·40
	14·22	23·11	9·20	5·64	12·84
Average,	14·30	23·03	8·89	5·44	13·22

Manganese.

	No. 5	No. 9	No. 11	No. 13	No. 20
	3·22	2·89	2·68	9·25	0·65
	3·32	2·81	2·72	9·53	0·87
Average,	3·27	2·85	2·70	9·39	0·76

"*Note:* The basic carbonate of lead used in the preceding method is prepared by adding to a hot solution of carbonate of sodium, a hot solution of acetate of lead as long as a precipitate is formed and washing the precipitate repeatedly by decantation until all sodium salts are removed.

COMPARISON OF RESULTS.

Analyst	No. 5	No. 9	No. 12	No. 13	No. 20
Eakins......................	14·64	24·11	10·71	6·81	16·09
von Schulz & Low...........	15·31	24·34	10·76	6·42	16·14
Jones......................	15·39	24·53	10·83	6·58	16·46
Hawkins....................	15·66	24·23	11·88	8·73	15·86
Knight	15·08	23·80	10·69	6·85	15·90
Page.......................	14·62	22·00	10·50	6·30	15·37
Mentzel....................	——	23·62	11·07	6·89	16·08
Hahn	14·30	23·03	8·89	5·44	13·22

A consideration of the above results leads to the conclusion that there are a number of the methods detailed that are satisfactorily adapted for the technical determination of zinc. All of the technical chemists employ the ferrocyanide solution for the final titration.

A method, however, like the one used by Mr. Mentzel will hardly commend itself on account of the repeated use of sulphuretted hydrogen. The unique method of Dr. Hahn for the combined determination of manganese and zinc from one solution is open to the serious objection that the zinc results are uniformly low. With this difficulty obviated, the method would be a highly commendable one.

The governing factors which should influence the selection of any given method for general adoption in technical laboratories are without doubt the accuracy of the results that can be obtained by its use, together with the time involved in its execution. When it is borne in mind that the technical chemist is daily confronted with a large number of determinations that are to be made, and

that not only are metallurgical calculations, but also treatment charges on ores dependent on his results, the desirability of having simple, quick and correct analytical methods is made apparent.

Without at all disparaging the methods employed by Messrs. Page, Hawkins and Knight, it seems to the committee that the method described by Messrs. von Schulz & Low approximates more nearly the conditions prescribed than do any of the others. It will be noted that the results given by Messrs. von Schulz & Low are comparatively high only in their determinations on samples Nos. 5 and 9, and attention is directed to the fact that in both of these samples the presence of cadmium is noted by Mr. Eakins, sample No. 5 containing the larger quantity.

The committee feels that the ores on which the investigations were made were such as have subjected the methods employed in the determination of zinc to a severe test. It is also aware that any method which would commend itself for general introduction, must not only be a satisfactory one in the hands of its originators, but that it must also be capable of yielding concordant results when operated by others. This can only be determined by a fair and impartial trial.

If the inducements pertaining to von Schulz & Low's zinc method seem sufficient to warrant other chemists in investigating its merits, the committee will be glad to aid such in furnishing requisite material; and it will no less be pleased to publish such criticism as may be offered, if weaknesses in the method which are not now apparent, are thereby disclosed.

E. N. Hawkins,
F. C. Knight,
L. J. W. Jones,   } Committee.
Henry E. Wood,
F. Guiterman,

THE POST-LARAMIE BEDS OF MIDDLE PARK, COLORADO.

BY WHITMAN CROSS.*

The Hayden geological map of Colorado represents a large area of Laramie strata as forming the divide between Middle and North Parks and extending for some distance on either side. The description of the Middle Park portion of this formation by Marvine, in 1873, brought out the fact that it is stratigraphically unconformable with the Cretaceous series beneath. The reference to the Laramie or "Lignitic" formation was based on plant remains, and an asserted general resemblance to the coal-bearing formation on the plains.

Although the Laramie has been generally defined in later years as the uppermost conformable formation belonging to the Cretaceous, and the Middle Park beds have presented the most pronounced if not the only decided exception to this relationship, their assignment to the Laramie has not been questioned until recently. In discussing various Post-Laramie formations of Colorado the writer† has shown that these Middle Park beds are the equivalent of the Denver beds of the eastern base of the Front Range. In the article cited, only the principal facts could be given. The present paper is intended as a contribution to the geology of Middle Park, to place on record the observations made, which, by their imperfections, indicate various directions for further research in this very interesting field.

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*Published with the permission of the Director of the U. S. Geol. Sur. and of Mr. S. F. Emmons, Geologist in charge of the Colorado Division.

† Post-Laramie Deposits of Colorado, Amer. Jour. Sci., Vol. XLIV., pp. 27-31, July, 1892.

HISTORICAL REVIEW.

F. V. Hayden, 1869.—The first description of the strata under discussion, known to the writer, was given by F. V. Hayden*
after a hurried reconnaissance in 1869. Hayden paid special at-
tention to the exposures on Grand River near Hot Sulphur Springs, and collected fossil plants at several localities. The vol-
canic breccia and conglomerate below the so-called "Lignitic" beds is called basalt by Hayden and is variously referred to in different places as intrusive, as formed of surface lava flows, and as a sedimentary deposit. The great series of lighter colored sand-
stones above the "breccia" he regards "as of the age of the coal formations of the West older Tertiary."

A. R. Marvine, 1873.—The field work of the Hayden survey in Middle Park was in charge of Archibald R. Marvine, who gave an excellent description of the geology in the Annual Report for 1873,† accompanied by maps, and by sketches by W. H. Holmes. In the season of 1874 Marvine studied North Park, but died, as the result of exposure undergone in prosecuting his work, before submitting his report, so that many observations upon the so-called Laramie of North Park are lost.

It must be assumed in the following pages that the reader has access to the Hayden geological map of Colorado, and to the an-
nual report of the Hayden Survey for 1873, containing Marvine's description of Middle Park geology. It will be a great aid to an understanding of the present article if the reader will place before him the map, and the excellent sketch by W. H. Holmes, forming Fig. 16, facing page 170 of this report. As a further aid there is given below a reproduction of the west end of Fig. 1 of Plate III of Marvine's report, with a few slight alterations. Before pre-
senting the results of the writer's recent observations, it will be necessary to give a summary review of the geology of the "Lig-
nitic" formation of Middle Park as understood by Marvine. It may be well to remind the reader that in 1873 the Eocene age of the "Lignitic" formation was unquestioned by members of the Hayden Survey.

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*Preliminary Field Report of the United States Geological Survey of Colorado and New Mexico, pp. 81–86 (for the season of 1869).
†Seventh Annual Report, U. S. G. and G. S., pp. 154–192.

From the map it will be seen that a large area of "Laramie" beds extends southeasterly into Middle Park from the continental divide, gradually narrowing until shortly before reaching Grand River, when it divides into two arms.   The eastern arm crosses Grand River east of Hot Sulphur Springs and ends in a point about four miles south of the river.   This arm has a general synclinal structure, for the beds have an inward dip all around the border of this spoon-shaped area.   As a dark volcanic breccia forms a marked rim to this basin area, Marvine used the convenient term "breccia spoon" in referring to it.

The western arm of the beds ends its continuous exposures in Mt. Bross, on the north bank of Grand River, at Hot Sulphur Springs, but the strata reappear in the same line on the ridge running southeasterly from the Springs toward Mt. Byers.   In the angle between the arms of "Laramie" appear the strata of the Cretaceous section, from the Dakota to the Fox Hills inclusive, with a N. W.-S. E. strike and a northeasterly dip of 15°-25°, which carries them in apparent conformity below the strata of the "breccia spoon," while the "Laramie" beds of Mt. Bross and of the ridge to the southeast rest in a nearly horizontal position upon the Archæan, and the edges of the Dakota and the Colorado shales. This is the unconformity discovered by Marvine.

The accompanying view and section, reproduced from Marvine's report, as stated above, represents the country north of Grand River, embracing the wide part of the "breccia spoon," the place where the Laramie area divides, the mass of Mt. Bross, and in the distance some of the points on the North Park divide.   The section line is that of Grand River, and the distance on the section line from east to west is about eight miles.

The strata in the broad syncline above the andesitic breccia are the "Lignitic" beds of Marvine.   They have a thickness of over 5,500 feet according to him.   Beneath the "Lignitic series" come the formations composed of volcanic materials called the "doleritic breccia" by Marvine, and regarded by him as distinct from the "Lignitic."   Of this he says:

"Above the Cretaceous No. 5, the next youngest rock is a local occurrence of volcanic doleritic material, consisting partly of subaqueous arranged
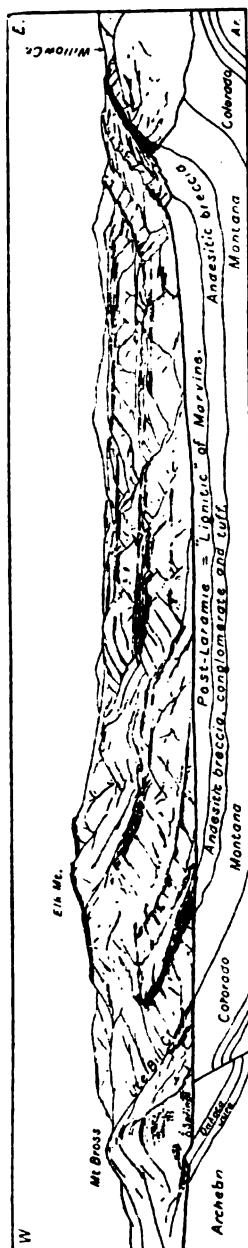
material—doleritic, tuff and breccia—and partially as accompanying lava-flows; reaching a maximum thickness of 800 or 900 feet."[*]

At the eastern or upper gorge, cut through the "breccia," now known as Windy Gap (see figure), the formation is shown

" to be composed of a rough, sedimentary aggregate of volcanic material; a series of conglomerates, breccias, sands and irregular material, of which the most distinct rock is of doleritic character. * * * This volcanic detrital series attains an estimated thickness of from 800 to 900 feet; the lower part being a massive accumulation, and showing distinct stratification, the upper part being well bedded, and often of fine materials. These strike nearly north and south, and dip westward at an angle of 60°[†] * * *." Of the breccia at the western or Potato Hill gap he remarks that here "another similar passage is found by which the river again breaks through a ridge of precisely the same material as before. It is, in fact, the same bed again appearing in view from beneath the same lignitic sandstones. * * * As before, much of this series is massive, or wholly indefinitely bedded, and some compact lava occurs, as if of distinct lava flows. The latter seems to be doleritic, crystals of augite being quite frequent, though some is basaltic, being fine and quite homogeneous. Most, however, is of a distinct conglomerate and breccia, some very coarse, of pebbles like the accompanying lava, many scoriaceous, while much is of fine material, finely and evenly bedded. Their total thickness was estimated at about 800 feet at this point."[‡]

Marvine's idea of the "doleritic breccia" is that it is local in origin, certain "dikes" of breccia south of the point of the "spoon" being thought to represent the eruptive vents. As to the period of its formation,

*Report, p. 156.
†Report, p. 166.
‡Report, p. 167.

he considers it prior to the folding which produced the uncon-
formity. He says:

"As the Hot Springs fold gradually rose, the edges of the Cretaceous
and of the breccia must have been eroded back to where the latter was nearly
horizontal, before the lignitic beds were deposited upon their edges."[*]

Marvine did not notice fossil leaves in the "breccia," and, in
a word, he treats it as a local intercalation between the Fox Hills
Cretaceous and the Lignitic Eocene.

The Lignitic formation of Marvine embraces the entire se-
quence of strata above the breccia up to the summit of the North
Park divide. The following is the general characterization of the
formation by Marvine:

"Resting upon the latter (the "doleritic breccia") when it occurs, but
elsewhere upon Cretaceous No. 5, and apparently conformable with the latter,
except at one point, where there is a decided uncomformability, is a series of
beds which reach a thickness of about 5,500 feet. Not being capped with any
beds following them in direct geological sequence, it is impossible to tell how
much thicker they may originally have been, erosion having already removed
an unknown amount of them. They are composed, in part, of sandy shales
in places more or less argillaceous and quite soft, spaced rather regularly with
more prominent and characteristic horizons of coarse sandstones, which are
often inclined to grits and fine conglomerates. The texture of the latter is
usually open and not firmly compacted, while the material of which they are
composed is characteristically the debris of the Archæan rocks of the moun-
tains, granitic debris prevailing. While some of the finer grained massive
beds are sombre brown in color, the usual colors are light gray or whitish.
Escarpments of the harder gravels, reaching thirty feet in height, separated
by shaly slopes of five to ten feet, often make up the hill-sides, while every
few hundred feet in altitude a predominance of the more massive gravels has
caused the erosion to carve the whole formation into a series of high terrace-
like steps, in places well defined, but in others indicated only by changes of
steepness in the long, wavy, graceful slopes of the hills. It gradually forms
a high, broken-terraced region. Impressions of deciduous leaves are quite
numerous at favorable localities and small isolated patches, and one or two
thin seams of carbonaceous material were also observed. No other fossil
were observed in these beds. It has been strongly affected by the last great
folding accompanying the formation of the Rocky Mountains, portions of it
being abruptly upturned, together with the underlying sedimentary rocks.
In position and character, therefore, this group of beds appears to be equiva-
lent of the lignitic group east of the mountains."[†]

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[*] Report, p. 169.
[†] Report, p. 156.

Marvine does not speak of any transition beds between the "breccia" and the lignitic beds, nor of eruptive material as a constituent of the latter at any point.

The unconformity between the lignitic and underlying beds was established by the following facts, easily understood by means of the map and the figure above. Passing westward down the valley of the Grand from the western breccia ridge, the entire Cretaceous section to the Dakota is seen, not in continuous exposures, but in such a succession as to show that no other formations occur, and the dip and strike remain about constant. At the base of Mt. Bross, on the very bank of the river, the hot sulphur springs issue from Fort Benton shales a few feet above the Dakota sandstone, and there are continuous exposures in the river bank showing the greater part of the Benton, the whole of the Dakota and Jura, and the Archæan granite below, through which the Grand then cuts a canyon for several miles.

Within a hundred yards of the springs begin the steep slopes of Mt. Bross, affording almost continuous exposures to the summit, 1,500 feet above the river. The strata of the mountain dip very gently northward. Debris conceals the actual contact of the Mt. Bross beds with the easterly dipping Cretaceous, but, as observed by Marvine, ·

"the position of the mountain is such that its beds must rest unconformably upon the upturned and eroded edges of the Cretaceous sandstones and shales below."*

The strata of Mt. Bross are evidently the equivalent of those above the breccia in the "spoon," and Marvine explains their position at Mt. Bross by supposing that the "Lignitic" strata overlap first the breccia and then the Cretaceous in the mass of Elk (Whiteface) Mt., and the ridge at the head of the Ute Bill Creek see (figure) connected with Mt. Bross. As will be pointed out later, a fault in Mt. Bross, not noted by Marvine, is an important factor in producing the observed relationships.

South of Grand River, Marvine found the "Lignitic" beds in nearly horizontal position resting on Archæan, Dakota, and Colorado of the Mt. Byers ridge, as shown by the map. This ridge is also shown in the panoramic view of Fig. 16 of his report.

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*Report, p. 168.

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Fossil plants were found by various members of the Hayden party in the strata of Mt. Bross and in those of the "breccia spoon." These fossils and the conclusions drawn from them will be reviewed in a succeeding part of this article.

While Marvine treats the unconformity near Hot Sulphur Springs as local, the Hayden map represents the "Laramie" beds under discussion as resting upon the Colorado Cretaceous at the southwestern extremity of North Park, and also long the eastern border of the formation both in North and Middle Parks. This drawing is apparently upon the basis of observations made in 1874, of which there is no other record. The map also indicates unconformity in the area west of Troublesome Creek, now occupied by lake-beds, in that to the eastward the "Laramie" beds rest upon Archæan, while to the westward the Fox Hills strata come immediately below them. In fact, the map seems to show clearly that the Cretaceous formations were folded and very much eroded in the whole central portion of Middle Park before the "Laramie" beds were deposited.

Dr. C. A. White.—In 1877 Dr. White visited Middle Park and examined the Laramie there for fossils, without finding any. He refers to a few invertebrate fossils found by Marvine in North Park, probably in the same formation, and says:[*]

"Of themselves they are not sufficient to determine the age of the strata containing them, or their equivalency or otherwise with those of the Laramie group."

And further, as a kind of summary of the evidence, he remarks:

"While we seem warranted in assuming that the strata in question, of the Middle Park region, are really equivalent with the Laramie Group of the upper Missouri, the Green River basin, and of the plains at the eastern base of the Rocky Mountains, the following comparisons are of interest. The strata in question have an aggregate thickness in Middle Park fully double that of those in the plains at the eastern base of the Front Range, but not greater than at the western base of the Park Range. The Middle Park strata contain no fossils that are certainly identical in species with any of the numerous forms found on each side of that region at the eastern and western bases, respectively, of the Rocky Mountains; and they contain, so far as known, only those imperfectly known species before referred to, that are pos-

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[*] Eleventh Annual Report, U. S. G. and G. Survey, p. 203.

sibly identical with forms in the Fort Union beds of the upper Missouri. So far as I am aware, no coal has been found in the Laramie beds of Middle Park, while it is more or less abundant in all the other known regions of that group."

While discussing the Middle Park beds, Dr. White does not refer to the unconformity discovered by Marvine, but in a footnote in another connection he says: *

"There is, as reported by the late Mr. Marvine, a limited unconformity of the Laramie strata upon those of the Fox Hills group in Middle Park, but that is believed to have been caused by comparatively slight movements that took place previous to those of the Rocky Mountain uplift proper."

Resume of Literature.—The reference of the Middle Park beds to the Laramie by Hayden, Marvine and White is based upon their general position with regard to the Cretaceous, treating the hot Springs unconformity as local; upon a few fossil plants; upon three shells of uncertain identity, and upon a general asserted resemblance to the " Lignitic" strata of other known localities.

The unconformity, the absence of coal measures, and the absence of the invertebrate fauna known from many places in the Laramie—all these were passed over as of little importance. The absence of definite evidence indicating any other special correlation seems to have determined the matter.

Recent Investigations.—In the summer of 1889, soon after the Arapahoe and Denver formations had been described,† Mr. S. F. Emmons, in charge of the Colorado division of the United States Geological Survey, sent George L. Cannon, Jr., to Middle Park to examine the so-called " Laramie" beds, for the unconformity with the Cretaceous; the fossil flora, and the lithological character of a part of the beds having strongly suggested an intimate relationship with the Denver formation for at least a part of the series. Mr. Cannon's report confirmed this idea.

In the fall of 1890, and again in 1891, the writer spent a few days in the vicinity of Hot Sulphur Springs, examining especially the lithological character of the breccia and of the beds above it,

* Ibid., p. 200.
†"On some stratigraphical and structural features of the country about Denver, Colorado," by George H. Eldridge, Proc. Colo. Sci. Soc., Vol. III., part 1, pp. 86-118.
" The Denver Tertiary Formation," by Whitman Cross, Ibid., pp. 119-133. 1888.

and the evidences of unconformity. The observations made were largely of local character, but the question at issue soon expanded to one regarding the geological history of the whole Middle and North Park areas in the period following the conformable series of Cretaceous deposits.

THE CHARACTER OF THE " DOLERITIC BRECCIA."

Marvine called the eruptive rock of the breccia beds "doler-ite " because it was dark colored and its only microscopic constituents noted by him were augite and plagioclase. This designation was a natural one, considering the state of petrography in this country at the time he wrote. The study of specimens collected at many points by Mr. Cannon and the writer shows that a large series of andesitic rocks take part in this formation. There are *pyroxene-andesites,* with augite and hypersthene, *augite-andesite, hornblende* and *mica-andesites,* and a variety of intermediate stages. Chemically they vary from quite basic rocks to those having some excess of silica. These andesites vary also in structure and texture, being coarse grained or dense aphanitic, vesicular or compact. No distinct basalts were noticed, though certain decomposed rocks may possibly have belonged to that group. On the whole, the rocks here 'represented bear strong resemblance to those constituting the Denver conglomerates and tuffs.

Breccia beds are not so prominent a feature of the complex as Marvine's description would suggest. No distinct lava flows were seen by the writer, but they may exist in portions not examined. The massive breccia layers are most prominent in the southern and eastern parts of the district, where the complex is thickest, and this fact seems to indicate the direction of the source from which the eruptive material came. Everywhere fine-grained tuffs and conglomerates alternate irregularly with the breccia, Nor is the latter always present at the same relative horizon. In some places breccia predominates in the lower part of the section, while in others a hundred feet or more of tuffs may be at the bottom.

Where more massive beds prevail, the cliffs are bold, and where the finer sediments are strongly developed, the cliffs will be broken down by cross ravines or depressions. Fine, brownish tuffs with fossil leaves occur locally between thick layers of brec-

cia. In general, the stratification is plain, but some breccia beds are so uniform in appearance through the indurated matrix of pure eruptive material that on freshly fractured faces the fragmentary structure is suppressed. Fragments three feet in diameter are occasionally seen. In form the fragments are sub-angular as a rule, but some are quite round. The pebbles of the conglomerates are usually small and very round. Going northward along the western breccia ridge, from Grand River, the beds become more and more distinctly stratified rocks, the thickness decreases, and at several places the cliffs are broken down by absence of hard massive layers.

Fossil plants occur in several layers within the breccia complex, but are usually not very well preserved.

Constitution of the "Lignitic" Beds.

The description of the "Lignitic" beds by Marvine implies that they are free from eruptive material, or, at least, from material similar to that of the breccia, and his conception that the two formations are separated in time by a period of folding and erosion necessitates a sharp boundary line between them. Here the writer's observations differ radically from those of Marvine, for at every place visited by him there are transition beds, and eruptive material is prominent here and there through the entire thickness of the beds examined, about 2,500 feet above the "breccia." An idea of the character of this series may be obtained from the following description of the nearly continuous section afforded by examining the faces of the terrace-like ridges represented in Fig. 1, beginning with western breccia ridge on the north bank of the Grand and passing in northeasterly direction to the center of the "spoon."

The crest of the dark ridge shown in the figure is usually a massive breccia stratum, 20–40 feet in thickness. The gentle slope eastward from this ridge dips somewhat less than do the strata, and it is estimated that 250–300 feet of beds are represented by the slope to Sheriff Creek. These beds are soft, fine-grained sandstones and shales of brownish color, seldom affording good outcrops. Locally, conglomeritic layers are developed, with much dark andesitic material; though quartz, feldspar and fragments of Archæan rocks predominate.

Fossil leaves are common in the fine sands and tuffs within fifty feet of the breccia. From one stratum Mr. Cannon obtained a number of well preserved species. Thin seams of very impure lignitic material led to fruitless explorations for coal near the road on the slope of the breccia ridge. Certain layers are micaceous sandstones.

The bluff facing Sheriff Creek on the east has about 650 feet in thickness of beds, exposed in two sections with a little bench between them in many places. The lower 200 feet are brown, coarse-grained, friable sandstones, with thin layers of finer grain, and usually darker color here and there. Three conglomerate beds, each six to eight feet in thickness, occur in the section, one near the top. The pebbles are less than three inches in diameter. Andesitic pebbles are abundant in all of these beds, and some of the sandstones contain eruptive grains. Concretionary masses are characteristic of certain beds. Plant stems and fragments of tree trunks were seen, but no well preserved leaves.

The upper 450 feet of beds in this ridge are predominantly yellowish-brown sandstones or grits. Some of them consist almost wholly of feldspar and quartz grains. Conglomerate layers appear at intervals as below, and andesitic pebbles are numerous in them, especially in the coarser ones. Certain beds are much richer in eruptive material than others. Shaly layers, rich in muscovite, appear here and there. Dark greenish clay strata are found occasionally. At the top of this ridge is a conglomerate 30–40 feet in thickness, of reddish tinge from the abundance of red feldspar and granite, both in pebbles and matrix. Andesite appears here sparingly.

Succeeding the last mentioned ridge northeastward is the valley of West Kinney Creek. The slope to that valley is almost a dip slope, not more than 100 feet of soft beds being represented on it. Facing West Kinney Creek on the east is a bluff on which at least 750 feet of sandstones, etc., are shown. For 150 feet above the creek no outcrops were seen, but above that to the summit of the ridge are prominent outcrops of massive sandstones and grits, in which, at considerable intervals, are bands of pebbles or of clay. A few clay banks 30 to 40 feet in thickness cause smooth slopes.

The massive sandstone banks of this cliff, whether in rounded forms and faces of rock are very markedly cavernous; some of the smooth walled cavities being six or eight feet in diameter laterally and two or three feet high. From a distance these faces appear pitted. The massive sandstones are composed almost exclusively of quartz and feldspar, and are very light-yellow or gray in color. In all pebble bands or conglomerates some andesite pebbles occur.

About 100 feet below the top of this ridge there appears a considerable amount of light-colored andesite, and conglomerate layers are rich in it. It is an andesite different from any seen below in the series. Soon, this material predominates in sandstones and grits. A coarse conglomerate at the top has some Archæan pebbles six inches in diameter. Few andesites occur in this. This conglomerate is estimated to be about 1,750 feet above the breccia on the line traversed.

In the high ridge between the forks of Kinney Creek, about in the center of the "spoon" are represented several hundred feet of strata above those last described. A continuous section was not found. Massive, cavernous sandstones like those described occur here, and above them come beds rich in a very light-colored andesite, both grits and conglomerates. A reddish heulandite forms a cementing material to some of the strata, giving them a pinkish color. Certain fine grained tuffs near the top of this ridge contain well preserved fossil leaves, and a number were collected.

From the point last mentioned, with an elevation of about 10,000 feet, run connecting ridges to Park View Mountain, on the North Park divide, 12,433 feet high. If the intervening strata with a slight northerly dip all belong to the formation under discussion, as believed by Marvine, it is clear that his estimate of 5,500 feet as the total thickness of the series is not an overestimate. And to this 5,500 feet should be added, for the "breccia spoon," at least 800 feet to represent the andesitic tuffs, conglomerates and breccias, here at the base of the series.

The strata of Mt. Bross are of the same general character as those described above. At least 1,500 feet in thickness is represented between the southern base and the summit of the mountain. There are good exposures on the southern face of the moun-

tain for more than 800 feet, and above that to the summit at in-
tervals.   Near the base, clayey and shaley beds, often micaceous.
prevail; and through their ready disintegration obscure exposures.
The strata are not to be closely correlated with those of the sec-
tion in the "spoon."   They are softer and do not include such
massive sandstones as were seen facing West Kinney Creek.   The
closest resemblance noted was between the strata of the summit of
Mt. Bross and the pinkish beds near the top of the ridge east of
West Kinney Creek.

Fossil leaves abound in a whitish tuff, occurring back of the
prominent bench at about 800 feet elevation above the river.
This stratum is apparently the one which yielded so many to the
members of the Hayden Survey, and Mr. Cannon collected a large
number here.   Good leaves also occur near the summit of the
mountain.

The beds of the uncomformable series on the south side of
Grand River are texturally similar to those of the " spoon."   Ex-
posures do not show good sections at any place seen.

The above observations show that the "Lignitic" beds of
Middle Park are lithologically very similar to the Denver beds,
and unlike the strata of the Laramie proper.   The asserted resem-
blance to the coal-bearing formations east of the mountains is not
borne out even by a casual examination.

STRATIGRAPHICAL RELATIONS.

The strata occurring below the breccia at the gaps cut by the
Grand River seem to belong without doubt to the Fox Hills or
upper division of the Montana Cretaceous.   But it seems probable
that the breccia of the spoon area rests upon an eroded surface,
and hence comes in contact with different horizons in different
places.   Mr. Cannon observed 150 feet of a light-colored sand-
stone immediately below the breccia at Willow Creek Gap, north
of Grand River, a sandstone much more closely resembling the
Laramie than anything else seen in Middle Park.   Below come
the normal Fox Hills sandstones.   No fossils were found in this
sandstone.

A short distance southeast of Potato Hill, Mr. Cannon found
a number of fossils in concretions in sandstone, at fifteen feet be-

low the breccia. These fossils were submitted to Dr. C. A. White for determination, who identifies the following species: *Pteria parkensis* White, *Scaphites nodusus* Owen, sp., *Ostrea translucida* M. & H., *Leda (Yoldia) scitula* M. & H.? *Inoceramus convexus* M. & H., *I. sagensis* Owen, *Baculites ovatus* Say, *B. compressus* Say,? *Placenticeras placenta* De Kay, sp., *Anchura*, sp. Dr. White remarks in reporting these fossils that they "seem to indicate the lower (Fort Pierre) division of the Montana group, though some of these species doubtless range up into the upper division of that group." On the slope below this locality Mr. Cannon found many concretions in sandstone and shale, without noting anything distinctly representing the marked Fox Hills sandstone occurring prominently below the breccia on the north side of the river. This may indicate an unconformity at this point, though observations are insufficient to establish it.

Southeast of the end of the "breccia spoon," within two or three miles, are several masses of dark andesitic breccia, which are thought by Marvine to be dykes. They occur above Dakota sandstone or Colorado shales in some cases, and have a steep dip like sandstones. In one case Marvine draws a fault just above one such mass, parallel to its strike, and it seems quite probable that these masses are remnants of the breccia in contact with the surface on which the breccia locally rested, but upturned in common with the underlying sediments by folding and faulting, like the masses next to be described.

Within one mile southeast from Hot Sulphur Springs two ridges set off from the Mt. Byers ridge, running in a northerly direction. These ridges are well shown in the Figure 16 of Marvine's report, and are marked as of Cretaceous sandstones. Probably Marvine inferred this, for they are both capped by dark andesitic conglomerate, while dark shales appear on the lower slopes. The longer ridge nearer the Hot Springs may be called Heimbaugh ridge from the gulch at its western base. On the west side of this gulch are outcrops of what is probably the Niobrara limestone.

The peculiarity of Heimbaugh ridge is that the partially-stratified volcanic material of the crest seems to have an almost vertical dip—that is, it seems at first to be a dyke in shales whose

structure cannot be made out. Fossil leaves were found in fine-grained bands, however, and on going to the point where the ridge joins the larger one, the strata of andesitic material are found to curve over to the west to a nearly horizontal position, passing around the head of Heimbaugh gulch, and to disappear on the wooded slopes of the Mt. Byers ridge in what seems to be their normal position as the first sediments of the "Lignitic" series. A short distance below on the main ridge are outcrops of the Dakota sandstones dipping northeast.

The short ridge east of Heimbaugh ridge has the same structure, according to Mr. Cannon. The ends of these ridges are nearly in line, with a fault observed in the mass of Mt. Bross, and they are possibly terminated by it. These two masses prove that the two dark andesitic deposits are present in much diminished thickness in the Mt. Byers ridge, and the structure of these ridges suggests a similar character for the various isolated breccia masses south of the "breccia spoon," some of which were regarded by Marvine as dykes. If they are remnants resting upon various Cretaceous rocks, though now much disturbed, they extend the proofs of radical unconformity.

Concerning the unconformity north of Grand River, the following observations were made. The breccia complex of the ridge on the western side of the "spoon" changes in character as it thins out toward Elk Mountain (see Figure p. 4.) Massive breccia layers give way to distinctly stratified tuffs and conglomerates, which are softer and more easily eroded. Where the ridge turns toward Elk Mountain, the dark andesitic beds run down the western slope of this ridge, flattening out in dip, and higher beds take their place on the crest of the ridge. Marvine erred in supposing that the breccia disappeared under the basalt capping of Elk Mountain, and it may be that he was misled by basaltic agglomerate which outcrops for several hundred feet below the basalt sheet on the southern slope of the mountain. This agglomerate is a typical "tumultuous assemblage" of angular and subangular blocks of basalt of various structures, textures, colors and sizes, and seems to mark a volcanic vent breaking up through the "Lignitic" beds. On the eastern spur of the north point of the mountain is a distinct, nearly vertical contact between the agglomerate

and "Lignitic" beds which seem to dip at a small angle eastward. This was only seen at a distance. Rhyolite plugs seem to penetrate the agglomerate.

The head of Ute Bill Creek is so much timbered that the course of the dark andesitic beds after assuming a nearly horizontal position is not clear, but it is probable that they swing around the head of the gulch to the ridge connecting Elk Mountain with Mt. Bross. Their thickness is very much reduced, and they are mainly tuffs or fine conglomerates. Whether these beds form the base of the unconformable series in the mass of Mt. Bross and to the northward, or entirely disappear by thinning out, is unknown.

The strata of Mt. Bross at Hot Sulphur Springs are brought to this level by the aid of a fault not noted by Marvine, and first seen by Mr. Cannon. The fault is actually seen at the southeastern base of the mountain where there is a polished plane with W. N. W. strike, and a dip 70° N. N. E. Its foot wall is a polished surface of sandstones and grits turning down to the fault when near it, and the hanging wall is made of soft, crumbling Colorado shales, much crushed, and probably presenting a westerly dip near the fault. These shales run up the smooth eastern slopes of the mountain for several hundred feet, the exact distance being impossible to determine on account of landslides and a growth of trees. It is possible that this fault lowers the strata of Mt. Bross sufficiently to bring the bottom of the "Lignitic" from its level at the head of Ute Bill Creek down to that of Grand River at the springs. But the hasty examinations made in this complicated region indicate the probable presence of other faults which may have helped to produce this dislocation.

AGE OF THE MIDDLE PARK BEDS.

As has been shown in the historical review, the reference by Hayden and Marvine of the strata above described to the Laramie or "Lignitic" formation was based upon their general stratigraphical position, a fancied lithological resemblance, and the alleged testimony of a few fossil plants. But it is clear that the importance of the unconformable relationship of the beds was not adequately realized, and that the lithological resemblance does not, in fact, exist. It becomes necessary now to review the evidence of the fossil flora.

In doing this a number of serious inaccuracies and misstatements in regard to the earlier collections must be pointed out. Marvine mentions the occurrence of fossil leaves at various localities, but, apparently, the identifications were not available for him. Hayden, however, in his introductory chapter to the report for 1873, speaking of Mt. Bross, says:

" From this hill we obtained a great variety of fossil leaves characteristic of the Lignitic group. From this group in the Middle Park Mr. Lesquereux has identified *Sapindus angostifolious, Staphylea acuminata, Planera longifolia, Rhus drymeja, Glyptostrobus europaeus, Sequoia angustifolia, Fraxinus prædicta, Ulmus tenuinervis, Myrica acuminata, Ilex sphenophylla. Pterocarya americana, Rhus Haydeni, Myrica latiloba.* * * * So far as we can judge from the fossil plants, this great series of strata in the Middle Park must belong to the Lignitic group, and is probably of lower Tertiary age."*

The responsibility for the statement that these plants are "characteristic of the lignitic group" undoubtedly belongs to Prof. Lesquereux, for in the same Annual Report is an article by him on the " Lignitic Formation and Its Fossil Flora,"† in which he describes a large number of plant species in four groups. The "Second Group " embraces six species assigned to definite localities, Mt. Bross, Troublesome Creek or Willow Creek, all in Middle Park, although this latter fact is not mentioned in any case. None of these species are included in Hayden's list. In the " Fourth Group" are included all the species of the above list, and all but one of them are said to come from Middle Park, with no further details of locality. *Glyptostrobus europœus* is here reported from Florissant, Colo., and not from Middle Park, and several other species are assigned to both localities. The other twenty-five species of this group are nearly all said to come from Florissant, Colo., or Elko, Utah. These latter floras were thus assigned by Lesquereux at this time to the "Lignitic."

The thirteen species mentioned by Hayden, together with the following six species, said to have been found in Middle Park, viz: *Salvinia cyclophylla* Lx., *Castanea intermedia* Lx., *Myrica insignis* Lx., *Podogonium americanum* Lx., *Sequoia Langsdorfii* Brg.,

S. affinis Lx., are included by Lesquereux in the flora of the Green
River group, in his Monograph on the "Cretaceous and Tertiary
Floras." *

Most of these species are there merely enumerated with refer-
ences to the original descriptions in the Annual Reports for 1873
or 1874, or to the Monograph on the "Tertiary Flora."‡ On turn-
ing to the latter monograph, it is found that the "Habitat" of
several species of Hayden's list, originally described from Middle
Park, is here given as Florissant, on the basis of the same speci-
mens, and without explanation. In fact, Lesquereux places these
nineteen species in the Green River flora, among very numerous
specimens from Florissant and Elko, without any comment upon or
reference to the fact that the strata of Middle Park are considered
as Laramie by Hayden, and that other species described by him-
self from Middle Park localities are still retained in the Laramie
flora.

Most of the original specimens concerned are now preserved
in the National Museum, and an examination of them by the writer
shows that Lesquereux was quite right in classifying them with
the Florissant species, for they undoubtedly came from this local-
ity, and not from Middle Park. The volcanic shale or ash of
Florissant is very characteristic, and the specimens, some of which
are still labeled "Middle Park," are indistinguishable in matrix
from specimens of the same species collected more recently at
Florissant. It is clear that the wrong label was placed upon these
specimens soon after their collection, and they can be dismissed
from further consideration as not belonging to the flora of the
Middle Park beds.

The six species of fossil plants undoubtedly collected by the
Hayden party in the strata under discussion, and described by
Lesquereux, as already cited, are: *Populus arctica* Heer, *Aralio,*
notata Lx. (=*Platanus dubia* Lx.), *Laurus Brossiana* Lx.,
(= *Persea B.* Lx.) *Cinnamomum polymorphum* Lx., *Cissus lobato-*
crenata Lx., *Cornus impressa* Lx. Three other species, viz.:
Juglans thermalis, Lx., *J. rugosa* Lx. and *Ficus lanceolata* Heer,
are described in the "Tertiary Flora" as occurring at definite

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* Monograph VIII., U. S. G. and G. S., pp. 127-217, 1883.
‡ Monograph VII., U. S. G. and G. S., 1878.

localities in Middle Park.   The first two are seemingly authentic, the last less certainly so.

Mr. Cannon obtained fossil leaves at several localities.   One of the most noteworthy horizons is very near the top of the dark breccia series, on the north bank of Grand River at Potato Hill Gap in a fine-grained tuff above the main breccia, but below some dark conglomerates.   Ferns are most numerous in this bed, which was explored at a point near the river, and at another above the wagon road.

A short distance east of the above locality, west of Glenn Sheriff's ranch, and near the old exploration shaft for coal, a dark shale in the transition series between the dark andesitic beds and the light-colored quartzose strata yielded a number of species.

Another horizon from which Mr. Cannon obtained leaves is the bench at about 800 feet above the river, on the south side of Mt. Bross.   He also found leaves in the debris below this level, and this hard, whitish tuff material is much like that of several specimens collected by the Hayden party on Mt. Bross.

The writer found fossil leaves most abundantly at the point mentioned (page 23) in the "spoon," between the forks of Kinney Creek, at about 2,200 feet geologically above the breccia.   This horizon is nearly the same as that of the summit of Mt. Bross, where a few leaves were found.

These newer collections have been identified by Messrs. Lester F. Ward and F. H. Knowlton.   But the value of these plants in indicating a close correlation of the Middle Park beds cannot now be correctly estimated, for the reason that so much uncertainty exists concerning the actual occurrence of many of the species which have hitherto been assigned to the Laramie, that a revision of the entire flora is necessary before further deductions from tables of distribution can be trusted.   Such a revision is now in progress by Messrs. Ward and Knowlton.   It is shown that errors like that above pointed out are numerous in the publications of Lesquereux, though seldom involving so many species. Further, it appears that statements of localities are often so general that, as in the case of the Golden Flora, it is impossible to tell whether particular specimens came from the upper or lower parts of a section that may embrace both Laramie and Post-Laramie beds.

The revision of the Denver and allied floras by Mr. Knowlton has very unfortunately been discontinued by failure of Congress to support the paleontological work of the Geological Survey. But the list of plants given below was made up by Mr. Knowlton in August last, and contains only those species which, in the light of the various examinations made by both of us, are believed to occur in the Middle Park beds. Those species collected by the Hayden party are marked by an asterisk (*); those of the recent collections by a dagger (†):

1. ?†*Pteris pennæformis* Heer,
2. †*P. pseudopennæformis* Lx. [D]
3. †*Asplenium erosum* Lx. sp. [D]
      (*Peteris erosr* Lx.)
4. †*Aspidium polypodioides* (Ett.) Heer.
      (*Lastræa polypodioides.*)
5. †*Woodwardia latiloba* Lx. [D]
6. †*Anemia subcretacea* (Sap.) Gard. & Ett. [D]
      (*Gymnogramme Haydeni* Lx.)
7. †*Sabalites Campbellii* Newb'y.
8. **Populus arctica* Heer.
9. *†*Juglans rugosa* Lx. [D]
10. *†*J. thermalis* Lx.
11. †*J. denticulata* Heer.
12. †*Platanus marginata* Lx. Heer. [D]
13. †*P. Raynoldsii* Newb'y. [D]
14. †*Ficus spectabilis* Lx. [D]
15. **Laurus Brossiana* Lx.
16. †*Cinnamomum polymorphum* Al. Br.
17. **Cornus impressa* Lx.
18. †*C. Studeri* Heer [D]
19. ?†*C. acuminata* Newb'y.
20. ?**Aralia notata* Lx.
21. ?†*Leguminosites arachioides* Lx.
22. †*Cinchonidium ovale* Lx.
23. *†*Cissus lobato-crenata* Lx. [D]
24. †*Vitis (Cissus) Olriki* Heer.
25. †*V. (Cissus) tricuspidata* Heer.
26. †*Rhamnus Goldianus* Lx. [D]
27. †*R. Cleburni* Lx. [D]
28. †*Zizyphus Meekii* Lx.

Four of these determinations are regarded as more or less question-ble (?), and three species are as yet unknown elsewhere,

viz.: *Junglans thermalis, Leurus Brossiana* and *Cornus impressa.* Deducting these, there remain twenty-one species of satisfactory determination which are known elsewhere.

An extended discussion as to the distribution of these fossil plants does not seem to the writer to be warranted at the present time, because the much needed revision of the floras concerned has not progressed sufficiently. However, the examination of the Denver flora by Mr. Knowlton, though incomplete, makes it probable that at least twelve of these species occur in the Denver beds at Golden. These have been indicated by the letter D in brackets [D], placed after the species in the list. It does not seem probable that an equal number occur in the true Laramie.

A consideration of the evidence presented leads the writer to the conclusion that the formation in the Middle Park assigned to the Laramie by the geologists of the Hayden Survey is the equivalent of the Denver beds, at least in as far as it has been examined. The upper portion may possibly belong to later formations. There is no positive evidence as yet discovered that the Laramie proper ever existed in the area of Middle Park. But the unconformity described is the result of folding followed by erosion which may have removed the Laramie wholly or in part, and the writer is inclined to believe that remnants of the Laramie will yet be found at some points.

The unconformable relationships, lithological constitution, and fossil flora all indicate the equivalence of the Middle Park and Denver beds. No evidence seems to indicate any other correlation.

It is not the intention of the writer to discuss in this article the question as to whether the Denver and allied formations belong to the Cretaceous, or to the Eocene Tertiary. He cannot submit, at present, any evidence of great importance bearing upon this point beyond what is contained in the article already referred to.* But it seems clear that the details that have been given concerning the Middle Park formation, afford strong support to the position taken by R. C. Hills† and the writer, to the effect that there

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*Post-Laramie Deposits of Colorado. Amer. Jour. Sci., Vol. XLIV. pp. 19-42, July, 1892.
†Orographic and Structural Features of Rocky Mountain Geology, Proc. Colo. Sci. Soc., Vol. III., p. 397.

in a group of formations which must be separated from the Lara-
mie in the interest of an appropriate chronology. And until
further evidence decides the question of their age, they may be
grouped as *Post-Laramie.*

It may be well to point out, in closing, that while no deposits
corresponding to the Arapahoe beds are known in Middle Park,
it is quite possible that they exist in North Park or still further
northward in Wyoming. And in this connection it is interesting
to note that the fossil floras of Carbon and Black Butte, Wyoming,
bear quite as close resemblance to the Denver flora as to that of
the Laramie proper. And the suggestion that the plant-bearing
beds of these two localities may possibly represent the deposits
contemporaneous with the erosion preceding the Middle Park
period, can hardly be called presumptuous in the present meager
state of information concerning them.

DISCUSSION.

Mr. R. C. Hills.—Few can appreciate better than myself the
value of the present contribution towards the solution of one of
the most interesting problems ever submitted to the students of
Rocky Mountain geology. Mr. Cross has succeeded in bringing
together a mass of facts having, in relation to this question, an
importance that can scarcely be overestimated.

I fully concur in his opinion that a revision of Laramie plants
and a more exhaustive study of the plants of the post-Laramie,
must of necessity precede a satisfactory comparison of the floras
of the two groups; though, so far as the facts can be credited, a
taxonomic difference is certainly foreshadowed. From my re-
membrance of the exposures near Hot Sulphur Springs, which I
visited years ago, I can testify to the existence of the Mt. Bross
unconformity; I may say that I regard the park depressions, situ-
ated as they are between two lines of intense post-Laramie move-
ment, as most likely to have been effected by the irregular subsi-
dence incident to this movement, or even by pronounced flexing,
or faulting, along pre-established lines of yielding, like the
Archæan ridge on Grand River below Mt. Bross. Under such
conditions, unconformity of post-Laramie beds with older sedi-
ments is to be expected, and the entire region may be considered

as exceptionally favorable for further study in the direction sug-
gested by the author's work. The probable extention of the beds
in question across the divide into North Park points to that local-
ity as likely to afford additional evidence of unconformity; while
the presence there of four thick seams of coal in what is presum-
ably the true Laramie, leads me to hope that the Middle Park
tuffs will be found to overlap in places the coal-bearing formation.

The red heulandite noted by Mr. Cross appears to be a con-
stant feature of the post-Laramie beds wherever they contain
tufaceous material. In Colorado, the small remnants at Canon
City are, I believe, the only exception. In Wyoming there is a
considerable development of loose grits, shales and soft, cavernous
sandstones between the recognized Laramie and the Wasatch
Eocene, but the several formations are not clearly defined, and
while it seems probable that the lignite-bearing strata at Black
Butte may belong to the basal member of the post-Laramie, I
question if the latter will range down far enough to include the
Carbon coal measures.

In conclusion, I desire publicly to express my thanks to the
author for his valuable paper.

A VOLUMETRIC METHOD FOR THE DETERMINATION OF LEAD.

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A technical method for the volumetric determination of lead, requiring but an ordinary amount of manipulation and occupying but a short space of time, has long been desired. A number of such methods have been suggested from time to time that promised more or less success. Of these there are but two which give results that are sufficiently accurate even for technical work, a brief outline of which will be given.

The first, which is the more practical, consists of neutralizing the nitrate of lead solution with ammonia or carbonate of ammonia, then adding an excess of acetate of sodium, and effecting the titration with a standardized solution of bichromate of potassium, the end reaction being indicated by a red coloration on bringing a drop of the lead solution in contact with a drop of a neutral solution of nitrate of silver. With careful manipulation this process yields good results. The greatest objection to be brought against the method is the uncertainty of the complete precipitation of the lead as the chromate if special precautions are not observed; the length of time involved in the process, and finally the ease with which the end point of the reaction can be overstepped.

The other method consists in precipitating the lead as carbonate from its solution, dissolving the precipitate in a measured quantity of normal nitric acid, to which then a neutral solution of sulphate of sodium is added. The sulphate of lead is precipitated and an equivalent amount of nitrate of sodium formed. The free nitric acid is subsequently determined with a normal

alkali solution, the lead percentage being calculated from the observed difference between the original amount of nitric acid used, and that found to be still free.   This plan requires the lead solution to be quite free from other elements, for which special precautions are necessary, and the length of time involved in the operations quite unfits the process for technical laboratories.

There is another method which has been lately described, which, while not volumetric, appears to offer great advantages over the preceding ones.   It consists in dissolving the sulphate of lead in an ammonium chloride solution, and precipitating the lead from the same in the metallic form by means of sheet aluminum, the lead finally being weighed.   The results appear to be very accurate.   The existing prejudice in technical laboratories against any method which involves a gravimetric determination will, however, operate as a bar against its general introduction if a method equally as accurate, or sufficiently so for all purposes, but volumetric, can be found.

The method about to be described is offered in the hope that it will meet the required conditions.   It is based on the formation of oxalate of lead, the decomposition of this salt by sulphuric acid, the determination of the liberated oxalic acid by permanganate of potassium solution, and the calculation of the lead percentage from the amount of oxalic acid with which it was originally combined.

It is not claimed that the idea on which this scheme is founded is new; in fact, a method along similar lines was proposed by Hempel, it being also stated by him that the results obtained were not absolutely accurate owing to the solubility of the oxalate of lead, which error, however could be reduced to within the limits of 1% by careful manipulation.

Fresenius, in discussing the solubility of oxalate of lead in water, states it to be distinctly greater than that of sulphate of lead, the solubility being still further increased by the presence of ammonia and ammonium salts.

A large number of experiments, instituted for the purpose of determining how the solubility of the oxalate of lead in water could be overcome, showed eventually that while it could not be entirely nullified, it could be reduced to its minimum by effecting the precipitation from an aqueous solution of the lead salt con-

taining about an equal bulk of 95% alcohol, only the slightest traces of lead remaining in solution under such a condition. Further experiments demonstrated that the precipitation was equally complete in the presence of free acetic acid which had been added to the alcoholic solution.

To a neutral solution of nitrate of lead measuring about 20 c.c., an equal volume of 95% alcohol and 5 c.c. strong acetic acid were added, and the lead precipitated by oxalic acid. The precipitate was filtered, well washed with hot water, and the filtrate saturated with sulphuretted hydrogen gas. A slight brown coloration was noticed in the course of time, but a precipitate of sulphide of lead failed to appear even after the solution had stood for several days.

This experiment was repeated a number of times with the same result, giving thus the assurance that the error due to the excessively slight solubility of the oxalate of lead, under conditions formulated, would not act as a disqualification of a technical method which was based on its use.

The oxalate of lead precipitated from cold alcoholic solutions comes down as a heavy white flocculent precipitate, which settles quickly on agitating the solution either by stiring or shaking, leaving the supernatant liquid perfectly clear. From heated solutions the precipitate falls as a brilliant crystalline powder. The composition of the salt is, however, in both cases the same, its formula being PbC_2O_4, containing 70·18% of lead.

The crystalline precipitate filters rapidly and is easily washed; the flocculent variety becomes reduced in bulk and crystalline on being washed with hot water. It is advisable to precipitate the oxalate from the solution which has been heated to 65° C.

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Pure lead having been prepared by reduction from c. p. acetate of lead, freeing the regulus from mechanical impurities and rolling it into thin sheet lead, varying quantities were weighed out to determine the accuracy of the method under consideration.

The standard of the permanganate of potassium solution containing 1·58 grams of $KMnO_4$ to the litre was established as follows:

3·65 grams c.p. crystallized oxalic acid were dissolved in 500 c.c. distilled water, from which three separate portions of 25 c.c. each were taken, 5 c.c. conc. sulphuric acid added, and the titration performed with the previously prepared permanganate solution. There were used in:

Experiment.	C.C. Oxalic Acid.	Containing grams. $C_2H_2O_4. 2 H_2O.$	c.c. KMnO$_4$
1	25	0·1825	58·30
2	25	0·1825	58·35
3	25	0·1825	58·40

Making an average of 58·35 c.c. of permanganate solution used, or 1 c.c. $KMnO_4$ solution $= 0·003127$ gram $C_2H_2O_4. 2 H_2O$, from which by the simple stoichometrical calculation,
1. c.c. $KMnO_4$ solution $= 0·00513$ gram lead, in the form of oxalate.

The standard being established, a portion of lead, was weighed out and dissolved in 3 c.c. conc. nitric acid, diluted with 10 c.c. hot water and carbonate of sodium in slight excess added. The precipitate was dissolved by the addition of 5 c.c. strong acetic acid, 20 c.c. of 95% alcohol being then added to the solution. This was heated to 65° C, and the lead precipitated by adding 10 c.c. of a saturated solution of oxalic acid, the precipitate, after settling, being filtered and thoroughly washed with hot water. The lead oxalate was now rinsed from the filter into a beaker, 50 c.c. hot water and 5 c.c. conc. sulphuric acid added. The solution was warmed to about 65° C and the titration on the freed oxalic acid effected. Ten determinations were made, the results being:

Exp. No.	Wt. of Pb. taken.	c.c. KMnO$_4$ used.	Wt. of Pb. found.	Per cent obtained.
4	0·05392 grams	10·4	0·05335	98·94
5	0·10150 "	19·7	0·10106	99·56
6	0·15266 "	29·7	0·15236	99·80
7	0·20878 "	40·6	0·20827	99·75
8	0·25540 "	49·7	0·25496	99·82
9	0·30016 "	58·5	0·30010	99·97
10	0·35204 "	68·6	0·35191	99·96
11	0·40290 "	78·4	0·40219	99·82
12	0·45252 "	88·2	0·45246	99·98
13	0·49876 "	97·1	0·49812	99·89

Average percentage obtained.....................99·749

In order to establish comparisons on a basis which would be

of greater value, in that the determinations would be made under conditions necessary in the carrying out of the method on ores and metallurgical products, another series of experiments was instituted, the lead taken for the analysis being brought into the solution, and reconverted into metallic lead, from which point on the process was as above described.

The precipitation of metallic lead from hydrochloric acid solutions was found to be easily, as well as completely effected by means of pure granulated zinc, the article used having been made by Merk, the granules being of a diameter small enough to allow them to pass through a screen containing 30 meshes to the linear inch.   Investigation proved it to be free from lead.

Dilute hydrochloric acid has no action whatever on metallic lead, and even boiling concentrated hydrochloric acid scarcely attacks it.   From dilute solutions of pure sulphate of lead in hydrochloric acid granulated zinc precipitates the lead quickly as a sponge, which is easily washed.

The lead taken for the following experiments was dissolved in 5 c.c. conc. nitric acid, 10 c.c. conc. sulphuric acid added, and evaporated until the sulphuric acid fumes appeared.   To the mass, when cool, water was added and the sulphate of lead filtered off; washed first with hot water acidified with sulphuric acid, and finally with hot water alone.   The sulphate of lead was then rinsed off the filter into a beaker, 3 c.c. conc. hydrochloric acid added, and enough water to bring the bulk to about 100 c.c.   The solution was boiled until the whole of the sulphate of lead was dissolved and two grams of pure granulated zinc added.   After an action of five minutes, an additional 0·50 gram of zinc was introduced and the solution again brought to the boiling point when 10 c.c. more of conc. hydrochloric acid were added.   In a few minutes all of the zinc had dissolved.   The solution was decanted from the lead sponge, the latter washed, re-dissolved in nitric acid and the precipitation as oxalate made as before described.   The results were:

Exp. No.	Wt. of Pb. taken.	c.c. KMnO$_4$ used.	Wt. of Pb. found.	Per cent obtained.
14	0·22150 grams	42·9	0·22007	99·76
15	0·21134 "	40·9	0·20981	99·32
16	0·20756 "	40·2	0·20632	99·39
17	0·16683 "	32·5	0.16672	99·94

Average percentage obtained.......................99·60

It has been mentioned that when pure sulphate of lead in hydrochloric acid solutions is precipitated with granulated zinc it comes down in a coherent, spongy mass. This is, however, not the case when certain impurities are associated with the precipitate; notably bismuth, a not uncommon constituent of our Western ores.

When the sulphate of lead is impure, the precipitated lead comes down in separate pieces which are with difficulty made to cohere, or the complete precipitation may even be prevented. The presence of bismuth especially is likely to prove vexatious and vitiate correct results if proper precautions for its total elimination from the sulphate of lead are not taken. The deportment of bismuth in solutions is so interesting that a mention of its behavior, where it exists as sulphate, may be of interest.

L. Laurent observes that there exist two sulphates of bismuth the one soluble and the other insoluble in water. If bismuth be dissolved in boiling nitric acid and sulphuric acid added to the solution, there is at times an abundant precipitate produced, and at others none whatever. The precipitate may be easily soluble in small quantities of water and again remain entirely insoluble, no matter how large an amount of water be used. These phenomena are dependent upon the relative amounts of free sulphuric acid present when the sulphate of bismuth is formed, and the temperature of the solution. If sulphuric acid be added to a cold solution of nitrate of bismuth, care being taken to prevent the mixture from becoming heated, no precipitate will be produced. If an excess of sulphuric acid should have been added, a sulphate of bismuth will be deposited in crystalline needles, which is scarcely soluble in sulphuric acid, but extremely so in water. If, however, a solution of this salt be heated, whether the quantity of water be large or small, a sulphate of bismuth will again be *gradually* precipitated which is insoluble in either hot or cold water, even if a considerable quantity of sulphuric acid should have been added.

I have found that the difficulty in regard to effecting a complete solution of bismuth may be obviated if, in the treatment of ores and metallurgical products, a large excess of sulphuric acid is added to the nitric acid solution, so that, when the evaporation takes place and the sulphuric acid fumes appear, the mass will still

be in a fluid and not in a pasty condition. If the mixture is then allowed to cool, and cold water added gradually to prevent heating, all of the bismuth goes into solution and remains so for a sufficient length of time to allow a filtration and separation from the sulphate of lead to be effected.

Another impurity not unlikely to contaminate the sulphate of lead, if sufficient excess of sulphuric acid is not added, is antimony. Such antimony would also be reduced to the metallic state in conjunction with the lead by the zinc. However, in re-effecting the solution of the lead by nitric acid, the antimony would remain as the insoluble oxide and thus be eliminated.

The following experiments demonstrate that even considerable quantities of bismuth and antimony, when originally present do not essentially affect the accuracy of the process. Five portions of lead were weighed out, and to these, severally, 100 milligrams each of metallic antimony and bismuth were added:

Exp. No.	Wt. of Pb. taken.	c.c. KMnO₄ used.	Wt. of Pb. found.	Per cent obtained.
18	215·44 mgs.	41·9	214·94 mgs.	99·76
19	232·21 "	45·1	231·36 "	99·63
20	258·58 "	50·1	257·01 "	99·38
21	244·50 "	47·6	244·18 "	99.86
22	250·74 "	48·5	248·80 "	99·22

Average percentage obtained......................99·57

In ordinary practice such combinations as given in the experiments just noted are hardly likely to be met with, and the results obtained are an ample demonstration of the sufficient accuracy of the method for all technical purposes.

In the analysis of ores and furnace products the following plan of operation has been found most suitable:

Place 1·0 gram or 0·50 gram, according to richness of the material, in a four-inch casserole; add 15 c.c. conc. nitric acid and 15 c.c. conc. sulphuric acid; cover with watch glass and heat on a hot plate until the decomposition is effected, and the fumes of sulphuric acid appear. Remove and cool; when cool, gradually add about 50 c.c. of cold water, heat to boiling and immediately

filter. Wash well with boiling water slightly acidified with sul-phuric acid, and finally with plain hot water. Now rinse the in-soluble residue into a beaker of about 200 c.c. capacity, using not more than 50 c.c. water; add 5 c.c. conc. hydrochloric acid, cover with watch glass and boil briskly for five minutes. The sulphates of lead and lime pass into solution.

If much silica and sulphate of barium be present, it is well to filter and wash well with boiling water. If such filtration is un-dertaken, it must be done rapidly. Small amounts of silica do not interfere, but larger quantities prevent the subsequent pre-cipitation of the lead in one spongy mass.

Dilute the solution with water to about 100 c.c., keeping it hot, but not boiling. Now add two grams of granulated zinc. The lead begins immediately to be deposited as a metallic sponge. When the action of the acid on the zinc has apparently ceased, add an additional 0·50 gram. After five minutes the solution is again boiled for a few minutes and then 10 c.c. conc. hydrochloric acid added. This dissolves the remainder of the zinc very quickly, and when the reaction is completed the lead sponge will be found floating on the surface of the liquid. Decant solution, wash the lead sponge with cold water, and press it out flat with the finger. Dissolve it in 1 c.c. conc. nitric acid and 20 c.c. hot water. Add now a slight excess of carbonate of sodium (the salt is prefer-able to the solution), and re-dissolve the precipitated carbonate of lead by adding 5 c.c. strong acetic acid; add 20 c.c. of 95% alcohol, heat the solution to 65° C, and precipitate the lead with a satur-ated solution of pure crystallized oxalic acid. The lead comes down at once as a dense white crystalline precipitate. Stir briskly until the precipitate settles rapidly, leaving a perfectly clear supernatant liquid. Filter and wash precipitate three times with a hot mixture of alcohol and water (1 alcohol : 1 water), and then four times with hot water alone. (In washing the precipitate it is well to use a fine jet, keeping the stream on the filter and not al-lowing it to flow on the glass, as otherwise the precipitate is apt to creep on to the funnel, and thus occasion loss.) When thor-oughly washed the precipitate is rinsed into a flask or beaker with about 50 c.c. hot water, 5 c.c. conc. sulphuric acid added, and the oxalic acid determined by permanganate of potassium solution in the usual way.

The only precautions to be observed are those which have already been mentioned with reference to bismuth, and when large amounts of silica or sulphate of barium are present.

As the ratio of the atomic weight of lead to that of the combined oxalic acid is very high, any error occuring in the titration will be magnified. It is advisable, therefore, to use quite dilute solutions of permanganate of potassium, the strength of this being not greater than 1·58 grams $KMnO_4$: 1 litre, which will give a strength of solution,

<center>1 c.c.=about 50 milligrams of lead.</center>

The standard of the solution in terms of lead is obtained by multiplying the standard in terms of crystallized oxalic acid by 1·6428.

The time involved in the execution of the method on a single assay occupies from 35 to 40 minutes, and the carrying out of a number of assays simultaneously is easily feasible.

The following results indicate what concordance can be obtained by the method:

Exp. No.

23	Broken Hill ore......................................	27·61%—27·50%
24	Silver precipitate of leaching process......	28·86%—28·75%
25	Oxidized ore..............................	2·56%— 2·66%
26	Galena associated with pyrite and chalcopyrite..............................	22·25%—21·95%
27	Galena ore (gravimetric, 66·75% Pb.).............	66·58%—66·66%
28	Oxidized ore..............................,	41·04%—41·29%

NOTES ON THE GEOLOGY OF PALMER LAKE, COLO., AND THE PALÆOZOIC EXPOSURES ALONG THE FRONT RANGE.

BY. GEO. L. CANNON. JR.

INTRODCTION.

The writer has been frequently requested, especially by his students at the Rocky Mountain Chautauqua, to furnish some literature descriptive of the geological features of the vicinity of Palmer Lake. In publishing some notes on certain recently discovered Palæozoic exposures at this place, it seems wise to supply this demand by adding to these notes, a semi-popular account of the geology of the neighborhood.

The locality has been visited by a number of geologists, but, with the exception of some fragmentary statements in works that are inaccessible to the general public, their observations do not seem to have been published. The Hayden "Atlas of Colorado" gives a fair representation of the topography, but the coloring of the stratigraphical maps is in need of considerable revision. The Hayden Report for 1874 (pp. 36–37) gives a brief description of the general features of the Arkansas-Platte divide region.

The data for the following paper were gathered during brief intervals of the writer's duties as lecturer at the Rocky Mountain Chautauqua Assembly during the past season. Although necessarily incomplete they will add some items to the present knowledge of the formations at the base of the eastern foothills of the Front Range and, in the absence of other literature on the subject, will be of value to the laity as an introduction to the study of the ancient history of the summer home of a large portion of the residents of the cities of the plains.

TOPOGRAPHY.

The town of Palmer Lake (elevation 7,238 feet,) is situated at the mouth of North Monument Canyon, about 52 miles from Denver and 25 miles from Colorado Springs. Its name is taken from the beautiful sheet of water in the broad valley between Ben Lomond and the granite foothills of the Front Range.

A scarcely perceptible erosion ridge runs through the town, from the base of Mt. Thompson to the Arkansas-Platte divide— the beginning of the crest of that great tract of upland country that projects far out into the area of the great plains. Near the Rio Grande Pavillion, drops of rain separated by a few inches space will start on that long journey to the Gulf by widely diverging paths, some falling north into the Plum Creek drainage, and seeking the " Father of Waters " by the way of Palmer Lake, Plum Creek, the Platte and the Missouri rivers; while other drops fall southerly into Monument Creek which joins the Fontaine qui Bouille at Colorado Springs, this in turn, the Arkansas at Pueblo, which empties into the Mississippi 400 miles below the mouth of the Missouri River.

The views from this point are among the most beautiful in Colorado. To the west rise the precipitous walls of Mt. Hermon, Mt. Cannon, Chautauqua Crest and Mt. Thompson, towering 1,500 to 2,000 feet above the valley. To the east, the curious " Elephant Rock," Phœbe's Arch, the Lion Head and the castellated summit of Ben Lomond. Stretching southward is the broad, open valley of Monument Creek, with its far-reaching pine-clad mesas and frequent exposures of brilliantly-tinted rocks of fantastic forms. To the north lies Palmer Lake, and the valley of Plum Creek, filled with numerous buttes, mesas and flat-topped ridges separated by gentle, undulating valleys. The gentler slopes are carpeted with a growth of silvery-green herbage, that contrast admirably with clumps of oak brush and dark pine forests, and with the warmer tints of the sandstone and granite exposures. In early summer the hill sides are often a mass of purple-blue, or gold from the acres of abundant mountain flowers. The scenery of this vicinity differs from that of other points along the foothills, in the substitution of mesas and buttes for the usual hogback configuration.

Considerable confusion exists concerning the names given to points of topographic interest, the lake itself having borne the various names of "Palmer's Notch," "Divide," "Lake Station," "Weissport," "Loch Katrine," and finally "Palmer Lake." It is to be greatly regretted that the elaborate system of poetic Scottish names once given to all of the prominent points in the neighborhood has been forgotten, Ben Lomond being the only peak that is known by its old name. The names "Mt. Hermon," "Chautauqua Crest," "Mt. Thompson," "Mt. Cannon," "White Ridge," "Pyramid Butte," etc., having been in general use for some time, especially among the large number of attendants at the Chautauqua Assembly, will be used in this paper in preference to the now obsolete terms.

GENERAL GEOLOGY.

The most prominent features of the local geology are, the general absence of the varied series of the typical foothills sections of Morrison, Canon City and Manitou, and the general covering of the older deposits by massive sheets of the Monument Creek sandstones. The whole divide country is a labyrinth of mesas, buttes and curious monuments, carved out of the freely resisting sandstones and gravels. The resident of Palmer Lake is prevented by the overlapping sheets of the Monument Creek measures from gaining access to the deeply-buried stores of coal, petroleum, lime, gypsum, fire-clay and building stone of the other foothills localities. The geological student is deprived by the same means of a wealth of fossil vegetation and extraordinary animal forms such as are found at Golden, Morrison and Canon City.

A trip of a few miles,will however, place the students in some of the most wonderful geological fairy lands of the West—the renowned localities of Perry and Monument parks. In the first named locality, a fairly complete record of the history of the earth's crust can be found and made to supply the deficiencies of the Palmer Lake Section.

DETAILED GEOLOGY.

ARCHÆAN ERA.

The oldest rocks in the neighborhood are the granite masses forming the mountains to the west. The front of the foothills is

composed of a bright-red coarsely-crystalline aggregate of red, orthoclase feldspar, and small amounts of milky quartz and black mica (biotite). Seams in this rock are strongly stained with the red and yellow oxides of iron (hematite and limonite.). Specimens of graphic granite (pegmatite) and poor crystals of smoky-quartz, commonly known as smoky-topaz, are occasionally found. The red feldspar is responsible for the ruddy hue of the soil at the foot of the mountains and for the brilliant tints of the fiery fronts of Mt. Hermon, Mt. Cannon, Chautauqua Crest and Mt. Thompson. The layers of red granite are highly inclined and a steep westerly dip may be seen in Fern Canyon—the deep ravine through which South Monument Creek debouches from the mountains.

About half a mile from the mouth of the various canyons, the character of the granite changes to a pale flesh-colored rock of compact texture, that weathers into large concretionary masses. The headwaters of the mountain stream run through valleys in this concretionary granite, that present some very wierd scenery. Rocky Canyon, a branch of North Monument Canyon, is filled with masses of huge concretionary boulders that completely hide the mountain brook at the bottom of the ravine, Between these gigantic boulders are spaces of considerable size, one of which is know as the Ice Cave, from its low temperature permitting the formation of ice during a large portion of the year. These rounded masses often bear a remarkable resemblance to the debris from glacial morains. Cook Canyon exhibits some curious monuments, while the gigantic concretion at the head of Rocky Canyon known as Dome Rock, is a conspicuous feature in the landscape.

All of these granites were probably formed miles below the surface in the distant ages preceding the advent of life on the globe.

The mountains are somewhat fissured with dikes and veins, showing enough traces of metalliferous deposits to have caused a considerable amount of prospecting. The writer has yet to learn of the shipment of any ore from this district, or of the securing of any assay of over $35 to the ton. The chances are against the discovery of profitable metalliferous deposits in this vicinity.

Several iron springs have recently been discovered in South Monument Canyon and in the future may add considerably to the

many attractions of this place. No analyses of the water of these springs have yet been published.

The "Magic Spring" in the gap between Mt. Hermon and Mt. Cannon is a mountain rivulet of local origin, and has none of the distant or mysterious origin that has been attributed to it.

Veins of milky-quartz are not uncommon; one fifteen-foot vein of this kind on the slopes of Mt. Thompson, known as the "Fish Hawk lode," is frequently mistaken for a tent on the hillside.

<div style="text-align:center">PALÆZOIC ERA.</div>

A notable feature of the sedimentary series at the base of the Front Range is, in the general absence of Palæzoic formations. Considerable development of these measures occur at Perry Park, Manitou, Manitou Park and at Canon City, but it has been generally supposed that in the intervals between these points, the Palæzoic beds were removed by erosion before the deposition of the "Red-beds" of the Jura-Trias, or else that the shore line of the Colorado sea-coast during the Mesozoic Era was to the west of its position during the Palæzoic Era.

The writer's observations of the past season would lead him to believe that the overlapping of the Palæzoic beds by those of Neozoic time is not always as complete as has been supposed. That careful examination of the contact of the clastic rocks with the Archæan will show, in many places, small patches of Palæzoic rocks: and that at no distant geological date, the foothills were covered, in several places, with exposures of Carboniferous or Silurian beds that have since been removed.

Mr. Geo. H. Eldridge mentioned, in the Society's Proceedings for 1888, the discovery of Carboniferous fossils in the pebbles of the Arapahoe group, Conglomerate at Brighton, and of Silurian fossils in the basal conglomerate of the Dakota group. Prof. A. Lake mentions the discovery of a cup-coral in the beds of Green Mountain.

In his article on the Quaternary of the Denver basin, the writer mentioned the discovery of cherts and jaspers, found in both the ancient and modern gravels of the Platte River and in the glacio-natant drift deposits on hills about Denver, containing

poorly-preserved casts of corals, crinoids, tuberculoid annelids and brachipods. The supposition that these cherts were derived from the carboniferous exposures in Perry Park by continuous stream transformation, has been, in a measure, confirmed by find-ing these materials in all portions of stream beds between Denver and that point. The recent discovery of this material in the Mon-ument Creek sandstones, at points outside the direct drainage of the modern streams coming from Perry Park, e. g. in East Plum Creek and Cherry Creek Basins, suggests that the cherts in the ice-drift deposits south of the Platte may have been derived from other places in the divide region than Perry Park, and that the cherts imbedded in the Monument Creek sandstones, like the andesitic debris in the Denver beds, are relics of exposures of cer-tain beds that have long since been eroded.

The writer has found these fossiliferous cherts quite abundant in the debris arising from the decomposition of the lower portion of the Monument Creek beds, about Palmer Lake, and also in the Archæan debris in the talus at the foot of several of the foothills far above the level of the Monument Creek beds, and in stream-drift accumulating at the mouth of the canyons. In Glen Park, an observant person will detect chert fragments in the roads about the Auditorium and the Music Hall, where the light-brown soil has been formed in place from the decay of the lower part of the Monument Creek sandstones. The fragments found near the Mikado House and elsewhere in the granite debris, in the talus above the level of exposures of sandstone, were probably derived from a ledge of Carboniferous rock hidden in the talus, or else are the relics of some former outlets of the Monument Creek sand-stone similar to the outcrop west of Ben Lomond Ranch.

One chert, found in the Glen, contains a cast of a small Orthoceratite—a type that had not been previously noticed among the fossils of this region.

If further investigation shall confirm the suspected absence of these cherts from upper portions of the Monument Creek beds, i. e., the firm sandstones and conglomerates such as constitute the cap of Ben Lomond, it would seem probable that the ledges of Palæozoic rocks that occupied the sides of the foothills at the be-ginning of the Monument Creek epoch had disappeared before the formation of the cap-rock of Ben Lomond.

The size and abundance of the Carboniferous chert concretions in the old river-drift of Monument Creek, near Colorado College at Colorado Springs, would seem to indicate some abundant source of this material in the hills to the northwest of Colorado Springs; although no such exposure is indicated on the existing maps.

It may safely be predicted that the collection of notes concerning the distribution of these cherts may yield considerable information relative to the location of the shore-line of the Palæozoic seas and of the appearance of the foothills region at various geological times.

As the Indians used this stone in making arrow-points, frequently carrying it to places where it would not naturally occur, care must be taken or some misleading data will be gathered. It is uncertain whether certain Carboniferous cherts found to the west of the Platte, near Denver, indicate a former existence of Palæozic beds on the hills west of Denver or whether they have been carried to that point by the Indians. The north side of Lookout Point is strewn with fragments of several kinds of rocks that seem to differ from any of the Mesozoic series and which appear to belong to the Palæozoic series. Among them are a gray, compact limestone, a white or flesh-colored quartzitic sandstone and a brecciated mass of fragments of red and buff-colored sandstone containing occasional large rounded pebbles and seams of calcite. A deposit of the last named rock may be seen on the north side of Fern Canyon, where a depression in Chautauqua Crest runs down to the South Monument Creek. The rock rests unconformably on the granite. In searching for this exposure, some care should be taken not to confound it with the two prominent exposures of the Monument Creek beds farther down the stream.

Mesozoic Era.

Jura-Triassic Period.

A prominent object in the landscape to the south of Palmer Lake is the pinkish-red sandstone climbing the slopes of Mt. Cannon. At the "Courts," a mile and a half south of town, are some interesting exposures of the Triassic sandstones. The soft irregular bedded sandstones have been worn by atmospheric agencies into a multitude of fantastic forms, a minature Garden of the Gods.

The "Spiral Rock" and "Old Sublimity" are located a short distance from the "Courts."

From this locality to near West Plum Creek the "Red-beds" are generally concealed by the overlapping Monument Creek sandstones. It is probable, however, that some small exposures occur at several points, for instance, in the excavation made to secure earth for the Estamere House terrace and on the south bank of North Monument Creek, opposite the Rocklands Hotel. These sandstones were formed in comparatively quiet waters and owe the great irregularity of erosion forms to the irregularities in the cementation and hardening of the rock. Their sculpturing is due to no other agencies than we can now see in operation. The variety in color is due to the varying percentages of the red iron-oxide in the rock.

When these sandstones were being formed, the land surface of Colorado consisted of an archipelago of low islands surrounded by seas that stretched easterly and westerly for hundreds of miles. At this time the great dinosaurs in the Connecticut Valley were making their famous "footprints on the sands of time," the mammalian type of life was beginning to appear, and the giant Cryptogams of the Carboniferous Age were yielding place to the more modern conifers and cycads.

Cretaceous Period.

While the greater portion of Monument Creek Valley is covered by the Monument Creek beds as shown by the Hayden maps, it seems probable that larger areas are occupied by exposures of Mesozoic formations than is indicated on the map of the Colorado Atlas. The patch of indefinite color Sheet 12 near the location of the "Courts" must be taken to represent Triassic exposures. It is doubtful if the post-Cretaceous or Laramie beds have the extensive development on both sides of the divide as shown on this map, the exposures in Plum Creek Valley going no farther south than Raspberry Butte, near Larkspur.

Several discoveries of fossil oysters and other marine shells have been reported from the Montana Cretaceous beds near the town of Monument.

CENOZOIC ERA.

Tertiary Period.

The surface rocks, covering the greater portion of the divide,

are feebly-indurated conglomerates, gravels and sandstones of
Hayden's Monument Creek group. The greater portion of these
beds are practically horizontal, but near the foothills they are in-
clined at an angle of about ten degrees from horizontality. The
older beds having a much steeper inclination were evidently tilted
before the deposition of the recent beds. These beds possess so
little of general interest that they have received little or no serious
study, and the beds near Palmer Lake are among the least inter-
esting of the series. It seems probable that the beds at this point
do not represent the upper or the lower portions of the series. To
the east of Ben Lomond may be seen mesas whose upper beds
must occupy a higher level than the cap-rock of that mountain.
Nor is it easy to correlate these beds with those seen near Castle Rock.

A local division may be made of the Monument Creek beds
into two groups, the lower being composed of light-colored gravels
and imperfectly lithified sandstones, and the upper of darker col-
ored and more firmly cemented sandstones. Good exposures of
the former may be seen in the railroad cuttings near the lake and
along the roads about Glen Park, and the cap-rock of Ben Lomond
is an example of the other. The material composing these beds
was in all probability derived from the waste of the adjoining
granitic areas. As a rule, the feldspar has lost its dark color and
crystalline structure, and the mica particles are rarely observable.
Large pebbles of white quartz are a conspicuous feature of upper
beds. As previously mentioned, the Carboniferous cherts common
in the lower beds seem to be absent in the upper layers. Cross-
bedding and various irregularities of deposition and cementation
are characteristic features and account for the variety of the ero-
sion features of the region. The beds of rhyolitic tufa, commonly
known as lava or trachyte, do not seem to approach Palmer Lake
as closely as is indicated by the Hayden maps.

As most of the beds are too coarse to preserve many forms of
life, it is not strange that but little is known of the life of this
time. Some bones of an Oreodon-like animal, and the *Megacer-
atops Coloradoensis*, Cope, are supposed to have been obtained in
this region. These fossils, taken in connection with the slight
dip of the beds and the feeble lithification of the rocks, would seem
to indicate that the age of the Monument Creek beds was recent
Tertiary—either Miocene or Pliocene.

Quaternary Period.

Erosion Epoch.—The adjoining mountains do not seem to present evidence of having been occupied by glaciers, but to have been carved into their present forms by atmospheric agencies. The erosion of the divide region affords an excellent means of estimating the extent of the great erosion of the time when the northeastern states were covered by a continental mass of ice, similar to that of Greenland of to-day. All of the larger buttes and mesas were carved out of the horizontal Monument Creek sandstones during this epoch. The elevations mark the situation of the harder portions of the rock, and the valleys the more yielding portions. The outlier of sandstone to the west of Palmer Lake is composed of the same material as the cap-rock of Ben Lomond; the intervening mile-wide valley having been eroded during this time. A curious feature in the landscape is a detached portion of Ben Lomond that bears a marked resemblance to the outlines of an elephant, Phœbe's Arch forming the trunk and the head of the animal. To the south of this Elephant Rock is another detached portion known as the Lion's Head. Indian Cave on the south side of Ben Lomond is a deep crevice in the mountain, where the Indians are reputed to have hidden when pursued by the early settlers. The "Petrified Frog" near Phœbe's Arch, is another curious imitative form. "The Ship Rock," also known as the "Pagoda," is another monument of the same kind for whose preservation it is difficult to account.

Loessial Epoch.—It seems improbable that the great sheets of water which covered the plains and lower valleys of the divide during this epoch (Champlain?) reached this elevation. But on the summit of Ben Lomond are some large fragments of fresh, unchanged granite in an indentical state of preservation with the freshly broken rock on the opposite Mt. Thompson. It would seem a violent supposition to attribute the transportation of these fragments to the agency of floating ice, but that seems the least improbable agent of transportation. It is certainly a mystery as to the agent that could have carried stones thirty or more pounds in weight across a valley a mile wide and six to eight hundred feet deep, and this at an elevation of between 7,000 and 8,000 feet. In considering this phenomenon, it should be remembered that no

stones of this size and unchanged composition are found in the cap-rock of the mountain, that the material is too fresh to have been transported before Palmer Notch was formed, and that there are no signs of former glaciers in the adjoining mountains.

Terrace Epoch.—While the greater amount of carving out of the valleys was effected during the Erosion epoch, the minor details of sculpture are the products of quite recent time; various natural monuments having perhaps no greater antiquity than some human monumental structures.

The mouths of canyons are chocked with masses of boulders brought down by freshets and the bottoms of the valleys, away from the foothills, are filled with thick accumulations of sand and gravel, washed down from decaying hills of Monument Creek sandstone.

The poising of a lake on the summit of a divide between two streams seems somewhat remarkable, but can be readily explained. The drainage channel of the stream coming from the first canyon to the north of town, empties into the drainage channel, coming from Palmer Lake, within a few feet of the lake. Although generally a dry stream-course, overgrown by weeds and bushes, the boulders of unchanged granite testify to the violence of the torrents that sometimes sweep down its channel. This material mingles with that washed down from the overhanging slopes of Ben Lomond, and forms a dam sufficiently strong to resist the feeble erosion of the small catch-basin in which the lake is situated. The area of the lake has been considerably enlarged by increasing the embankment at its outlet and piping in water from the reservoir of the Palmer Lake Water Co., up North Monument Canyon. The fountain in the lake is of course produced in this manner. A portion of the water of the lake seeps through gravel and comes out into the Monument Creek drainage in a spring to the south of the D. & R. G. Pavilion.

An examination of the railway cuttings on both sides of the lake will show that there has been a slight folding of lower portions of the Monument Creek beds over an axis of uplift nearly identical in position with the crest of the divide near the Railroad Pavilion, an axial line nearly perpendicular to the trend of the foothills.

THE GEOLOGY OF DENVER AND VICINITY.

ADDRESS OF THE RETIRING PRESIDENT.

BY GEORGE L. CANNON, JR.

In retiring from the chair that I have occupied for the past year and for considerable periods during the two previous years, I desire to express my appreciation of the honor you have conferred upon me, and to return thanks for the hearty co-operation, and uniform courtesy that I have received from the members of this Society. I am under especial obligations to our Secretary, Mr. Franklin Guiterman, for many invaluable services rendered me, and whatever credit is due my administration of the affairs of the Society is largely attributable to his energy and executive abilities.

I desire to congratulate the Society on its present prosperous condition and on its bright promise for the coming years; on the recent large additions to our membership; on the strength and the diversity of the new elements thus introduced; on the formation of a strong branch of the Society at Pueblo; on important accessions to our library, with its recent catalogue and other improved facilities, and, finally, on securing the present luxurious quarters for our meetings.

The comparison of the publications of this Society with those of the older and larger societies of the eastern states, or of Europe, reflects great credit on our work. It is a source of much satisfaction to note the increasing demand for our "Proceedings" and, also, the frequent references to papers, read at our meetings, by numerous scientific and technical journals. Never has the work of the Society been so generally appreciated both at home and abroad as at the present time.

While it is true that our present success is largely due to the concentration of our energies in a few departments of scientific research, it is to be greatly regretted that we are still far from occupying our natural position as the Academy of Sciences of the Rocky Mountain region. Metallurgists, mining engineers, chemists and geologists find a congenial home in our association, but specialists in other equally important branches of science, notably in the biological sciences, find but little sympathy or appreciation of their work. As a rule, they do not care to co-operate with us preferring to work in connection with learned bodies of far distant localities. Unless proper action is taken by the Society, it is but a question of time when these neglected elements will be forced to form an independent organization which must prove a formidable rival, and necessarily diminish our resources. Our older members will readily recall how much our progress was impeded by the opposition of the few persons composing the so-called Colorado Historical Society, and can anticipate the difficulty of executing some of our long-cherished plans for the future, were we opposed by an active and popular society of natural history.

Your attention is also called to the increasing strength of the scientific associations connected with the prominent educational institutions at Golden, Boulder and at Colorado Springs. It is to our interest to have the energies of the talented men of the several faculties engaged in the work of our Society, rather than to have them dissipated in upbuilding rival societies of a local nature. The progress of scientific work in this state would be greatly facilitated by the concurrent action of several local sections of one central Academy of Sciences. A frequent cause of the death of the small local organization is the inability of the necessarily few working members to prepare enough papers of sufficient merit to keep up the general interest in the work The promising Denver Microscopical Society perished from this cause. Our proposed plan, of the interchange and duplicate reading of papers, prepared by the members of the several local sections, would do much to prolong the life of some of the weaker scientific associations of Colorado.

I would again emphasize the importance of forming, at the earliest possible date, the beginning of collections illustrating the natural history and economic resources of this state, both as a means of popularizing our work, and thereby securing needed legislative appropriations, and, securing the addition to our own collections of several important local collections, e. g. the Carter zoological collection of Breckenridge, and the collection now stored in the Chamber of Commerce Library.

It was my wish, as retiring president, to have followed the example of my predecessors in presenting, at the close of their terms, papers embodying the results of recent original research. Numerous requests, however, have been received asking this Society to publish, at the earliest possible date, a semi-popular account of the geology of the immediate vicinity of Denver. While a considerable literature on this subject is in existence, it is unfortunately too largely written in the mystic language of the scientific priesthood, and is published, as a rule, in rare, or generally inaccessible works. The people of Denver, especially our educators, have a right to demand from their leading scientific association some reasonable account of the ancient history of their homes, and I deem it my duty to sacrifice my personal interests to this popular demand. No further apology will therefore be necessary for the re-introduction of the matter already discussed at previous meetings of the Society, or for the elementary, semi-popular style of composition.

THE GEOLOGY OF DENVER.

There are a few districts that at first sight appear so devoid of objects of geological interest as the immediate vicinity of Denver. Gently undulating plains merge almost imperceptibly into the broad, shallow valleys of the Platte River and its tributaries. The plains are covered with a massive mantle of light-brown earth and the stream courses are generally filled with thick accumulations of sand and gravel. The Platte and its tributaries have carved but shallow trenches in the horizontal bed rocks of the plains; only the denuded tops of a few small knolls, an occasional exposure in the banks or beds of the creeks, or some artificial excavation

affords us an occasional glimpse of the formations underlying the city. There is but little to tell us of the miles of sandstone, clay and limestone beneath our feet, of the vast buried cemeteries of the ancient world, abounding in the remains of extraordinary monsters that rival the fabulous creations of classical or mediæval romancers. We would not dream that where the cactus and buffalo grass now draw but a scanty sustenance, has flourished a most luxuriant semi-tropical vegetation, and that "where now the long street roars hath been the stillness of the central sea."

Our present knowledge of the local geology has been obtained only after years of careful observation of every natural or artificial exposure. The few generalizations given below are the results of hundreds of observations of cellar excavations, irrigating ditches, brick pits and railway cuts; not to mention the natural exposures on hill-top or river bank. At first sight it would seem (to use the language of Colorado's most eminent geologist) that "the game was not worth the powder." "But the day of small things" is not to be despised, for the years of patient drudgery have been rewarded by securing to the inhabitants of the metropolis of the Rocky Mountains a fair knowledge of the wonderful pre-historic times of this portion of ancient Colorado. The scientific world has also been enriched by some discoveries of no little importance.

Although the geological records are not available locally for the inspection by the Denver student, Dame Nature has kindly supplied the deficiency by opening the stony volumes at no great distance from the city, and a short trip to the neighboring foot-hills will enable us to get as good a knowledge of the hidden beds as though we had sunk a shaft to the depth of two or more miles below the surface of the plains.

For hundreds of miles along the eastern front of the Rocky Mountains the formerly horizontal beds of the plains have been tilted up so that they now rest against the granite at a high angle to their former position, and we can walk over the upturned edges and peer into the pages of many of the chapters of geological history. The storms of countless centuries have eaten deep notches into the edges of these volumes and have thus exposed a greater surface of the records to our inspection.

The Denver student must visit either Morrison or Golden to acquire a knowledge of the deeply buried beds. The former locality is to be preferred, because at that point most of the formations have a typical development, while at Golden, owing to local causes, many beds do not attain anything like a normal development. To obtain a perfect knowledge of our local geology, visits should be made to both places, as certain formations that are well developed in one locality are wanting in the other.

MORRISON SECTION.

A twelve-mile ride from Denver will bring the student to this village, at the mouth of Bear Creek Canon, nestling under the shadows of Mount Morrison and protected from the storms of the plains by the huge rampart of the great Jura-Dakota hogback. The section cut through the upturned edges of the sedimentary formation by the corrosion of Bear Creek has always called forth the warmest expression of admiration from both geologists and artists. Few sections are so easily legible, show such a marked interdependence between the surface forms of relief and underlying rock character, or present such a wealth of warm coloring in rocks and soil.

Geological time is divided into five great eras, the Archæan, the Paleozoic, the Mesozoic, the Cenozoic and the Psychozoic. In relation to these are two important volumes of geological history open to our inspection in the Morrison section, viz.: the volume of the prehistoric geological ages—the Archæan Era— and the volume of the geological middle ages—the Mesozoic Era.

The colossal ridges that form the foot-hills to the west are composed of some twenty-five thousand feet of greatly folded and crumpled metamorphic rocks, principally granite, hornblendic and micaceous schists, seamed with numerous dikes and veins of quartz, feldspar and various eruptive rocks. Associated with these fissure formations are indications of various metals, but in no place in this vicinity has the amount of either base or precious metals equaled the cost of its extraction; nor is it probable that any deposits of minerals of economic importance will be found along the edge of the foot-hills, or that the various prospect holes will increase in richness as depth is gained. These rocks contain

many objects of interest to the mineralogist; beryl, fluorspar, rose and milky quartz, mica, epidote, feldspar, hornblende, calc-spar and coarse garnets. The metamorphic rocks of the mountains have not received sufficient detailed study to enable us to state to what portion of the Archæan Era they belong. No fossils have yet been detected. We may, however, safely say that they do not represent the original crust of the globe formed from cooling, and that a large portion may have been at one time sedimentary rock that was altered to its present condition while buried under thousands of feet of strata, subsequently deposited. These rocks may have been formed before life was introduced on the earth, or while it was as yet represented by only the lowest forms of animals or vegetables, the Protozoans or the Protophytes.

<p style="text-align:center;">PALEOZOIC ERA.</p>

In a typical section of the earth's crust, we expect to find the rocks of the Archæan Era covered by an extensive series of formations belonging to the Paleozoic Era, the division of time corresponding to the ancient or classical periods of human history.

In the sections near Denver, the Archæan rocks are covered unconformably by the red rocks of the Mesozoic Era, and we pass directly from the pre-historic times of geology to its middle ages.

The absence of Paleozoic measures along the foothills, from Platte Canon to near the Wyoming line, is due to one or both of the following causes: When the Paleozoic limestones, conglomerates, shales, or quartzites, were being formed in the shallow waters of other portions of the Rocky Mountain region, this neighborhood was elevated above sea level, and received few or no sedimentary deposits. It is possible that some Paleozoic deposits may have existed near Denver, but they were eroded before the red sandstones of the Jura-Trias were deposited. A few Carboniferous fossils found in pebbles composing the conglomerates of the Dakota and the Arapahoe epochs, indicate the former existence of some Paleozoic beds near the mountains west of Denver.

Our section is, therefore, deficient, lacking the records of those three great ages, the Silurian, the Devonian and the Carboniferous. The age of gigantic crustaceans, trilobites, brachiopods and crinoids; the age of enormous reptilian-fishes; and the age of

gigantic club-mosses and tree-ferns, all passed away, leaving scarcely a trace to indicate their existence in this region.

It is not uncommon to hear the coal fields of Colorado spoken of as belonging to the Carboniferous Age, and equivalent in time with the great coal fields of Pennsylvania, England and other portions of the world. This is great error, for, with a few unimportant exceptions, our coal beds were formed at the close of the next era, the Mesozoic.

During the Paleozoic Era, the Rocky Mountain region was occupied by an archipelago of islands, of variable size, bordered by wide seas toward the east and west, and the conditions favorable for the accumulation of the immense deposits of vegetable matter from which coal is formed were generally absent.

There is some reason to believe that the shore-line of the island nearest Denver was not far from the present contact of the sedimentary and metamorphic rocks, and that, at a short distance to the east, the plains, including Denver and vicinity, are underlaid by the usual series of Silurian-Carboniferous measures. The student, wishing to study the nearest Paleozoic exposures, should go to Perry Park, or to the more distant exposures at Manitou and Canon City.

The chert nodules found in the gravel-beds of both the ancient and modern Platte Rivers, and that occasionally contain poorly preserved brachiopods, crinoids, corals and annelid-tubes, were probably derived by direct, stream transportation, from the exposures at the head of Plum Creek, and the same material found in the ice-drift, on Capitol Hill, probably came from the same source by glacio-natant action.

MESOZOIC ERA.

The Mesozoic Era is divided into three periods—Triassic, Jurassic and Cretaceous—all of which are well represented in the Morrison section. With the exception of an uncomformity between the beds of the Niobrara and Ft. Pierre Epochs, the Mesozoic formations in this vicinity appear to be conformable throughout, and dip away from Mount Morrison at an average angle of 35° with the horizon.

For a long distance along our foothills, the lowest sedimentary formation is the famous "Red Beds" of the Rocky Mountains. As these beds form the beginning of the historic rocks of this neighborhood, great interest is attached to the determination of their age. But here, as elsewhere in America, the record is obscure, and it is difficult to separate the typical Triassic rocks from those of the preceding Permian Period or from the succeeding Jurassic Period. No fossils have been found in these rocks near Denver, and the testimony of the fossils from the nearest fossiliferous "Red Beds" is of a somewhat contradictory character. Some portions of the beds may be Permian, or even Carboniferous, but it seems highly probable that they are of Triassic age, and the equivalent of the famous foot-print-bearing rocks of the Connecticut Valley, and of the "New Red Sandstone" of England. I would emphasize the last clause, because it is not uncommon to hear these beds spoken of as the "Old Red Sandstones," i. e., the Devonian, and some costly experiments in boring for oil are supposed to have originated from this blunder. It should be said in this connection that, whatever may be true of the oil horizons of the trans-Mississippi States, the proper place to look for oil and natural gas in the Rocky Mountain region is above the Red Beds, if not above the Dakota sandstones.

The Red Beds are composed of some 1,500 feet of massive beds of red or pinkish sandstones and conglomerates. Being deposited in water affected by very strong currents, the composition and bedding of the formation is very irregular, and has given origin to the greatest variety of erosional forms and color effects. The world-renowned Garden of the Gods at Manitou, and the curious red rocks near Perry Park, Platte Canon and on Turkey Creek are the products of this irregularity of deposition. A conspicuous object in the Morrison landscape is the mass of ruddy ledges abutting against the base of Mount Morrison. This labyrinth was once known as "the Garden of the Angels," but the glowing hues were more suggestive of beings of another nature, and the name has been superseded by that of the "Garden of the Titans." These stony forms, indeed, suggest the ancient Titans struggling to escape from the miles of rock under which they were

buried, and to scale again the heights of the overhanging Olympus (Mt. Morrison). The rock is too coarse for building stone in this neighborhood, but further toward the south, at Perry Park and at Red Rock Canon, near Manitou, the quieter waters permitted the formation of the beautiful light red sandstones used in the construction of Denver buildings. The variety of red colors of the rocks is, of course, due to the different percentages of iron oxide, and indicates the general absence of organic matter in the waters in which these sandstones were deposited. When these beds were being laid down, Colorado was an archipelago in the land-locked ocean occupying the interior of the present North American continent. Mammalian and bird life was then at its inception; even the reptiles, although the "lords of creation," had not yet attained their highest development, and the reign of the pines and cycads was being established to the extinction of the giant cryptogamous forms that had ruled the forests of the previous Carboniferous Age.

The Red Beds are succeeded by a massive stratum of light-colored sandstone, that contains, in places, great quantities of small concretions of brown, iron-oxide (limonite). This ledge weathers into a somewhat prominent hog-back, with rounded outlines. The Indians frequently occupied this ridge for purposes of observation, and nearly everywhere along its trend arrow-points, and quantities of chipped flints, may be found, sometimes so abundant as to resemble the debris of a weathered conglomerate. The well known arrow-head manufactory at Apex[*] is at the base of one of these outcrops.

The upper portion of this bed was regarded by the writers of the Hayden Survey as marking the summit of the Triassic, but those of the present Geological Survey are disposed to include in Triassic some 600 feet of super-imposed strata—taking a twenty-foot stratum of pinkish siliceous sandstone as the division line between the Jurassic and Triassic Periods. In the absence of fossils, it is necessary to correlate the beds with fossiliferous beds of similar lithological structure a hundred or so miles away.

The upper six hundred feet of the Triassic strata consist of beds of fine-grained red sandstones, with thin bands of limestone

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Smithsonian Report, 1877, p. 237.

(formerly much worked to supply the rude lime-kilns of early days) with layers of bright, variegated clays and beds of gypsum. The gypsum deposit proved too thin to warrant working, and a sufficient supply could not be obtained to operate the old Morrison "plaster mill." A thin band of cherty limestone, containing vermillion cherts, fragments with faint traces of a radiate structure, occurs near the gypsum layer. The red sandstone that caps the the Triassic measures was formerly much used in Denver for building purposes, but is so highly siliceous as to be difficult to cut, and is also somewhat marred by alkaline spots.

<div align="center">JURASSIC PERIOD.</div>

The Jurassic measures, as limited by Mr. Eldridge, are not over 200 feet in thickness. Two-thirds of this thickness is composed of light-colored clays, known as the Atlantosaurus clays from the extraordinary fossil monsters found in their upper portion. Above this is a twenty foot bed of light brown sandstone sometimes filled with yellow pulverulent concretions of iron-oxide. This stratum has yielded a number of dinosaur bones and has hence been called the "Saurian Sandstone." The upper portion of the Jurassic formation consists of beds of variegated clays with thin layers of limestone.

The little village of Morrison is classic ground, for it was here that the first of the gigantic dinosaurs of the sub-order Sauropoda were discovered, and directly over the Morrison hotel may be seen the excavation from which the huge thigh bone of *Atlantosaurus immanis*, Marsh, was obtained; casts of which bone are to be seen in every prominent museum.

In 1877, Prof. A. Lakes, of the State School of Mines, and Capt. H. C. Beckwith, found the type species of the genus Atlantosaurus, (*A. montanus, Marsh,*) about two miles north of Morrison. This notable animal is probably the largest land animal known to the scientific world. It was an elephantine herbivorous dinosaur, bearing some resemblances to our modern crocodiles. Anatomists have differed as to the length of the animal but are now disposed to make an estimated length of eighty feet, the estimate of one hundred and twenty mentioned in Le Conte's geology is probably a gross exaggeration. Whatever is true as to the accuracy of

these determinations, it is certain that we took out bones that exceeded any reasonable belief. Ribs, measured along the curve of the bone, were about ten feet long and four inches thick. Some vertebræ were over a yard wide from the tip of one process to the other. Limb bones from five to ten inches wide were common. One thigh bone was some six feet, two inches long, and twenty-eight inches wide at its thickest end. This bone served as a seat for three men at our dinners on the dump of our mine. As the clay containing these bones dipped under a heavy ledge of "Saurian Sandstone" it was a matter of great expense and some danger to remove the scattered bones from their hiding places in the rock. Three times did heavy masses of debris fill up our workings. Prof. O. C. Marsh of Yale College employed a party of several men for nearly ten months in taking out the bones of the various animals that were found in several places along the hogback near Morrison. Several tons of bones were sent to the Peabody Museum, a large portion of which are on exhibition to visitors. The collection contained about a dozen new species, some of which are not only the type species of new genera but also of new sub-orders of the Dinosauria, and the information obtained from these specimens resulted in an important revision of the Dinosauria.

Two species of a distant relative of the Atlantosaurus belonged to the new genus *Apatosaurus* (*A. Ajax and A. laticollis*) and were animals at least fifty feet in length. *A. laticollis* had neck vertebræ over three and a half feet wide, implying a neck five or six feet wide. The *Diplodocus lacustris,* Marsh, was another herbivorous dinosaur perhaps about forty feet long. The above Dinosaurs are members of the sub-order Sauropoda (the lizard-footed dinosaurs) animals that walked erect on all four limbs and probably, rarely, if ever, taking the semi-erect position of the other members of this order.

The most extraordinary although not the largest dinosaurs we obtained were the new Stegosaurs—the plated or armored saurians—strange creatures some twenty-five feet long covered with great plates of bone. A crest of bony plates from two to three feet wide ran along the spinal column, terminating on the tail in pairs of formidable spines or horns some of which were two feet long.

The fore limbs were very short, and the animal must have maintained a semi-erect attitude using the anterior limbs for gathering food or in defending itself. The massive tail was used as a weapon of defense and also as the third leg of a tripod in sustaining the weight of the body. As strange as were the external characteristics, the internal structure was stranger still, for the brain cavity was exceedingly small, and a large brain-like expansion of the nervous cord in the sacrum must have been the seat of most of the nervous activity of the body. Not only did we find the largest known dinosaurs at Morrison, but also the smallest. The *Nanosaurus* was a bird-footed dinosaur, no larger than a cat.

In connection with the dinosaurian bones, we found the remains of various turtles and crocodiles. One crocodile's skull (*Diplosaurus*) was a genuine missing link having the skull of a modern crocodile with the teeth of his ancestors in the Triassic.

The discovery of similar bone deposits at Canon City and at Como, Wyoming, caused the abandonment of bone hunting at Morrison. Large portions of these monsters remain entombed in the heart of the hogback but it would cost thousands of dollars to remove any considerable portion of the skeleton. Two skeletons recently found near Golden and sent to Germany are said to have cost five thousand dollars to excavate and to reach that place.

CRETACEOUS PERIOD.

The Hayden survey divided the Cretaceous period into six groups or epochs, as follows: Dakota group (No. 1), Ft. Benton group (No. 2), Niobrara group (No. 3), Ft. Pierre group (No. 4), Fox Hills group (No. 5) and Laramie group (No. 6). These names are taken from western localities, where these formations have a typical development, and where they have received especial study. Difficulties having been experienced in distinguishing the Ft. Benton from the Niobrara, the two formations are now spoken of as one formation, under the name of the Colorado group, and a similar difficulty with the Ft. Pierre and Fox Hills beds resulted in the adoption of the term Montana group. The old terms, Ft. Benton, Niobrara, Fox Hills and Ft. Pierre, are still used as con-

venient designations for the upper and lower Colorado beds and the upper and lower Montana beds.

Dakota Epoch.—One of the most conspicuous features of the country along the eastern base of the Colorado range is a persistent ridge of hard, cream-colored sandstone. The eastern side of this sharp ridge has a uniform slope, corresponding with the dip of the sandstone forming the surface, while the western side, being composed of the softer Jurassic beds, is moulded into rounded and scolloped reliefs. The existence of this hogback is due to the protective influence of the hard Dakota sandstone; the softer Triassic and Cretaceous beds having worn away rapidly. This is separated from the foot-hills by a valley about half a mile wide, and from Green Mountain by a valley one mile wide. Both of these valleys are broken into smaller ones by the projection of various hard ledges of rock.

The greatest portion of the Dakota is composed of one or more massive beds of pale cream-colored sandstone, sometimes broken by bands of an excellent quality of fire-clay, the latter being extensively used in the manufacture of fire-brick, crucibles, etc. The sandstone splits readily into convenient slabs for paving purposes, and is extensively used throughout the western country for sidewalks and foundation walls. The sandstone is so strongly siliceous that it resists mechanical abrasion and chemical decomposition to an admirable degree, but the frequent stains of iron rust unfit it for a finishing stone. The iron stains give great variety to the flagstones in our Denver streets, and sometimes slabs are covered with iron stains that closely simulate vegetable forms; e. g., those on the walk leading to the main entrance of the High School. These stones are extensively ripple marked and occasionally bear the imprints of the feet of several species of small reptiles, varying in size from that of a rat to that of a fox. Several fine examples of the foot-prints may be seen on the walks about the High School grounds and elsewhere in the city. Foot-prints may also be found in the red Triassic flagstones used in our pavements.

The basal member of the Dakota is a bed of pebbles of quartz, jasper and cherts, cemented by such a firm silica cement that the pebble will break, rather than the cement. Between this con-

glomerate and the sandstone are a few feet of blackish shales, containing numerous leaf impressions of willow, aralia, buckthorn, sassafras, laurel, poplar, oak, myrtle, etc., with some species of a warmer climate, such as palm, fig and magnolia. A similar flora is also found in the sandstones above, and sometimes a few marine and brackish water shells are found, showing that although the Dakota beds, like the Jurassic, were of fresh-water origin, yet the sea was not far distant. The black shales have often been fruitlessly explored for coal. It should be remembered, in looking for coal near the city, that the prolific coal measures are always many hundred feet above the conspicuous Dakota sandstones.

Colorado Epoch.—The beds of this epoch may be divided into two series, the Ft. Benton and the Niobrara. The eastern slopes of the great Jura-Dakota hogback are buttressed by some four or five hundred feet of blackish, finely laminated shales of the Ft. Benton series. These shales contain quantities of fish scales and various poorly preserved casts of marine shells. The upper portion of the shales contain intercalations of limestone and are succeeded by a bed of limestone about forty feet thick, from which is obtained a large part of the limestone used in Denver as a flux and for various building purposes. This Niobrara limestone contains large quantities of fossil shells, principally of the genus *Inoceramus*, a distant relative of both the oyster and the clam. One species of this genus, the *Inoceramus deformis*, Meek, was as large as a saucer. The shells of these species are frequently covered by a crust of small oyster shells (*Ostrea congesta,* Conrad.) A rare fossil sometimes found at this point is the peculiar mollusk, *Radiolites Austinensis*, Roemer. The flattish shell so characteristic of this formation is the *Inoceramus labiatus*, Schloth. The limestone weathers into a small ridge, looking not unlike a railroad embankment.

Near the point of contact of the Dakota and Colorado beds indications of petroleum are frequently found, and in one place, near Turkey Creek, a considerable deposit of bituminous matter is found on the side of the hogback. Most of the prominent iron springs of the State occur at this point of contact. Two strong chalybeate springs are found near Morrison, one just outside the

Bear Creek water gap, near the site of the old Sanitarium, and the other at Rooney's Iron Spring Ranch, about a mile and a half north of Bear Creek. The Soda Lakes of Morrison are ponds of concentrated alkaline water, whose mineral salts have been leached out of the surrounding formation.

I have now given a description of the formations found on the north side of Bear Creek, near the village of Morrison. The Denver student desiring to continue the section should leave the banks of Bear Creek and go to the southwest end of Green Mountain, following one of the prominent arroyas running from this mountain, making a careful examination of the exposures on its banks.

Montana Epoch.—The Montana Epoch includes the two groups formerly known as Ft. Pierre and Fox Hills. While a considerable unconformity between the strata of this epoch and the siliceocalcareous shales that mark the close of the Niobrara has been noted by Mr. Eldridge, there is but little difference between the rocks or fossils of the two groups. The floor of the valley between the hog-backs is composed of some drab, shaly clays, with concretions of a grey, fossiliferous limestone. The thickness of these beds averages about 8,700 feet—nearly a mile and a half in thickness—of fine sediments deposited at the bottom of the sea. During this epoch the land surfaces of Colorado were submerged to greater depths than they had been for ages, and the deposits of these Cretaceous seas cover very large areas of Colorado; the deep sea waves having rolled for centuries over areas that are now from seven to eleven thousand feet above sea level. The Cretaceous period was characterized by profound depression, preceded and succeeded by shallower waters. Toward the end of the Montana epoch, the increasing arenaceous character of the clay-shales indicates the commencement of the draining off of the Mediterranean Ocean that for ages had separated the eastern and western halves of North America.

A great variety of marine shells are abundant throughout this series of beds; among them are numerous species of *Inoceramus* and a great variety of Cephalopods, ranging from the straight staff-like *Baculites* to the coiled *Ammonite*. The remains of the former species are often mistaken for "petrified snakes" or

"petrified fishes." The shells of the large *Haploscapha* are no mean rivals of the large *Tridaena* shells that ornament some of the Denver front yards. The Cretaceous measures of Kansas abound in a numerous and varied reptilian life that, for some unknown reason, seems to be but poorly represented in the beds of this State. It is, however, probable that many of the serpentine sea-lizards swam in the Colorado seas, and that the Colorado islands were inhabited by birds with teeth and by the great bat-winged Pterodactyls, some of which, perhaps, had a spread of wing, from tip to tip, of twenty-five feet

The economic features of the Montana are confined to furnishing a superior brick-clay, and afford the principal horizon of the oil of the western States.

Laramie Epoch.—The seas of the Montana Epoch were succeeded by brackish waters, and finally by great fresh-water swamps. The marine fossils are necessarily succeeded by land fossils, and by fossils differing greatly from those of the land fossil of earlier times. It was formerly thought that these changes marked the close of the Mesozoic Era, as the abundant fossil leaves bore a marked resemblance to the well-known European Tertiary flora. The discovery of vertebrate remains, the most delicate means of estimating the length of lapses and changes of time-divisions, showed that the fauna was still of typical Mesozoic character, with not a few Jurassic features. The conflicting testimony of these two kinds of fossils led to a great controversy as to the age of the western coal beds. The result of this conflict was, that the vegetable paleontologists were gradually obliged to yield ground to the vertebrate paleontologists; some of the steps in the compromises being to call the beds early Eocene—a transitional epoch, called the Post-Cretaceous—and finally, the noncommittal term, Laramie Group, was adopted. The discoveries of the present U. S. Geological Survey have reopened the question, and years must elapse before it will be finally settled.

The upper 100 feet of the Montana beds are occupied by a yellowish sandstone, containing numerous fossil sea-weeds and a variety of shells. This is succeeded by about two hundred feet of the basal sandstone of the Laramie, composed of clear, glassy quartz, and then come some 400 or 500 feet of clays, of various

colors, with nodules of iron-stone containing plant remains.   The Laramie beds, like many of the modern beds, are characterized by great variability, both laterally and vertically.

The coal found in the lower portion of the Laramie will occur in one locality in a number of seams of workable thickness, but which may diminish, in a mile or so, to mere streaks of carbonaceous matter.   Denver is undoubtedly underlaid by the Laramie coal measures, but it is not certain that if a shaft were sunk to the depth of fifteen hundred or two thousand feet the coal horizon would be penetrated where the coal seams would be sufficiently thick to pay for working.   It is needless to say that a coal vein at that depth could only be operated at great expense, both on account of raising the coal to the surface and the trouble from the water of the artesian basin.

The coal found near the foot-hills occurs in some variable beds in the basal sandstone, but out on the plains, to the east of Denver, it is found in the upper portion of the Laramie beds. The coal found near Denver is not, as a rule, a lignite, but approaches more to the condition of bituminous coal.   Detailed accounts of the coal beds of this and other portions of the State have been so extensively described by Mr. R. C. Hills, Prof. A. Lakes and Mr. G. H. Eldridge, that a further description here seems unnecessary.

The harder sandstones, at the base of Laramie, form a series of prominent outcrops, that serve to indicate not only the location of the coal measures, but also the division-line between the sea-formed and the fresh-water beds, or between the Montana and the Laramie.

During the formation of the coal beds, the vicinity of Golden and Denver was occupied by great swamps and fresh-water lakes. The country was then near the sea level, and the Rocky Mountains were not to receive their present elevation for thousands of years to come.   A semi-tropical vegetation, like that of Southern Texas or California extended far north of Denver, and the sandstones about both of the above cities abound in fossil leaves of elm, oak, maple, beech, button-ball, birch, willow, walnut, hickory, redwood, hazel and poplar, associated with the leaves of a more tropical nature, such as magnolia, fig, cinnamon and palmetto.   Numerous

beautiful ferns and some fossil fruits, supposed to be those of a species of palm, are common fossils. About one hundred species of leaves have been found at Golden. A large proportion of them are new species, and many of them have been found in no other locality. The museums of this and other countries have been supplied, by Professors Lakes and Garvin, with magnificent suites of fossils from the beds of Golden. Some of the palm leaves are several feet in diameter. In a recent cutting near Golden, the side of the bank was covered with a number of beautiful impressions of palm leaves.

We have now completed our survey of the beds inaccessible to the student at Denver, but before we pass to a consideration of the surface beds we must first consider a few generalizations pertaining to those previously described. We have examined a thickness of over two miles of sedimentary beds of various origin, ranging from fresh-water to deep-sea deposits, from the conglomerates formed by violent currents to the shales laid down in quiet waters.

It may be noted that all these beds are practically conformable, having the same horizontal position on the plains, and the same angle of uplift along the abrupt fold at the foothills. Erosion unconformities, between various adjoining formations, probably occur to a greater extent than has so far been discovered.

Although this series of beds contains horizons of the greatest scientific interest, it is, with the exception of a few hundred feet, practically unfossiliferous; even the sea-formed beds, that usually yield such an abundance of fossils, have a comparatively meager fauna.

In speaking of the strata, hidden from sight at Denver, it should not be forgotten that distant views can be obtained of portions of the upturned edges of the belt of sedimentary beds. At sunset, the long, dark wall of the Jura-Dakota hogback broken by rifts of sunlit water-gaps, is a prominent object in the western landscape. In favorable lights, the Red Rocks, south of Turkey Creek, at the Garden of the Titans, and even the serrated vertical cliffs beyond Platte Canon become quite prominent. The jagged peaks near Boulder are composed of the Triassic Red Beds

that have here such a resistance to atmospheric degradation as to present nearly vertical faces, towering two thousand feet above the neighboring plains. The prominent double peak of that vicinity (South Boulder Peaks) indicates the position of a great fault in the Archæan and Triassic measures.

POST-LARAMIE FORMATIONS.

The Colorado Atlas, published by the Hayden Survey, depicts the plains of Eastern Colorado as covered by a sheet of Post-Cretaceous or Laramie strata; only the valleys of the Platte and the Arkansas rivers being free from a surface covering of these beds. Detailed examinations of a large portion of this area have shown that only a comparatively small portion is covered by this formation. The Rocky Mountain Division of the U. S. Geological Survey has demonstrated that the supposed Laramie beds, near Denver, must be regarded as separable into three distinct groups, distinguished from each other by prominent differences in lithological constitution, and by marked erosive unconformities. The two uppermost of these groups have been designated, respectively, "Arapahoe" and "Denver." In the earlier descriptions, the same groups bear the names "Willow Creek beds" and "Green Mountain beds," but to prevent confusion with formations of similar names in other sections of the country, it seemed desirable to use the above-mentioned names. The lower, coal-bearing portion, still bears the old name of "Laramie," and the two upper are collectively known as the "Post-Laramie beds."

Arapahoe Epoch.—No prominent exposures of the Arapahoe beds are to be found near the city, and it is somewhat questionable as to what extent the city is underlaid by this formation. At the junction of Sand Creek with the Platte River the Denver beds appear to rest directly on the Laramie, without the intervention of the beds that separate the two formations in other places, such as near the mouth of Clear Creek, about a mile to the north of the mouth of Sand Creek. Such records of the artesian well borings as are accessible to the writer afford but little information except to show that the characteristic Denver sediments disappear within less than one hundred feet from the surface, and that the bed of the Platte River must not be many feet from the contact with the next underlying formation, be it Arapahoe or Laramie.

The greatest areas of Arapahoe exposures are in the vicinity of Ralston and Willow Creeks, in Jefferson County.

The character and thickness of these beds differ greatly with the distance of the exposures from the mountains. Near the foothills, the basal conglomerate is remarkable for two peculiarities: First, the highly siliceous character of the pebbles. Jasper, flint, agate and chalcedony are characteristic of this formation, being quite rare in the other formations near Denver. Second, the conglomerate is composed of pebbles derived from all of the series of the subjacent Archæan and sedimentary rocks, and some fragments, for instance those containing the Carboniferous fossil *Beaumontia*, constitute the only evidence we have of the former existence of certain formations in the country to our west. The conglomerate varies in thickness, from over two hundred feet near the foothills to the merest attenuated edge on the plains, e. g., at Brighton. On the plains, the particles composing the debris are so reduced in size that the conglomerate is changed to a gritty sandstone.

The upper portion of the Arapahoe strata is a series of grey shales, having variable proportions of argillaceous and arenaceous constituents, and containing masses of a firm quartzitic sandstone, with occasional ironstones. The total thickness of the group where it has not been exposed to erosion varies from 600 to 1,200 feet.

But little is known of the flora of these beds. A quantity of fragmentary bones has been obtained by Mr. Geo. H. Eldridge, and a smaller quantity by the writer. Most of these bones belong to animals of the *Ceratopsidæ*, or horned Dinosaurs; a description of which will be given in the account of the life of the next epoch. It is believed that the species *Ceratops montanus*, Marsh, and *Triceratops galeus*, Marsh, were members of this fauna.

No deposits of economic value have been noted in this group.

Denver Epoch.—The plains near Denver are underlaid by a somewhat remarkable series of tuffs and conglomerates. These beds occupy basins eroded in the underlying Arapahoe and Laramie formations. Not only are the strata of the two groups separated by erosion unconformities, but they can also be easily distinguished by the nature of the materials composing the differ-

ent kinds of rocks. The Arapahoe is mainly composed of debris derived either directly from the Archæan formations or indirectly from the same source, from the waste of sedimentary formations formed from Archæan debris. The Denver beds, however, are, in their lower portions, composed almost exclusively of various kinds of andesitic lava debris; Archæan sediment, except in the upper portions, being quite rare. The absence of the latter material indicates that the streams, coming from the west, ran over bed-rocks of lava that effectually hid all of the older formations, and thus prevented the deposition of anything but andesitic debris in the beds then forming on the plains. The hundreds of feet in thickness of these andesitic tuffs indicates a still greater thickness of the original lava sheets and the great variety in the nature of the andesite would seem to testify to the outpouring of a number of separate lava flows. Probably the present foot-hills were cov-ered with lava, one or more thousand feet thick, for a distance of at least twenty-five miles along the foothills.

It is a singular fact that repeated searches through the moun-tains have failed to reveal any source of this great quantity of eruptive material, either of any remnant of the former sheet of lava, or of the tubes through which it came to the surface of the earth.

The area of the Denver beds is not over 400 square miles, and the formation is confined to the drainage of the South Platte River. Extensive deposits of similar nature, and apparently simi-lar age, have recently been found in other portions of the State, and, in time, will probably be considered as the equivalent of the Denver beds.

The mechanical structure of the Denver beds shows great variability, both laterally and vertically. Sections taken but a few hundred feet apart will often show a marked difference in the succession of the various kinds of rocks. A coarse conglomerate will occupy the place of a fine clay, and vice versa, cross-lami-ation and slight, erosion unconformities being exceedingly common.

Variations in the percentages of the mineral composition may also be noted. The Table Mountains at Golden, and the expos-ures near Denver and on Bear Creek, are not far from the same

geological horizon. While the Table-Mountain exposures are remarkably free from Archæan debris, those on Bear Creek contain as high as 25% or over of that material. The sandstones near Denver will, in nearly every case, show, on close inspection, small particles of quartz and feldspar. It is possible that some elevated mass of land escaped the general lava deluge, and afforded the source of the Archæan material. On Green Mountain, where the total thickness of the Denver beds is displayed, the history of the removal of the lava sheets may be read. In the lower beds, granitic debris is conspicuously absent, but as we ascend in the series to the mountain top the percentage of andesite decreases and that of the Archæan increases gradually until, in the remarkable boulder masses crowning the summit, a fragment of andesite is a rarity. This last formation contains a considerable amount of the harder sedimentary rocks of the adjoining hog-back region.

The strata of this group can be distinguished from the surrounding formations by their warm tints of brown, contrasting with the drab hues of the older beds, and the paler tints of the Pleistocene beds. The cement of the various beds is frequently composed of zeolitic minerals, that of the conglomerate showing conspicuously the crystalline structure of pinkish-red heulandite.

The disintegration of this rock would yield a soil of superior fertility; but, unfortunately, there are but few places where we have any considerable extent of residuary soil of this formation in this neighborhood.

Numerous exposures of Denver beds may be seen in the ravines in North Denver. The cellars near Blake and Wazee Streets cut into arenaceous clays of this group, and an erosion-ridge of this sandstone comes near the surface in Wyman's and McCollough's Additions on Capitol Hill.

A complete section of the whole formation is nowhere to be found except on the southwestern slopes of Green Mountain—the upper 900 feet being nowhere else preserved. The two mesas at Golden are composed of the lower portion of the beds, and owe their preservation from the enormous erosion to which the surrounding country has been subjected to the protection of several outflows of basaltic lava that welled up from a crack in the earth between Ralston and Van Bibber's creeks. This lava ran south-

erly toward Green Mountain, and a remnant of the attenuated edge of the sheet may be seen on the northeastern side of the mountain. The basaltic cliffs show in places a rude columnar structure, and on the western side of the north mesa are some curious erosion forms that were formerly supposed to be the craters from which the lava proceeded. In many places the basalt has an amygdaloidal structure; being filled with a large variety of interesting zeolitic minerals, such as analcite, chabazite, heulandite, laumontite, thompsonite, mesolite, stilbite, levynite and apophyllite.

The andesite pebbles in the conglomerate, near the top of Table Mountains, must not be confounded in origin with the basalt of the protecting cap-rock of the mesas.

In speaking of the Table Mountain zeolites, it should be remembered that the zeolite "ptilolite" recently discovered by Mr. Whitman Cross, was described from a small amount of material obtained in geodes in the andesite of the Denver beds.

The fossils of the Denver epoch are of the highest interest. The beds at Golden are noted for the variety and beauty of the forms of fossil leaves. Over a hundred species have been obtained from the so-called Laramie beds at this point. The writer gave in the account of the Laramie flora a brief general synopsis of forms found at Golden. Recent examination of the collections from this neighborhood show that over sixty species came not from the Laramie, but from the Post-Laramie beds. A large number of these are species new to science, and others have never been found elsewhere in the United States. Until a thorough reexamination and study shall have been made of the vegetable fossils from the Post-Cretaceous, and from the true Tertiary formations, the value of chronological estimates based on this class of evidence must be questioned.

The Denver beds contain considerable quantities of silicified woods that have not yet received proper attention. In some places the wood is replaced by a variety of zeolitic minerals, having lost all trace of internal structure. Toward the upper portion of the series, the silicification becomes more and more perfect, and in the large trunks in the boulder-conglomerate on Green Mountain, they are highly colored by iron or other minerals. The

variety of colors associated with the crystalline and botry-
oidal structure and veins of agate, affords some very beautiful
specimens.   The wood of Table Mountains was quite decayed
before petrifaction, and the borings made in the original fibre by
insects are not infrequently found.   Stumps of palms or palmet-
toes are quite common.   In several places a number of stumps
found within a small area indicates the location of a former palm
forest.   One of these locations is on the slopes above Manhattan
Beach.   In some wood found near Golden, the interior is changed
to a black or grey color, veined with blue and white chalcedony,
making specimens of great beauty.   Another similar variety,
showing a marked color-contrast between the line- and dot-
structure of the vascular bundles and the ground mass of the cel-
lular tissue, is sold to the lapidaries for fifty cents a pound.   The
woody bundles projecting from decaying wood and the aerial
rootlets near the base of the trunk are sometimes mistaken for
"petrified worms," "petrified vermicelli," etc.

The account of the discovery of the vertebrate remains of the
Denver group presents an interesting and instructive chapter in
geological history.   In 1887, the writer obtained from the Denver
beds a number of fragmentary bones that appeared to resemble
the bones he had previously obtained from the Jurassic beds, and
also a pair of large horn-cores, with attached cranial matter, that
bore marked resemblances to those of modern bovines.   These
bones were forwarded to a skilled anatomist, and the surmises as
to the nature of the bones were confirmed by the provisional de-
termination of the supposed reptilian remains as those of typical
Jurassic dinosaurs, and of the horn-cores as a new species of Bison
of late Pliocene type.   In making these determinations, little or
no attention seems to have been given to whatever may have been
written concerning the localities from which the bones had been
obtained, and the inference was drawn that they had been ob-
tained from well-known horizons near Denver, where their pres-
ence would not be remarkable.   It was, and is still, believed that
the dinosaurs became extinct at the close of the Cretaceous, and
that such modern types as the hollow-horned ruminants were not
perfected until late in the Tertiary.   The discovery of such oppo-
site chronological types in the same stratum, within a few feet

vertically and laterally, and in identical states of preservation, created a great anachronism. It would not be a greater absurdity to find a copy of the most recent street song inclosed in the inner wrapping of an undisturbed Egyptian mummy, as to find Jurassic dinosaurs and Pliocene bisons living together. It seemed incredible that the highly specialized Stegosaurs of the Jurassic could have survived all the changes of environment that occurred in the long ages separating the Jurassic from the Cenozoic; or that the highly specialized Bison should appear so long before the rest of the highly developed mammalian life, down in beds that were not regarded as later than the Eocene. It was an easy way out of the difficulty to assume that serious errors had been made in the collection of the specimens, or in the estimation of the age of the strata from which they were gathered. It was also assumed that the bones had been washed out from various formations of different ages and re-entombed in the Denver beds. To prevent the important testimony of these fossils being obscured by these plausible surmises, it became the duty of the writer to publish the article, "Tertiary Dinosauria Found in the Denver Beds," demonstrating that the bones belonged to animals that co-existed at the time of the formation of the Denver sandstones. The discussion was terminated in a most happy and unexpected manner by Mr. J. B. Hatcher's discovery in Converse County, Wyoming, of the skull of dinosaurs surmounted by bovine-like horns! This duplication of the horn systems of modern ruminants, occurring in the Reptilia, was an entirely unexpected feature that no anatomist could be expected to anticipate. Whatever may be ultimately proved as to the validity of the term "Tertiary Dinosauria," it can not be justly said that the writer's position was one of serious error in accepting as correct the determinations of America's best anatomists and statigraphical geologists, or that the conclusions founded on these premises were illogical. The continued discovery of numerous genera and species of extraordinary monsters in the supposed thoroughly explored districts of the eastern states, not to mention those of the west, prove the necessity for using the greatest caution in making any general statement based on our present fragmentary knowledge of either animal or vegetable fossils. Now is the time for the collection of

the data from which the scientist of the twentieth century can safely make his generalizations.

Mr. Hatcher's remarkable discoveries have afforded the material for the creation of a new order of the sub-class Dinosauria, the order *Ceratopsia* and its two families, *Ceratopsidæ* and *Nodosauridæ*. The family *Ceratopsidæ* includes several genera, prominent among them being the genera Triceratops (three-horned-face) and Ceratops (horned-face). One or more species of both genera have been found in both the Arapahoe and the Denver beds.

The Triceratops was one of the most extraordinary animals that ever lived. The skull of the largest specimens exceeded those of any known land animal and, with the exception of some whales, those of any water animals, living or extinct. The skull was from six to eight feet long and weighed, when taken from the rock, in the neighborhood of two thousand pounds. The most prominent feature of the head is an enormous pair of horn-cores situated directly over the orbits. The nose was armed with a formidable horn, and the sharp, horny beak could have been used as a weapon, as well as to cut off the foliage of the trees on which the animal fed. The back of the skull and the neck were protected by an enormous ruff of bone projecting from the back of the skull that also served as a place of attachment for the powerful muscles of the neck. Rows of small horns adorned the edges and other portions of the ruff. Notwithstanding the enormous size of the skull, its brain capacity was proportionately the smallest of any known vertebrate. In addition to the head armor, the body was probably protected by various spines and bony plates. The animal was some twenty-five feet long, and was probably a very stupid, clumsy, herbivorous reptile.

The Ceratops was a somewhat similar animal, probably of less specialized structure.

The Denver beds have also yielded specimens of other orders of the Dinosauria, both herbivorous and carnivorous. The *Ornithomimus velox*, Marsh, found by the writer near Green Mountain, was a bird-footed dinosaur about the size of a kangaroo. It was remarkable for the close similarity of its leg bones to those of modern birds. Several species of turtles and crocodiles; among

the latter specimens of fluted-toothed crocodiles. The writer obtained one tooth of a small mammal of one of the lower orders, similar to those found by Prof. Marsh, in the Laramie to the north of us. It was, unfortunately, lost before an identification could be secured.

A few imperfect fresh-water shells were obtained by Mr. T. W. Stanton, in a ravine near Cheltenham Heights. Among them were the species *Viviparus trochiformis, Goniobasis tenuicarinata,* and the undetermined species of *Corbicula, Physa* and *Unio.*

The age of the Denver beds is yet a matter of controversy; some regard them as a portion of the Laramie and others as a distinct formation. The faunas and floras of the Laramie, Arapahoe and Denver beds have not yet been clearly separated. It is believed, however, that thorough investigation will show a considerable difference in both fauna and flora. At the present time, the faunas must be regarded as having a decidedly Mesozoic aspect.

An important feature of the Denver basin is the artesian well system of Denver. Water is obtained in various strata from 250 to a little over 1,000 feet below the surface. About 600 feet would, perhaps, be near the average depth of the wells. The water-bearing strata appear to be in the Laramie measures. The water enters the upturned edges of folded strata of the shallow synclinal fold of which Denver is the center. It is a question whether most of the pressure comes from the water pressing down from both sides of the fold, or from pressure coming from the inability of the subterranean waters to penetrate the finer grained sandstones on the other side of the fold. The somewhat common theory of the water being contained in underground caverns instead of the interstices of a porous sandstone has no value. In the boring for water thin seams of lignite were encountered, and some supposed indications of petroleum have been observed; but no proof has been secured as to the probable proximity of either coal, oil or natural gas in any considerable quantities.

The water is, of course, free from organic impurities, but must not be regarded as either wonderfully free from mineral salts or, on the other hand, as having medicinal qualities from the small amount of mineral salts it contains. The pressure has seriously diminished since the wells were first struck in 1883. This

is due both to the improper casing of the wells and also to the reduction of pressure, due to the sinking of too many wells within a small area. It is not known whether the amount of water used is exceeding the supply, but, for theoretical reasons, this would seem to be the case.

CENOZOIC ERA.

TERTIARY PERIOD.

Monument Creek Epoch (Miocene).—A few miles south of Denver the Denver beds are covered by the Monument Creek formation—an extensive series of beds that have not been systematically examined. These beds are unconformable, both by their angles of dip and by erosion. The Denver beds have about the same angle of uplift as the rest of the series, while that of the Monument Creek beds does not exceed 15°. The greater portion of the Denver beds were eroded before the deposition of the succeeding beds. Some bones, supposed to have been obtained from the Monument Creek beds, would seem to confirm the generally supposed Tertiary age of the formation. The areas of these beds approach nearer to the city than is indicated on the Hayden maps. The debris from their decomposition affords the gravel filling the channels of Cherry and Sand creeks.

QUATERNARY PERIOD.

Post-Tertiary history may be divided into three provisional epochs, distinguished by three important changes—two periods of subaerial degredation separated by one of extensive deposition. These epochs may, perhaps, be the equivalents of the Glacial, the Champlain and the Terrace epochs of the eastern states; but it seems best, until a satisfactory correlation shall have been made, to use the provisional names given in the writer's article on the Quaternary of the Denver Basin: the Erosion epoch, the Loessial epoch, and the Terrace epoch.

Erosion Epoch.—The plains of Colorado and probably the foot-hills of the Front Range have never been covered by an extensive ice-sheet, similar to that which covered the northeastern states. The phenomena of typical alpine, or local, glaciers are easily observable in all the higher mountain masses of Colorado; as, for instance,

in the canyon above Georgetown. But there seems to be a notable absence of unequivocal signs of former glaciation in the lower foot-hills. Exception should, of course, be made in the case of the Ruxton Creek morainal deposits at Manitou. Subsequent to the deposition of the latest Pliocene beds, and previous to the deposition of the loess, a long period of subaerial degredation occurred. We cannot secure the date of the beginning of the erosion from the data of our vicinity, as probably both the Denver and Monument Creek beds were covered, to an unknown extent, with a series of feebly indurated and easily-eroded strata in which the erosion began. It may have had its origin in Tertiary time, or may have been confined to the Quaternary. The amount of this erosion must be estimated by the cubic mile. All the reliefs of the plains, and a large portion of those of the mountains, were carved out during this period, from the elevated plateau that formerly covered the region. Green and Table mountains, and the various hogback formations, were separated from each other and from the main mountains, and the mountain canons were deepened hundreds of feet, even if they did not originate during this time.

The top of Green Mountain has an elevation of nearly 7,000 feet, while the bed of the Platte River is somewhat less than a mile above sea level (5,280 feet). After making all due allowances for the diminished thickness of the beds due to distance from the source of the sediment, and to some possible tilting of the strata forming Green Mountain, it is clear that from 1,000 to 1,500 feet of horizontal strata have been removed from above the site of Denver, not to mention a thickness of hypothetical beds that may have covered the Green Mountain boulder-conglomerate. A thickness of Denver beds, equal to the height of Green Mountain above the surrounding country, has probably been eroded from the top of the Table Mountains, besides the excavation of the water-gap now separating the two portions of the formerly continuous mesa. Away from the mountains the erosion of the country kept pace with the corrosion of the streams, so that on the plains the slopes of the valley are of the gentlest nature possible; whatever abruptness of slopes that occur are the product of recent erosion. The Platte River has carved out a broad, shallow

valley, far exceeding the capacity of the modern stream, even at its greatest height, and the same is true of its tributaries.

Loessial Epoch. (River Drift.)—The wide drainage channels of the previous Erosion epoch are filled with accumulations of debris, which indicate that streams of much greater volume and velocity formally ran through the channels now occupied by the trivial streams of the plains. The depth and width of these deposits and the presence of stones far beyond the transporting power of the modern streams, all testify to the existence of a formerly greater precipitation.

The business portion of Denver occupies a terrace of stratified gravel that shows all the typical phenomena of a river deposit. This river-drift probably does not exceed twenty-five feet in thickness and is found on both sides of the Platte River, formerly making a continuous sheet from the North Denver bluffs to some point east of Broadway. Good sections of this drift may be seen in any cellar excavation from Market Street to Broadway. The river-drift of ancient Cherry Creek extends somewhat to the north of its present channel, being found in the cellar of the State Capitol and in several places in the hillsides to the south.

The greater part of the Platte River drift was derived directly from the mountains, but the streams from the south have brought much material from the headwaters of Plum Creek and from the Monument Creek beds such as the peculiar petrified woods; the Monument Creek sandstones and pinkish rhyolitic tufas; jasper and flints from the Arapahoe beds on Willow Creek, fossiliferous cherts from Perry Park, and smokey quartz crystals from the mountains south of Platte Canon.

All the gravel under the city contains appreciable amounts of gold, and in many places it is sufficiently rich to work by the panning process. The discovery of gold near the present City Hall drew some of the first settlers to the site of Denver.

A number of the molar teeth of elephants have been found in digging cellars in various portions of the city; that in the Chamber of Commerce Museum was found at Sixteenth and Larimer streets, and that in the High School collection at the corner of Seventeenth and California streets. Bones of a camel-like animal have also been obtained by the writer, in this deposit.

Loessial Epoch. (Loess).—The surface of the great plains, form-
ing the old-time "Great American Desert," is covered with a
massive sheet of recently formed material of a lossoid character.
It possesses throughout its extent remarkable uniformity of
characteristics, passing over beds of clay, limestone and sandstone
without much change in its chemical or physical nature. It is a
pale-brown, fine grained earth, neither a sand, a clay, nor yet a
marl, still, possessing characteristics of all three, and bearing a
general resemblance to the loess of the Rhine or of the bluffs
along the Mississippi River. It shows in many places a distinct,
nearly horizontal stratification that conforms to the inequalities of
the surface on which it rests. It often contains in its lower por-
tions small amounts of fine pebbles, and occasional rounded
stones, the size of a man's head or even larger, are found sus-
pended in the fine silt in the basal portions. The absence of the
characteristic wind-stratification, and the phenomena just noted,
would seem to argue against the theory that has been advanced
which supposes that this loess, like the loess of China, is an ex-
tensive wind deposit. It seems more probable that it was formed
from the vertical deposition of silt from the muddy waters of one
or more enormous bodies of fresh water. No sufficient theory
seems to have been advanced that will account for the retention
on plateaus, thousands of feet above the sea, of such great sheets
of water. It seems highly improbable that orographic move-
ments of sufficient magnitude to account for this phenomenon
have occured in such recent times. The disposition of the drift,
found suspended in the loess, near its contact with the underly-
ing sandstones, presents some curious phenomena. Bosses of
projecting sandstone of the highly eroded surfaces of the Denver
beds, are crowned with a conglomerate of Archæan pebbles and
cobblestones cemented together with a lime cement, while the
slopes of the hills above and below these sandstone knolls will
have few or no stones at the loess-sandstone contact. It would
seem as if these erratics had been transported from the shores of
the lake on floating ice, and on the melting of the ice dropped
through the yielding silt until they reached, or nearly reached
bed-rock.

The erratics on the west side of the Platte differ from those on the east side of the present stream. The metamorphics and basalts of the vicinity of Golden are not found on Capitol Hill, nor are the cherts, rhyolitic tufas, the peculiar Monument Creek petrified woods, etc., found on the hills south of the Platte, found on the other side of the stream. A difference in materials may be seen by comparing the ice drift deposits on the west side of the stream with each other. Deposits separated but a few miles will show a great difference as will also the country rocks of the two districts from which the drift was derived, e. g. the ice drift on Berkeley Bluffs, and that on the banks of Dry Creek near the town of Barnum as compared with the rock at Golden and Ralston.

The loess is quite porous and water from rains and from irrigating ditches sinks through the silt until it reaches bed-rock, following then the drainage channels cut in the sandstones by the erosive agencies of the former Erosion epoch. It is, therefore, necessary to sink through the entire thickness of the loess before a permanent supply of water can be found. On the plains east of Denver where the loess is from one to two hundred feet thick, the sinking of a well involves a serious expense. Happily the loess is easily cut with a spade and such wells require little or no brick or timber supports to the side.

The basal layer frequently contains large quantities of alkaline material that has been leached out from the layers of loess above and concentrated in the lower layers. Most of the brick manufactured in Denver is made from the earth of the loess formation. Its fragile nature and poor color are due to deficiencies in the amounts of its argillaceous and iron constituents.

When sufficiently irrigated it makes a fertile soil of nearly purely inorganic nature. The loess is poorly adapted for the preservation of organic remains and with the exception of bones, fossils are quite rare in the local loess, only a few fresh-water mollusks of the genera *Physa, Planorbis, Succinea, Pupa* and *Linnea* being found in the peculiar local deposit near the mouth of Dry Creek. The vertebrate remains include bones of one or more species of Proboscideans, a camel, numerous rodents, skeletons of snakes and frogs, and the bones of a horse, scarcely dis-

tinguishable from those of the modern horses introduced into America by the Europeans. Most of the rodent, snake and frog skeletons are probably modern intrusions. The alleged discovery of a portion of a human skull in the loess of the C. C. R. R. cutting near Argo, although frequently mentioned, in archeological works as a supposed relic of loessial man, is now regarded as a mistake. The discoverer, Mr. Thos. Belt, was on the verge of insanity when the discovery was made, dying in a fit of insanity a few weeks later. Dr. Pierce who examined this specimen could see nothing of a human aspect in it. Furthermore, the fragment was found too near the surface to preclude the possibility of recent intrusive burial by modern animals.

Terrace Epoch.—The conditions that permitted the formation of the great loessial bodies of water were changed and modern erosive agencies resumed their sway. Great amounts of loess and river drift have been removed from the river valleys, and the loess covering the hill-tops has also been largely removed. The surface features of the loess are in broad sympathy with the topography of the bed rock underneath. The modern streams have wandered somewhat from their ancient channels, and are now cutting down these channels below the stream beds of the Erosion epoch.

The characteristic peculiarity of a loessial formation to resist lateral erosion, and to preserve vertical faces for indefinite periods, receives illustration in all artificial cuttings, and especially in the bluffs on Sand Creek. In some place a tendency toward the formation of a series of terraces may be seen. The best example of this kind has now been destroyed in grading the streets of Denver. Formerly, in walking up Ffteenth street from the river, three different terraces would be observed, traces of which may still be seen. The first, from the immediate bank of the river to Wazee street, where slight exposures of sandstone may be found. From this point to the level of Larimer street one walks over the beveled edge of the river-drift terrace. This river-drift bench extends to Broadway, where it is covered by the loess terrace forming Capitol Hill. A ridge of sandstone running to the west of City Park forms something like a fourth terrace.

We have now completed our survey of the geology of Denver, but the account would be incomplete without directions for the

continuance of the study by practical field observation.   The following list of localities will be found of value.

A few Laramie exposures may be found north of Sand Creek, and the Arapahoe beds may be found in the ravines near the mouth of Clear Creek and near the new Westminster College. The bluffs on the south side of Clear Creek near Berkeley, and the ravines near the town of Barnum, afford the best accessible exposures of the Denver beds; the same places will show typical deposits of the ice-drift, peculiar to the western side of the Platte. In the brick yards near the Colfax bridge, an exposure of a peculiar local loess, containing the small mollusks above mentioned, is worthy of special attention.   The bluffs of Cherry Creek near the South Denver water-towers afford the best place to study the ice-drift of the eastern side of the Platte.   Any brick pit should be examined for fossil bones, and a study of any exposure of the ancient or modern gravels of the Platte River will offer much to interest the amateur collector.   Exposures of Denver sandstones should be carefully examined for fossil bones or leaves.   It is to be greatly regretted that the interesting ravines in North Denver have been filled up in grading for building lots.   Some of the classic spots mentioned in the older accounts of the geology of Denver are no longer accessible, e. g., the picturesque ravine near the old St. Luke's Hospital, on the Boulevard, that yielded so many leaves, bones, and shells, and in which the McCormic well, the first artesian well bored in Denver, was located.

LITERATURE.

The literature on the subject of our local geology is widely scattered, and is generally inaccessible; but it will be possible to mention some of the more important articles and works.   The reports of the U. S. Geological and Geographical Surveys of the Territories (commonly known as the Hayden Surveys) for 1873, '74, '75, and '76, contain many maps and sections of value and considerable text of more or less value.   It should be remembered that the Hayden surveys were more in the nature of geological reconnaisances than detailed surveys, and that they labored under peculiar discouragements from which the modern geologist is largely exempt.   It would, therefore, be unjust to expect from

these works that fullness and accuracy of detail that are seen in the
modern reports. The Colorado Atlas gives a good idea of the
stratigraphy and topography of the state as known before the '80s.
These works can be found in the larger libraries of Denver or can
be secured from any large dealer in old books. Prof. Arthur
Lakes, of the State School of Mines, has published a considerable
amount of semi-popular literature bearing on our local geology.
The Annual Report of the State School of Mines for 1889 gives
an excellent account of the general geology of the state. The
sections and views of the geology of Golden are so full that the
writer has preferred to refer the student to this work rather than
to lengthen this article by a detailed account of the geology of
Golden. Mr. Geo. H. Eldridge's able article on "Certain Peculiar
Structural Features in the Foothill Region of the Rocky Moun-
tains near Denver, Colorado," published by the Washington Philo-
sophical Society, June, 1890, is invaluable to students of the
geology of Golden.

Hall's History of Colorado, Vol. II, contains one of the best
general descriptions of Colorado geology, written by Colorado's
ablest stratigraphical geologist, Mr. R. C. Hills. Any copy of the
American Journal of Science for the past twenty years is liable to
contain considerable information descriptive of Prof. Marsh's dis-
coveries of the fossil monsters of this region; as well as articles
on other subjects pertaining to our local geology, e. g., Dr. Whit-
man Cross' article on the "Denver Tertiary Formation," the
"Post-Laramie Deposits of Colorado," and Mr. J. B. Hatcher's
"Ceratops Beds of Converse County, Wyoming." The Annual
Proceedings of the Colorado Scientific Society contain many arti-
cles of interest, especially the "Report on the Artesian Wells of
Denver," and the Proceedings for 1888, which contain the prelim-
inary reports of specialists engaged in the study of the Denver
Coal Basin made by the Rocky Mountain Division of the U. S.
Geological Survey, and published in advance of the formal mono-
graph on the subject. To those who have examined these prelim-
inary reports, the indebtedness of the writer to this source of
information will be readily apparent. A detailed acknowledge-
ment of the writer's indebtedness to various authors would have
unnecessarily burdened the text; but he wishes now to express his

great obligations to Messrs. S. F. Emmons, Whitman Cross, Geo. H. Eldridge, Prof. A. Lakes, Prof. O. C. Marsh, Dr. C. A. White, T. W. Stanton, R. C. Hills, A. Marvine, F. V. Hayden, L. Lesquereux and E. Blackburn for the information received from their writings, or from his personal association with these savants.

Although the writer enjoyed a considerable connection with the government surveys, this former connection must not be taken as in any way committing such surveys to any error of fact or opinion that may be found in these pages. This paper aims to be a semi-popular presentation of the information on the subject of our local geology gathered from a large number of works. The writer is alone responsible for any generalizations, or the acceptation of any questionable facts or theories that may not meet the approval of other specialists who have labored in this field.

Knowing that the magnificent monograph on the Denver Coal Basin (a work that for all time must serve as the basis of all future studies of this vicinity, and which, when published, will immediately relegate into obscurity any such trivial contribution as the paper before you) was in the hands of the government printing office, the writer has for years resisted the appeals of the members of the Society, of his brother educators and of his pupils, not to mention numerous requests from citizens of Denver, interested in the natural history of their homes, for a concise compilation of existing information on our local geology. The demand is, however, too urgent to be resisted any longer. If this provisional paper shall satisfy this demand until the appearance of the government reports, the writer will feel justified in sacrificing his personal interests in substituting a semi-popular version of old material for the more formal and original address usually expected from the retiring president of such an important body as the Colorado Scientific Society.

THE PRODUCTION OF COLUMBOUS AND TUNGS-
TOUS OXIDES IN FORMING COMPOUNDS
OF IRON AND TIN.

BY WILLIAM P. HEADDEN.

In an article on some compounds of iron and tin,[*] I made
reference to certain products as iron-bottoms[†] and stated that they
have the property of collecting, either mechanically or by solution,
certain other compounds which were subsequently obtained as
crystals, either wholly or in part. Some of these substances are
presented in this paper.

NECESSARY CONDITIONS FOR THE FORMATION OF THE CRYSTALS
—THEIR CONSTITUTION AND CHARACTERISTICS.

The collection and crystallization of these compounds seem to
depend upon the formation of the bottoms; for I found none of
these crystals in any reguli which had no bottom. Further, the
amount of insoluble matter in the iron-tin compounds was small,
not exceeding four-tenths of one per cent, and was not crystallized;
but in the iron bottoms it was always either crystalline or crystal-
lized, and amounted in one instance to about 20%, and in no case
less than 2%.

In the first batch of the iron-tin compounds, which was ob-
tained from the dross, I observed a single crystal, whose face was
apparently an equilateral triangle and which was then noted as
probably belonging to the regular system. It was in the regulus

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[*] Address of retiring President for 1891, Proc. Colo. Sci. Soc.
[†] The term " iron-bottom," as here used, indicates a very pure variety of " hard-head,"
an incidental product obtained in the reduction and smelting of tin ores.

yielding this material that I first observed the occurrence of an iron-bottom, and it was from this that the crystal was derived.

I have elsewhere briefly stated that the formation of these iron-bottoms is dependent upon two conditions, a high percentage of iron and the presence of carbon. What part, and how important a one, the latter may play in the formation of the substances which are the subjects of this study, is not clear.

The first iron-bottom analyzed afforded a large amount of a crystalline residue, which proved to be a compound of columbium. This lead me, as I had but a small quantity of alloy, to endeavor to obtain more of it by using a mixture of columbite, magnetite and stream-tin. The result of a great deal of labor in this direction was the production of a quantity of very hard tin, which gave, when manipulated in the usual manner, a large iron-bottom resembling those previously obtained. When this was dissolved in hydrochloric acid there remained a small quantity of a well crystallized substance. The crystals were octahedrons, the larger portion of which had smooth faces with sharp edges and angles, but in many cases the faces were depressed. These crystals suffered but little change when heated to bright redness for half an hour in an oven crucible, only the smallest particles being more than superficially oxidized.

The ignited crystals were not soluble in hydrochloric acid, but yielded a portion to this agent, giving a slightly yellow solution which was perfectly clear, but on being poured into a cold beaker solidified into a slightly-yellow, buttery mass, which was converted by the addition of water into a yellowish-white, curdy precipitate. This proved to be tungstic acid, being soluble in ammonium hydrate, and giving with zinc and hydrochloric acid, first a blue and then a brown solution.

The reaction is given so fully because I am not aware that more than one investigator, J. W. Mallet, has mentioned the solubility of tungstic oxide in any acid. The statement in Gmelin-Kraut's Handbuch der Chemie that "acids, even concentrated sulphuric acid, do not dissolve it," refers to tungstic acid. I understand both this and Mallet's statement to refer to the acid as precipitated from soluble tungstates. I have obtained such a solution in two instances.

The crystals remaining after treatment with hydrochloric acid were fused with potassium bisulphate, whereby they were oxidized. The acid which separated from the melt, upon solution in water, was soluble in ammonium carbonate, and the solution responded to the usual tests for tungsten. There was only a very small quantity of tin and iron present, so these crystals were essentially either crystallized tungsten, or a lower oxide of this metal. The tungsten was derived from the stream-tin. The quantity of these crystals was so small that no quantitative analysis of them was attempted; besides, they differed so palpably from those sought that it was evident that I would not attain my present object by pursuing this line of experimentation.

Since the form and color of these crystals indicated that they did not represent any known oxide of tungsten, while this was practically the only metal present and had been obtained in similar forms, it is probable that they were crystals of metallic tungsten.

On examining the iron-bottoms, obtained by remelting the dross from the liquation of tin, which had been reduced in batches of several pounds each, I found them to contain a varying portion which was insoluble in hydrochloric acid, difficultly soluble in nitric acid and also in aqua regia. When this insoluble portion was carefully washed, two parts, differing in general appearance and specific gravity could be recognized The residues from different bottoms did not resemble each other in all respects, but each of the three treated of in this paper contained some crystals having the same form. The bottoms themselves resembled one another in having a conchoidal fracture, a fine-grained texture and a light-gray color, which in the case of number one, inclined to brown and tarnished to slightly iridescent shades of this color but numbers two and three did not change on exposure to the air. They were very strongly magnetic and readily attacked by hydrochloric acid, evolving hydrogen smelling faintly of hydrocarbons, and yielding residues which were evidently mixed.

The total quantity of such residues obtained was small, and I was unwilling to sacrifice too large a portion of them in trying to obtain purer products which in the end would scarcely have been better than those used.

The specifically lighter portion was quite readily attacked by

warm nitric acid, and the whole of the residues from bottoms one and two were treated with this acid in order to obtain the heavier portion as pure as possible. The final residue obtained from the first bottom was a brownish-gray, very fine crystalline and wholly non-magnetic powder which under a magnification of 140 diameters appeared to consist for the most part of prisms. It was first ignited and then examined, when it was found to contain columbic acid with no tantallic acid, and only a small quantity of tungstic acid, with a very little iron and tin.

The residue from number two was washed with water and then treated with warm nitric acid. The resulting solution indicated the presence of one or more compounds rich in iron, with some tungsten and tin. The gray, crystalline residue was washed successively with cold concentrated nitric acid, aqua regia, water and alcohol, and gave when subsequently digested with a large excess of cold hydrochloric acid, sp. gr. 1·2, a deep-blue, but clear solution, the color of which was discharged by dilution with water, and also upon being heated. A small portion of the residue was quite non-magnetic; but the rest of it was strongly magnetic. These portions did not seem to differ as to the form of the grains and crystals, and they were divided by a careful manipulation with a stream of water into a finer crystalline, and a coarser, well crystallized portion. The crystals have a gray to tin-white color, varying slightly with the individuals and their size. The form of these crystals is that of a triangular prism whose height is often, in some samples always, several times as great as the altitude of their triangular bases. The face, which I interpret to be a basal pinacoid, is apparently an equilateral triangle, and the form is a hemi-prism belonging to the hexagonal system. These crystals are often grouped in clusters, and many of the larger ones are invested with an abundance of smaller crystals. Cases of penetration are frequent, but no case of modification has yet been observed. Some of the crystals are striated, but this is probably due to interference. While no difference can be observed in these crystals, even under the microscope, they are not equally attracted by the magnet.

CHEMICAL CONSTITUTION OF THE CRYSTALS.

The magnetic portion from the residue of bottom number two,

as used for analysis, consisted for the most part of crystalline particles, but there were a few crystals, presenting either triangular or quadrilateral faces.   Repeated observations convinced me that the latter belonged to triangular prisms lying in such a position as to present a prism plane.   It oxidized slowly and imperfectly when fused with potassium bisulphate, but when heated to dull redness in an open crucible it ignites and burns to a yellow voluminous powder which is gray or very light buff when cold.   Complete oxidation is effected with some difficulty.   The analysis presented no difficulties which are not already well known, except such as shall be mentioned hereafter.   The columbic acid was separated from the stannic and tungstic oxides by fusion with sodium carbonate and sulphur, and the tungstic oxide was subsequently treated to regain the columbic acid which was taken into solution.

This analysis was made on 0·5 gram., as were also the succeeding ones, because of the small portion of material at my disposal.   The results of the analyses were:

	I	*at. eq.*			
Cb.	37·72	40·13	10	⎫	=14 (a)
W.	29·04	15·80	4	⎬	
Fe.	19·62	35·10	9	⎭	
Sn.	5·04	4·27	1		
O.	8·78	54·90	14		14 (b)
	100·20				

a : b : : 1 : 1.

This suggests the composition $10CbO + 4WO + Fe_9Sn$.   Such a mixture would require for its oxidation 24·42% of its weight of oxygen.   The amount actually absorbed was equal to 24·88% of its weight.

The feebly or non-magnetic portion from the residue of number two was gray when wet, brown when dry, but under the microscope it appeared quite black with a strong metallic luster.   There were many crystals present whose reflecting surfaces were either triangular or quadrangular, and which were identical with the larger triangular prisms.   The larger masses, recognizable as such only under the microscope, showed upon closer study that they too

included such crystals. It is difficult to account for the variation in the intensity of the magnetic property, but it may be due in part to the greater or less admixture of the iron-tin alloy. The analysis of this portion gave:

	II.	at. eq.		
Cb.	48·56	51·60	10·30	14·39 (a)
W.	37·64	20·46	4·09	
Fe.	3·22	5·75	1·15	
Sn.	0·72	0·61	0·12	
O.	10·08	63·00	12·60	12·60 (b)
	100·22			

a : b :: 1·14 : 1.

The gain upon ignition in this case was 22·00%. The formula suggested is the same as in the preceding case, i. e., $10CbO + 4WO + Fe_9Sn$.

The third bottom showed, after a portion of it had been dissolved by hydrochloric acid, the triangular prismatic crystals disseminated through the mass and particularly abundant at the bottom where the greater part of them had collected. The residue obtained from this bottom consisted of a mixture of substances, which fact was evident from the easily distinguishable difference in the specific gravity and color of the parts. When the residue was suspended in water and allowed to subside, two strata were

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NOTE.—I have repeatedly obtained an anomalous reaction which is due to tungstic oxide, but which is not given in either our text books or manuals. It consisted in the production of a strongly-yellow colored filtrate when the tin and tungsten sulphides were thrown down from the ammonium sulphide solution of the oxides of these metals by the addition of dilute sulphuric or hydrochloric acid. The reaction is produced by the formation of potassium-oxy-sulpho-tungstate, $K_2WO_2S_2$, which is formed by the action of the ammonium sulphide upon the potassium tungstate formed by the fusion with potassium bisulphate, a part of the tungstate being converted into the sulpho-tungstate, which unites with the unaltered tungstate, forming the oxy-sulpho salt, from the solution of which the tungstun is not precipitated by the reagents named, unless somewhat concentrated, and then incompletely. The extent to which this salt may be formed is indicated by the result obtained in an analysis of some material containing 86·86% of tungstic acid, in which case I obtained from the yellow filtrate, by repeated evaporation with addition of nitric acid, 0·1278 gram, or 34·67% of the tungstic acid present. This salt is given in Gmelin-Kraut's Handbuch der Chemie, Vol. II., part II., page 126, as being mentioned by Berzelius, stating that it is sometimes met with in the preparation of tungstic sulphide by fusing together potassium tungstate and sulphur. The same statement is made in Watts' Dictionary of Chemistry, Vol. V., page 914, but the reaction is nowhere recorded, so far as I can find, as produced in the manner here given.

obtained which could be easily freed from the more slowly subsid-
ing portion of the residue. These two strata were separated
according to their relative specific gravities, but the unevenness
in the size of the crystals rendered the attempt almost futile.

The lighter part, as seen under the microscope, was composed
of crystalline masses and crystals; the triangular prism was the
most abundant form among the latter, but there were also some
six-sided plates. The color of the crystalline masses was either
black or brown, and that of the crystals was gray, inclining to tin-
white. One portion of the mixture was readily attacked by nitric
acid with copious evolutions of the lower oxides of nitrogen, which
was true of the finest portion of the mixture to a greater extent than
we would expect from its fineness alone. Consequently, the whole
of the lighter portion was divided by a sizing process into two
parts, but not until after all that could be removed by a magnet
had been separated, which being very small in amount, was not
examined further.

The finest portion from the bottom, or part one of the residue,
was very slightly soluble in hydrochloric acid, yielding a deep-blue
solution whose color was discharged upon the addition of water.
When treated with aqua regia, the reaction presented two well
marked phases. The first was violent, and produced a solution
rich in iron, and turbid from suspended tungstic acid; the second
was very slow, and the solution contained but little iron. An
analysis of this gave, after deducting 21·70% insoluble, and the
oxygen in excess, the following:

	III.	at. eq.		
W.	31·78	17·27	⎫	
Fe.	34·50	61·60	⎬ 93·98	(a)
Sn.	17·83	15·11	⎭	
O.	15·89	99·31	99·31	(b)
	100·00			

$$a : b :: 1 : 1·05.$$

This analysis does not admit of any conclusion as to the real
character of this portion beyond the fact that the metals were
probably all combined with more or less oxygen, and that the ratio
1 : 1 may correctly represent the state of oxidation. That this is

the signification of the result receives some confirmation from the fact that the iron and tin represent one part of the mixture, and the tungstic acid another. It is further certain that the tungstic acid is in part, if not wholly, derived from a compound represented by the triangular prisms, whose composition is that of a lower oxide, which, however, is not necessarily all crystallized in the definite form specified, but may form a part of the crystalline masses.

The statement that the tin and iron represent one portion of the mixture, and the tungstic acid another, is based upon the deportment of the material when treated with aqua regia, which removes the tin and iron first, and then acts upon the residue, converting it into tungstic acid. The following results, bearing directly upon this point, were obtained by treating some of this material with two successive portions of aqua regia. Each portion was evaporated to dryness after digestion for about an hour at a gentle heat. The results were:

1st treatment, $WO_3=0.0810$ gram. Fe_2O_3 0.1857 gram.
2d treatment, $WO_3=0.0510$ gram. Fe_2O_3 0.0067 gram.

The solution from the first treatment contained a great deal of tin; that from the second only a small quantity of it. The residue from the first treatment consisted of crystals with a few crystalline grains; that from the second contained only a few crystals, which owing to their larger size had more effectually resisted the action of the solvent. The final residue was heated in a platinum dish, when it did not ignite, but oxidized to a yellow powder which consisted of tungstic acid with a little columbic acid.

In treating this portion the second time with aqua regia containing a large excess of hydrochloric acid, I obtained a clear, yellow solution which gave upon addition of water a precipitate of tungstic acid, to which reference has already been made.

The finer portion from the " bottom," or part two of the residue, consisted of larger and smaller particles. The former showed nothing characteristic, being aggregations of smaller particles inclosing crystals with triangular end-surfaces; the latter, together with some crystals, made up the bulk of the mass. The varying color, from brown to black, seems to depend upon accident as in

some cases nearly all of the particles in the field of the microscope
are brown, but in others this is not so, depending upon the light,
the size of the particles, and possibly also upon the extent to which
they were heated in drying.

While the crystals were mostly triangular prisms, there were
some six-sided plates, which were thin, though relatively large, and
nearly all of them were pitted; the luster of these plates were bril-
liant metallic. Similar plates were more abundant in the residue,
obtained as the result of my experiments with mixtures of colum-
bite, magnetite and stream-tin. These crystals do not resemble
graphite from cast-iron. The analysis, after deducting 66·66% of
insoluble, and the oxygen absorbed, gave:

	IV.	at. eq.	
W.	54·83	29·80	3
Fe.	25·86	46·18	5
Sn.	11·51	9·75	1
O.	7·80	48·75	5
	100·00		

One cannot attach much importance to these results, but in
the light of the preceding analysis they may be interpreted as in-
dicating that the portion more readily soluble in aqua regia was a
mixture of an alloy of iron and tin with one or more oxides; con-
sisting, in this case, of a mixture represented, in the main, by
oxides of the preceding sample, but not in the same proportions.
That this residue was obtained from an alloy of iron and tin
which might not have been completely dissolved is owing to the
fact that it might have contained some compound of these metals
which is difficultly soluble in hydrochloric acid. The deficiency
of oxygen in the analysis, and also the results obtained in other
analyses, indicate that part of the iron and tin might have been
present in the form of compounds containing no oxygen. On the
other hand, there can be no doubt but that a large portion of the
tungstic acid was derived from the crystals which are slowly acted
upon by aqua regia, yielding tungstic acid.

These facts led me to treat the remaining portion of this
material with warm nitric acid and analyze the purified residue,
which amounted to 42% of the original by weight. The crystals

are evidently attacked by this acid, but very much more slowly than the rest of the mixture. Neither the mixture itself nor the purified residue impart any color to a boiling concentrated solution of potassium hydrate, nor is there any perceptible evolution of ammonia or other reaction; but if the crystals are first digested with cold aqua regia and potassium hydrate be then added, it is colored brown upon standing. The purified residue did not appear materially different from the original, except that the triangular prisms were much more abundant, forming by far the larger part of the mass. Some of the crystalline aggregations remained and had the same brownish color, while six-sided plates were still recognizable. The residue was gray and had a high specific gravity. When heated in the air it did not ignite, but was slowly converted into a yellow powder. This residue was submitted to analysis with the following result:

	$V.$	$at.\ eq.$			
Cb.	6·56	6·98	4·9	}	34·0 (a)
W.	76·12	41·37	29·1		
Fe.	9·06	16·18	11·4		
Sn.	1·68	1·42	1·0		
O.	6·34	39·63	28·0		28·0 (b)
	99·76				

$$a : b : ; 1·21 : 1.$$

The gain upon ignition equalled 20 66%. If we calculate the columbium, tungsten and oxygen to one hundred, we obtain:

$$Cb.\ 7·37,\ W.\ 85·57,\ O.\ 7·12 = 100·00.$$

The third—that is, the coarsest portion of the residue from the fourth bottom obtained, was passed through a 148-mesh bolting cloth, and that which remained on the cloth was reserved for further study. The portion used for analysis consisted of many triangular prisms. I estimated them to represent as much as, or possibly more than 85% of the whole; the rest of the mass being made up of crystalline aggregations with a few of the six-sided crystals noticed in the last sample. When ignited in the air it did not take fire and glow, but oxidized as the last one to a yellow powder. The gain equalled 19·10%, and the analysis gave the following:

	VI.	at. eq.		
Cb.	1·46	1·55	1·34	
W.	86·64	47·09	40·94	42·28 (a)
Fe.	4·32	7·71	6·70	
Sn.	1·96	1·15	1·00	
O.	6·32	39·50	34·35	34·35 (b)
	100·10			

$$a : b :: 1·23 : 1.$$

This result indicates an excess of tungsten over that required by all of the oxygen for the formation of tungstous oxide; but if any metallic tungsten was reduced in the regulus, we would expect to find it here because of its high specific gravity, and the fact that careful washing was the only available method for separating and purifying the portions into which the residue was divided. That this is not an illegitimate assumption is warranted by the demonstration of crystals of metallic tungsten in experiments which have already been described.

The results of the preceding analysis show a similar excess of the metals. The fact that the material on which that analysis was made had been boiled with concentrated nitric acid does not alter the conditions, except that it would tend to concentrate the columbous oxide and metallic tungsten, as these are either only very slowly attacked or not acted upon at all by this agent. The material was more or less mixed in both cases, as has already been stated.

As it was practically impossible to separate, or even to distinguish the individual components of the various products treated of except under the microscope, and not very satisfactorily even with the aid of this instrument, we are compelled to have recourse to the study of those ratios which remain constant while other relations vary.

The first two analyses are comparable, the two portions of material analyzed differing in no respect as to source, manner of preparation or physical properties, except that number one was strongly magnetic and number two was not, with no sharp line of division between them. We may divide the results into two groups, one containing the iron and tin, and the other the colum-

bium, tungsten and oxygen.   The iron and tin together constituted
25% of the first sample and rather less than 4% of the second, but
the ratio of iron to tin is the same.   This is best seen when the
results in each case are calculated to one hundred, when we obtain
for:

	I.	II.
Fe.	80·47	81·72
Sn.	19·53	18·28
	100·00	100·00

The agreement of the ratios obtained for the remaining ele-
ments is quite as satisfactory, though the absolute difference in the
quantities of them present in the two samples is much larger.
These results may be exhibited in the same manner.   We have for:

	I.	II.
Cb.	49·91	50·44
W.	38·42	39·09
O.	11·67	10·47
	100·00	100·00

The results correspond to a mixture of $10CbO + 4WO$, which
requires Cb. 49·473%, W. 38·737% and O. 11·890%.

The method of obtaining columbous oxide, and also its prop-
erties, agree with those of this substance—that is, it is produced
by the action of a reducing agent on columbic acid at a high
temperature.   It is quite insoluble in aqua regia.   It ignites when
heated in the air, and burns with incandescence, yielding columbic
acid.

The remainder of the material from part one was washed, to
see if the triangular prismatic crystals were present, because of
their bearing upon the question of the nature of the material,
whether it was a mixture or a compound.   As they were present, I
believe that the material was a mixture.   The significance of the
presence of these crystals will be more fully established further on.

The residue from the fourth bottom, which furnished the
material for the other four analyses, was treated in such manner
as to effect its separation into parts, whose appearance indicated
that they might be radically different from one another.   No two
of these analyses are comparable to the same extent that numbers

one and two are; still, numbers V and VI agree in giving 1 : 1·21 and 1 : 1·23, respectively for the ratios of the columbium and tungsten to the oxygen.

A comparison of numbers IV and V, representing the same material before and after treatment with nitric acid, shows that the iron and tin are attacked much more rapidly by this agent than the tungsten compound, and the residue, after treatment with nitric acid, indicates that the triangular prismatic crystals yielded the greater part, if not all, of the tungstic acid which appears in analysis IV, which is also inferable from the results obtained in analysis VI. But, while the direct relation between the greater or less abundance of the triangular prismatic crystals and the quantity of tungstic acid obtained, is clearly shown by the results of the analyses, the most direct and conclusive proof that these crystals are tungsten, or a compound of it with no iron or tin, or at most with only a very little of them, is afforded by the material on which analysis III was made; for when it was treated with successive portions of aqua regia it yielded on the second treatment 0·0510 gram tungstic acid and only 0·0067 gram ferric oxide with a very minute quantity of tin. This is particularly cogent, as the residue from the first treatment was composed almost exclusively of such crystals. From all of which we conclude that this hemiprism is the crystal form of the compound of tungsten which occurs in these residues.

A comparison of the materials used in, and the results of analyses II and VI leaves no doubt that the former represents a mixture of columbous and tungstous oxides; for in number II we have a fine crystalline powder, with only a few triangular prisms; while in number VI we have a comparatively coarse powder consisting of such crystals, with only a few crystalline masses. The same is true of number V, but not to the same extent as in number VI. These analyses give for columbium and tungsten the following results:

	II.	V.	VI.
Cb.	48·56	6·56	1·46
W.	37·64	76·12	86·64

Analysis number II gives the ratio of 1 : 1 for the atomic ratio of these metals to the oxygen, and numbers V and VI give

approximately the same ratio. From which it appears that number II represents a mixture of columbous and tungstous oxides and that the triangular prisms are crystals of the latter oxide.

TUNGSTOUS OXIDES.

Tungstous oxide, WO., as thus obtained, crystallizes in the hexagonal system, mostly in hemiprisms, having a light-gray to tin-white color, a metallic luster, a hardness greater than glass and a dark-gray streak.   Hydrochloric, hydrofluoric and sulphuric acids, also a boiling solution of potassium hydrate, have no perceptible action on it.   Nitric acid and aqua regia attack it slowly, converting it into tungstic acid, WO_3.   The crystals can be kept under water, or exposed to the air in a dry state, without change; but when heated to redness in the air they are converted *without* incandescence into yellow tungstic acid accompanied by an increase in volume, but it is less than that which takes place when columbous oxide is ignited in this manner.

. It has been repeatedly stated that the source of these oxides was certain iron bottoms obtained by remelting tin-dross at a temperature sufficient to melt cast-iron. It is probable that the following is the explanation of the changes which took place in their formation:

The original charge of stream-tin contained columbite, wolfram, possibly huebnerite and magnetite as impurities.   The reduction was effected at a high heat sustained for several hours, in some cases as many as six hours and upwards, whereby the iron and tungsten, and possibly the columbium, were reduced to the metallic state, (see experiments with columbite, stream-tin and magnetite).   The molten charge was poured while very hot.   The slag was afterwards broken and treated for the tin contained in it as prills.   The whole of the tin was subsequently liquated, at as low a temperature as was feasible, and carefully drained off from the dross.   This dross contained much tin, together with the alloys of iron and tin, carbon, tungsten, columbium (columbous oxide), and stannous oxide formed during the remelting of the tin.   In this particular case this liquating process had been repeated very many times, so that a considerable quantity of stannous oxide was formed; but the tungsten and columbium (columbous oxide) were

not changed, because the temperature was too low, and besides they would sink to the bottom of the molten mass and be effectually protected from the influence of the atmosphere. But when the mass was remelted at a high temperature the stannous oxide acted as an oxydant toward the tungsten and columbium, converting them into the monoxides, which passed into the iron-bottoms from which they were obtained in the form either of a crystalline powder or well developed triangular prisms.

ON A SERIES OF PECULIAR SCHISTS NEAR SALIDA, COLORADO.*

BY WHITMAN CROSS.

In the summer of 1888 the writer accidentally discovered a series of schists in the hills on the eastern side of the Arkansas River opposite Salida, Colorado, which is different from any other series in the Rocky Mountains of which he has any information. In this series are certain rocks closely resembling quartzites and other metamorphosed sediments, and the complex was at first supposed to indicate the existence of pre-Cambrian (Algonkian) strata, allied to those occuring near Ouray, Colo. In accordance with this idea, this series has been referred to by Emmons† as probably of Algonkian age. The investigations to be described render it probable that no true sediments have as yet been observed in this section, but that the series may nevertheless be of Algonkian age.

A few days were spent in examining the occurrence of the rocks in question in October, 1891, and microscopical examination has shown something of their true character. Incidentally, other new facts regarding the geology of the region were observed, which may be appropriately mentioned in this place.

GEOLOGY OF THE SALIDA REGION.

In referring to the geology of this district it is necessary to point out that the representation of the Hayden map for this locality, for which Dr. F. M. Endlich is responsible, is almost wholly

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* Published with the permission of the Director of the U. S. Geological Survey.
† " Orographic Movements in the Rocky Mountains," Bull. Geol. Soc. of Am., Vol. I. p. 257, 1890.

incorrect. The writer's observations, being directed to a special
end, do not afford a basis for a thorough revision in all respects,
but the general character of the corrections necessary may be
stated.

In the first place, the area mapped as of volcanic rock,
"trachorheite," between the Arkansas and Badger Creek is not
occupied by a continuous mass of any rock, nor is there a strip of
schists bordering the Arkansas opposite Salida. Directly opposite
the town the first hills are of andesite breccia, tuff and small lava
flows. On following up the gulches cutting through this breccia
to the Arkansas, one finds greenish schists, with a steep northerly
dip appearing in the beds of the gulches at distances of a few hun-
dred yards or less from the canyon mouths. They then rise rap-
idly, and at less than two miles from the river form the hills, with
scattered patches of andesite or of rhyolite upon them. Within
three or four miles from the river, lower Palæozoic quartzites and
silicified limestones appear in remnants, with varying dips, resting
on the edges of the schists. Volcanic rock in patches rests on the
strata here and there.

The andesitic breccia covering the schists on the river bank
thins out rapidly south from Salida, and has entirely disappeared be-
fore reaching Cleora switch, two miles below the town. From Cleora
down to the point where the sedimentary rocks cross the river, five
miles below Salida, dark and for the most part massive rocks,
closely related to the schists, form the steep hills on the northeast
bank of the Arkansas. The representation of a volcanic rock
crossing the river at this point is wrong.

On the southwest side of the Arkansas below Salida the repre-
sentation of the Hayden map is likewise incorrect. Tertiary lake-
beds occupy a large area at the base of the Sangre de Cristo
Mountains, and run in behind the low exposures of the schistose
and massive rocks which appear on the bank of the Arkansas.
Any Palæozoic sediments which may exist on the south side of the
South Arkansas are not directly connected with the main body
crossing the Arkansas. The large area of Lower Carboniferous
limestone represented by the map as in contact with the Archæan
does not exist, for the base of the sedimentary section after cross-
ing the Arkansas River runs southerly up the slopes of the Sangre

de Cristo.   Bear Creek, which forms the boundary line between
Chaffee and Fremont counties on this slope of the mountains, dis-
closes no sedimentary rocks except the lake-beds.

STRATIGRAPHY AND GENERAL CHARACTER OF THE SCHISTOSE SERIES.

The schistose rocks of the Salida section have been examined
for a distance of ten miles across their general strike.   At about
five miles north of Salida a rhyolitic lava conceals the schists near
the river, and time did not allow of efforts to trace the series
further in this direction.   From this point to the line where the
Palæozoic strata cover the lower end of the section, below Salida,
the schists are almost continuously exposed.   As the section was
nowhere found in connection with undoubted Archæan rocks, it is
a matter of inference as to which is the top and which the bottom
of the series.

Where covered by the rhyolite, the schists stand nearly ver-
tically with a strike somewhat north of east.   A similar strike,
with very steep dips, rarely less than 70°, and prevailing to the
north, continues southward to near Salida.   Here, the dip de-
creases to 45° or less, and, passing down the river, it becomes
gradually lower until, shortly before meeting the sedimentary con-
tact, there is a flat anticlinal, and the dip of the formation appar-
ently changes to about 30° southeast.   The massive character of
the rocks here makes dip determination difficult.   Unless there is
a great inversion, the lower end of the series as known is the south-
ern end.

In structure and composition of the rocks there is a great
change from the one extreme to the other of the section.   The
lower rocks are prevailing coarse grained, and occur in alternat-
ing, irregular banks whose lateral extention has not been traced
out.   Some of these rocks are granitic, but a larger number are
dark, hornblende rocks—metadiorites.   The third important type
is dark and dense, in most cases with a banding of apparently
primary character, and, as will be described below, this rock is
referred to original lava flows on an ancient rhyolite.

Passing northward, the schistose character becomes more

marked, and a massive structure is retained only in the larger bodies. As the beds approach a steep dip the schistosity becomes more pronounced, and there is a succession of micaceous and amphibolitic schists in which the relationship to the original massive types can be more or less plainly made out. From Ute Gulch to the northern end of the section the schists are often so much changed that no trace of their original rock remains. Near the · Sedalia copper mine, four miles north of Salida, there is a succession of fine mica-schists, locally staurolitic, actinolite and chlorite schists, with garnet developed in various forms. The enormous dodecahedrons, so widely distributed by mineral dealers, come from a fine chlorite schist near the Sedalia mine, and the copper deposit of the latter is a thick bed of actinolite schist richly impregnated with copper minerals.

In this upper part of the section are some fine-grained gneissoid rocks free from mica. Granitic and pegmatitic veins traverse these schists, especially at the mouth of Sedalia Gulch. Dykes of a dense, white quartz-porphyry, much like the Leadville "White Porphyry," cut the schists at several places opposite Salida, and the head of Bear Creek, in the Sangre de Cristo Mountains.

ORIGIN OF THE SCHISTS.

The field observations of a few days upon this great series of rocks, whose relationships were at first entirely unknown, were naturally not sufficient to furnish a basis for their complete description. But a preliminary notice concerning their character and origin can be given, indicating the probable course of the metamorphism to which they owe their present form.

The rocks of the series may be divided into three general groups. The first embraces a number of massive rocks, principally low down in the section, which retain certain characteristics of the original rocks. The second group contains the intermediate members of the series, and here the connection with the first group is evident; but all indication of the primary rock is gone. The schists of the summit of the series form the third group, and for many of them no clear evidence as to their origin has been obtained. Doubtless, a detailed study will yield intermediate stages connect-

ing many of the most completely metamorphosed types with the primary rocks from which they have been derived.

The least altered rocks are moderately coarse granite-diorite, and quartz-diorites with hornblende and biotite. These occur in the sharp peak at the north end of the Sangre de Cristo Range, at the head of Bear Creek, and on the west bank of the Arkansas between Bear Creek and Salida. They are probably limited to large bodies, and no special modifications of the schists have been traced to them.

Far more abundant than the preceding are dark, hornblende rocks of coarse grain, which on weathered surfaces often present a structure strongly resembling diabase. Numerous sheets of these rocks occur in the lower half of the section. Microscopical study of the least altered shows an ophitic structure, through the relation between rudely idiomorphic plagioclase crystals and the massive green hornblende which encloses them, as does the augite in an ophitic diabase. No remnant of augite nor any direct evidence of its former presence in these rocks has been found, aside from such structures. The further alteration of these metadiorites,* as they may be called, takes place in one direction by a new generation of hornblende. The new needles or short prisms attach themselves more or less regularly to the massive hornblende grains, and penetrate the feldspars. Biotite generally accompanies the hornblende, as does epidote in some cases. In this way the plagioclase is obscured or entirely replaced.

Where the structure, also includes the production of a schistose structure, the plagioclase areas seem to give way to a granular mixture of quartz and a simple feldspar (orthoclase?), with impregnation by hornblende and biotite. In the production of schistosity, the massive hornblende grains yield gradually to bundles of prisms often of a lighter, seemingly actinolitic amphibole, and through the two processes there results a dense, more or less fibrous amphibolite, with a little biotite and varying amounts of quartz and orthoclase (?).

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*The terms " metadiorite," " metadiabase," etc., once proposed by Dana for metamorphic rocks, are seldom used at present; but it seems to the writer a very desirable manner of designating rocks now similar in mineralogical composition and structure to certain igneous rocks, but derived by metamorphism from something else.

The other rock preserving traces of its primary character is a dense, fine-grained porphyry, dark-gray in the hand specimen, but weathering to light-gray. A banded structure is often seen parallel to the general bedding of the series, and a porphyritic structure is sometimes plain. Microscopical study shows the phenocrysts to be plagioclase, or rarely quartz. These crystals are like those common in rhyolite, according to the author's experience. The predominant ground-mass is in nearly all cases a granular mixture of colorless grains with biotite and muscovite. In some cases the grain is sufficiently coarse or irregular to show plainly the presence of quartz and apparent orthoclase feldspar; in others, one cannot distinguish between these minerals owing to their small size and equal clearness. The phenocrysts are not always present in these masses, either on account of decomposition, or because they were never developed. In different parts of sheets several hundred feet in thickness the grain of the rock varies in coarseness, and the phenocrysts in abundance. Apatite and zircon are rare. Ore grains have usually been decomposed. These rocks seem to have been rhyolites or quartz-porphyries whose ground-masses have undergone a re-crystallization.

A further change to which these last mentioned rocks have been subject consists in the introduction of biotite, and occasionally of actinolite. The biotite uniformly has the form of very small, irregular, brownish, or sometimes greenish, flakes, disseminated evenly through the rock, causing the characteristic dark color, and also, in the finer grained modifications, a kind of vitreous lustre which suggests quartzite. These flakes are not macroscopically identifiable as mica, except where the schistose structure is sufficiently developed to bring them into approximately parallel arrangement. The lustre then becomes that characteristic of mica schists. The brown biotite is sometimes so abundant and in such irregular arrangement as to give the rock a very dark and almost black color. In some cases the composition of the mass has evidently been very greatly changed by the extent of this new formation. Chemical analyses illustrating this have not as yet been made.

Actinolitic and tremolite amphibole are occasionally found accompanying biotite as new formations, but are seldom of much

importance.   They appear in the bed of metamorphic rock imme-
diately under the sedimentaries on the west bank of the Arkansas.

Muscovite is present in varying quantity in almost all these
rocks.   It appears in clusters of flakes with parallel orientation
penetrated by quartz and feldspar grains, producing a micropoiki-
litic structure.   The comparatively large surfaces of the clusters
make them conspicuous in the schistose rock.

Many beds of dense, banded rocks found in the middle part
of the section seem macroscopically like micaceous quartzites.   In
some of these rocks the phenocrysts of plagioclase can be micro-
scopically made out, but they have become so impregnated with
biotite flakes as to render them macroscopically indistinguishable.

At the extreme schistose end of the known section are rocks
already referred to which may plausibly be considered as extreme
alteration products in the directions above outlined.   But the hurried
field examination did not disclose all the intermediate stages, and
it is, of course, quite possible that other original eruptives or sedi-
mentary beds may have existed at this part of the section.

RELATIONSHIPS OF THE SERIES.

As no distinct sediments have been identified in the Salida
section described, the question of their age is entirely a matter of
stratigraphy and lithology.   The series clearly lies below, and un-
conformable with, the Palæozoic section of the region.   It is ques-
tionable whether there is any Cambrian in the section of the
Arkansas River, but the known development of that formation
elsewhere in Colorado is as a thin series of quartzites and shales
conformable with the Silurian.   The Salida schists are therefore
to be considered as pre-Cambrian.

As neither end of this section is exposed where studied, the
relationship to undoubted Archæan gneisses and schists is un-
known.   But rocks similar to these have not been reported from
the Archæan complex.

According to Endlich,* the north end of the Sangre de Cristo
Range and the mountains north of Marshall Pass are largely made
up of hornblende schists.   As the strike of the Salida schists and

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* 7th Ann. Rep. U. S. G. and G. S., 1873, pp. 325, 326.

amphibolites would carry them into the mountains named, it
seems reasonable to infer that the rocks seen by Endlich belong to
the series described above.   Endlich also reports dark schists in
the Sawatch Range to the north, where they are cut by the Sawatch
granite, which he considered of post-Silurian age.   The writer
found greenish schists in place on Tin Cup Pass.   But an isolated
observation made by the writer in 1890, a few miles northwest of
the town of Tin Cup, seems to afford the only direct evidence of
sedimentary rocks in the crystalline series of the Sawatch.   At the
place named there is a highly crystalline marble, blueish or gray
in color, with silky needles of pale amphibole, interbedded between
greenish schists and a fine grained gneissoid rock.   These beds
strike a few degrees west of north, and dip very steeply to the east.
The bed is several yards in thickness.   This fact shows that meta-
morphosed sedimentary rocks do exist among the crystalline
schists of Colorado.

Near Ouray is a great series of pre-Cambrian sedimentary
rocks, quartzites, slates and conglomerates, referred by Emmons[*]
and Van Hise[†] to the Algonkian system.   These have not been
studied in sufficient detail to show whether any of them are meta-
morphosed eruptives or not.

It is significant, in considering the age of the Salida schists,
to note that extensive series of flows of various basic and siliceous
rocks are known in the great Algonkian sections of the Colorado
Canyon, and of the Lake Superior region.   In the light of the
known facts, the writer inclines to the belief that the schists and
massive rocks of the Salida section likewise represent a great series
of surface lavas erupted in Algonkian time.   This preliminary
notice is intended to indicate one phase of the great problem pre-
sented in the study of the crystalline schists of the Rocky Moun-
tain System.

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[*] "Orographic Movements in the Rocky Mountains," Bull. Geol. Soc. of Am., Vol.
p. 257, 1890.

[†] Bull 86 U. S. Geol Survey, Correlation Papers, Archæan and Algonkian, p. 322, 1892.

THE LATEST METHOD OF ELECTRIC CAR CONTROL.

BY IRVING HALE, DENVER COLO.

The controlling mechanism of an electric car, although apparently a minor feature, is really one of the most important parts of the equipment of an electric railway, and no portion of the system has received more study and experiment, or more seriously taxed the ingenuity of workers in this field.

A satisfactory controller should fulfill the following conditions:

(1)   It must give a smooth start and gradual acceleration of speed, while enabling full speed to be obtained in a reasonably short time.

(2)   It must be as free as possible from "arcing" and burning in passing from one position to another, and in breaking the current, and should require a minimum of attention and repairs.

(3)   It should be economical of power at all speeds, and should reduce, as far as possible, the rush of current when the car is started.

(4)   It should have the greatest possible simplicity consistent with the preceding conditions.

Until recently, all street railway systems have employed one of two methods (or a combination of the two) adopted by the two companies who first entered this field on a commercial scale and made the electric railway a practical success.

RHEOSTATIC CONTROL.

The rheostatic control formerly used by the Thompson-Houston Company, consists of a variable resistance in circuit with the motors; the amount of resistance being regulated by a contact arm actuated through suitable gearing by the motorman's lever.

The principal advantages of this method are comparative simplicity of mechanism and wiring, and ability to secure a perfectly smooth start and increase of speed.

The chief disadvantages are the "arcing" and burning of the resistance and contacts, especially when the rheostat, which is usually placed under the car, is subjected to mud and water; and, what is of greater importance, the waste of power caused by passing the current through this idle resistance at slow and medium speeds— the energy dissipated in this way frequently exceeding the amount utilized in the motors.

This method, therefore, fulfills the first and fourth conditions very satisfactorily, the second condition only passably well, and the third condition very poorly.

COMMUTATED FIELD CONTROL.

The other method, known as the "commutated field," originally employed by the Sprague Company and afterwards by the Edison Company, consists in making the field coils in three sections and throwing these into various combinations by means of a cylinder switch, so as to vary their resistance and, consequently, the current and speed. An outside resistance is also used in starting, but is thrown out immediately thereafter.

The most important advantage of this method is its superior economy of power at the slower speeds, due to the fact that the resistance employed to cut down the current consists of the field-coils of the motors instead of an extraneous idle resistance, so that the current passing through this resistance is doing some useful work. Nevertheless, when the field-coils are in the combinations giving the higher resistances, the relative resistances of fields and armature are not such as to give the highest efficiency. Consequently, the efficiency of the equipment is not as high at low as at full speed, although better in this respect than the rheostatic control. The starting current is large.

The disadvantages of this controller are a somewhat jerky start under some conditions, the "arcing" and burning of contacts in switch unless carefully handled, and greater complexity of parts and wiring.

This method is rather unsatisfactory in regard to the first and

second conditions, fairly satisfactory as to the fourth, and while fulfilling the third better than the rheostat, is not all that could be desired.

SERIES-PARALLEL CONTROL.

A new method of control called the "series-parallel," which has been brought into practical use during the past year and which will probably supersede both the others, consists in throwing the motors themselves into different combinations, starting with the motors in series and with resistance in circuit, passing through various intermediate positions such as motors in series without resistance, same with portion of field-coil cut out, single motor, motors in parallel with resistance in circuit, to the final position which is the same in all controllers, motors in parallel without resistance. The intermediate combinations may be arranged in a variety of ways to accomplish the same general object, viz.: smooth transition from starting to full speed, with as good efficiency throughout as practicable.

The great feature of this system is the connecting of the motors in series at starting and slow speeds, thus utilizing not only their combined resistance, but what is much more important, their combined counter electromotive force to cut down the current and give increased efficiency at these speeds. The total energy absorbed by two 500-volt motors in series on a 500-volt circuit ought to be just half the amount required to run the car at *same speed* with the two motors in parallel, because in the former case the voltage is divided between the motors, 250 volts to each, and all the energy is utilized in the machines, while in the latter case enough idle resistance must be introduced to cut down the voltage from 500 to 250 volts—in other words the resistance will dissipate as much energy as is usefully absorbed by the motors. For example, suppose that when the two motors are thrown in series the car moves eight miles per hour and the current is ten amperes. The motors being in series, the E. M. F. at terminals of each will be 250 volts, and the current in each will be the same as the current in the main wire from the trolley—ten amperes. Each motor absorbs 2,500 watts of energy, making 5,000 watts for the two. Now, throw the same motors in parallel, and introduce enough resistance to bring the speed down to eight miles per hour as before. The

load and speed being unchanged, the torque of each motor must
be the same as before, and, consequently, each motor will take the
same current—ten amperes.   In order to make it take the same
current under identical conditions of load and speed, the voltage
at its terminals must be the same—250 volts.   The resistance
must, therefore, absorb the remaining 250 volts, and as the current
through the resistance, which is in main circuit, is 20 amperes
(the motors being in parallel), the energy dissipated in the
resistance will be 5,000 watts.   The energy absorbed by each
motor will be, as before, 2,500 watts, or 5,000 watts for the two.
The total energy taken from the line is, therefore, 10,000 watts;
twice as much as with the motors in series.

The results of the tests hereafter described correspond very
closely with these theoretic conclusions.

In the intermediate positions, using only one motor, a higher
efficiency may be expected than with two motors in parallel with
sufficient resistance in circuit to give the same speed; not only
because there is no wasteful resistance in the former case, but also
because a single motor is more efficient for work within its capac-
ity than a pair of motors doing the same work, as the latter do not
work exactly together, and the load on each is too light to give the
best efficiency.

In the final positions of controller (motors in parallel without
resistance) the economy is, of course, the same, regardless of the
method of control.

COMPARATIVE TESTS.

To determine the relative merits of the series-parallel and
rheostatic methods of control, in regard to current required to
start and power used at various speeds, the following comparative
tests were made on a sixteen-foot motor-car equipped with two 25
H. P. single-reduction motors and series-parallel controller, and
an exactly similar motor-car with rheostatic controller, the same
trail-car being hauled by each.   The trial took place on the South
Broadway Electric Road, Denver, Colorado, on a practically level
course one-tenth of a mile in length.   Owing to the distance from
power house (about five miles) the voltage was rather low and
variable, which accounts for the slight irregularities in the tests,
such as a lower speed and efficiency in the third position of series-

parallel controller than in the first. These irregularities, however, are too small to materially affect the comparison.

The series-parallel car was run over the course in each direction with controller in first position (starting far enough back to acquire steady speed before reaching measured course), and observations taken on time, current and voltage; a mean of the readings in the two directions being taken to eliminate effect of the slight grade. The same run was made in each position of the controller. From these readings the speed, power and horse-power hours per mile were computed and curves plotted, showing the two latter quantities at various speeds. The same runs were made with the rheostatic car with various amounts of resistance in circuit, the resistance used in the first run being just sufficient (as determined by experiment) to give the car the same speed as with first position of series-parallel controller, and similar curves were computed and plotted for this car.

These observations are compiled in Table 1. The curves showing power required at various speeds are plotted in Fig. 1, and the curves showing H. P. hours per mile (power divided by speed) at various speeds are given in Fig. 2. As position 9 of S. P. controller is the same as the position of rheostatic controller having no resistance in circuit and full field on motors, and position 10 of S. P. controller is the same as final position of rheostat (no resistance and weakened field), the corresponding points of curves should coincide. The difference is due to slight differences in motors, bearings, etc., of the two cars. To make the comparison perfectly fair, the two curves should be made to coincide from 9 to 10, and the remainder of the rheostatic curve should be moved down the same relative amount as at 9, as indicated by the dotted line. The same is true of the curves in Fig. 2.

To compare the currents required to start and attain constant speed, the S. P. controller car was started and run on first position, taking readings at instant of start (maximum swing) and every two seconds thereafter, until current and speed became practically constant. The same test was then made on the rheostatic car with the amount of resistance necessary to give same final speed as first position of S. P. controller. These readings are given in Table 2 and plotted in Fig. 3.

, The following conclusions are derived from an examination of these tables and curves:

First: The average current required to start the car and attain slow speed, is about half as great with the S. P. controller in first position as with the rheostatic controller having sufficient resistance in circuit to give same speed. This means less strain on generators and engines, and a smaller station plant to operate a given number of cars; since less surplus station capacity is re- quired to provide for excessive starting currents.

Second: The starting current drops much quicker with the S. P. controller on account of the more rapid rise of counter E. M. F. of the two motors in series. With this controller the current fell in about two seconds to the amount taken when running with motors in parallel on full field with all resistance out, while with the rheostat it remained above this amount for the entire fourteen seconds during which readings were taken. With the latter, therefore, a much larger proportion of the cars would be simulta- neously taking a current in excess of that required when running at full load, and the station plant would have to be correspondingly larger. This test, in which each controller was left in first posi- tion for fourteen seconds, does not, of course, represent the condi- tions of actual running. In the latter case, either controller would be moved around quite rapidly, remaining not more than two or three seconds in each position. Subsequent tests in regular ser- vice, in which readings were taken of maximum swing in each position of controller, as car was brought up to speed in the usual manner, made fully as favorable a showing for the S. P. controller.

Third: At slow speeds, corresponding to position of S. P. controller with motors in series, the power required with this con- troller is about half that required with the rheostat.

Fourth: At medium speeds corresponding to position of S. P. controller using only one motor, the saving effected by the con- troller is about 30%, which agrees very closely with tests made at various times on the relative economy of one motor vs. two motors. This position is not a good one for heavy work, being intended, in such work, merely as a transition combination, but it is an eco- nomical running position when the work is suitable for a single motor.

Fifth: In the final positions (motors in parallel), the conditions are the same with either controller.

Sixth: Fig. 2 shows that with the rheostatic controller the efficiency is lower, or "H. P. hours per mile" larger, at slow speeds than at high, while with the S. P. controller the reverse is true.

Seventh: Another important advantage of the S. P. controller is the fact, that at starting, and until considerable speed is acquired, the motors, being in series, must necessarily take the same current, and equally divide the work, while with any method of control in which the motors are in parallel throughout, experience has shown that they never divide the current equally and that the difference is liable to be the greatest at starting, when the current is the heaviest and an unequal division the most dangerous. The appended tables do not illustrate this point, as they do not give the separate readings for the two motors, but the fact that two motors in parallel divide the current unequally is too well known to require any demonstration, and in fact any particular set of observations would have no weight as a general criterion on this point, since the difference between the current taken by the two motors depends entirely on their relative conditions, and may be anywhere between nothing and 100%.

The objection may be made to the above tests that they were not made under the conditions of actual service, and therefore do not indicate the relative economy of the two controllers in a regular run, including stops, varying speeds and all kinds of grades. While this is true, it is, nevertheless, a fairer test, and shows more conclusively the difference in power required at various speeds, since the two cars were subjected to identically the same conditions. This is impossible in a test made in actual service, where, even if the same number of stops are made, the cars will not be run at exactly the same speed and in the same manner over the same portions of the route, and the readings taken at fixed intervals will not be distributed alike with reference to stops and starts.

The tests show very satisfactorily the saving of power in starting and at each particular speed. The average saving in actual service will depend entirely on the nature of the service, being greater for city lines, where stops are frequent and cars are run

during much of the time at half speed, than for suburban lines requiring high speeds and few stops.

<center>TESTS IN ACTUAL SERVICE.</center>

To get an approximate idea of the average saving on an average line, a comparative test was made on two cars, one equipped with S. P. controller and the other with rheostat, in regular service on the Lawrence Street Line of the Denver Tramway Company, from South Water Street and First Avenue to Williams and Fortieth Streets and return, a distance (round trip) of 10·92 miles. The middle of the line, for about half a mile, is in the business district, the remainder being through residence portions of the city. The maximum grade is 1·7%, and most of the line under 1%. The cars and motor equipments were exactly alike, and each motor-car hauled a trailer. The runs were made within a few minutes of each other, and the number of stops and passengers and time of round trip were practically equal. It was intended to use the same motorman for both cars and to run them as nearly alike as possible, but this was impracticable, as no extra men were available, so the cars were run by the men who happened to be on them at the time. The man on the S. P. car started much more quickly than the other and did not handle his car in a manner to get as good economy. On the whole, therefore, the conditions were a little against this car, and the saving shown for it may be regarded as conservative.

Throughout each run, one observer called time every five seconds and recorded stops and starts, another read the current and a third the voltage. By taking observations at such short intervals, the element of chance was largely eliminated, as at least one reading was obtained during each stop or zero period and each heavy starting current, and generally more than one.

Table 3 summarizes the results of this test and shows the following facts:

The mean starting current (first reading after each stop) was 56% less with the S. P. controller than with the rheostat. The readings (which were too numerous to tabulate in full) also show that the heavy current lasted much longer with the latter than with the former.

With the S. P. controller the current exceeded 82 amperes (50 E. H. P. at mean voltage) but once, and then reached only 85 amperes, while with the rheostatic controller it exceeded this amount 51 times, and frequently rose as high as 100 to 120 amperes.

The total saving of power effected on the round trip by the S. P. controller was 30%.

SUMMARY.

To summarize the above tests, the use of the series-parallel method of control means a more equal division of load between the motors, less strain on motors and generating machinery, less fluctuation in station load, smaller power plant, fewer firemen, reduced consumption of fuel.

This controller, therefore, fulfills in a most satisfactory manner the third requirement specified at the beginning of this paper. In fact, nothing more could be asked in this respect, as it is efficient at all speeds, and by utilizing the combined counter electromotive force of the motors, by connecting them in series, attains even a higher efficiency at slow speeds and light work, than when the motors are running at full speed and near their rated capacity.

The first condition is not as perfectly fulfilled by this controller as by the rheostat; in fact, no method of control involving distinct steps can be expected to give as smooth a start and perfect graduation of speed under all conditions as can be secured by a gradually varied resistance.   However, by having a sufficient number of steps and properly arranging the various combinations, this requirement can be fulfilled well enough for all practical purposes, and as well as it is accomplished by the rheostat as handled by the average motorman.

The particular type of series-parallel controller used in these tests avoids "arcing" and burning of contacts, which might be expected to give trouble in this general form of apparatus, by means of the "magnetic blow-out" which consists in breaking the circuit in a strong magnetic field, the arc being thereby extinguished.   In freedom from burning and consequent repairs, this controller will doubtless be superior to either the rheostat or the switch heretofore used with the commutated-field method of control.

SERIES–PARALLEL AND RHEOSTATIC CONTROLLERS.

COMPARATIVE TESTS.

Denver, Colorado. February 11th, 1898

Table 1. Power Tests. See Figs. 1 and 2.

Type of Controller.	Position of Controller.		Mean Amperes.	Mean Volts.	Mean E.H.P.	Time, Round Trip 1·5 mile. Sec-onds.	Miles per hour.	H.P. Hours per mile.
Series-Parallel Controller.	Motors in Series.	1	9·0	453	5·4	88·5	8·1	·67
		2	8·8	425	5·0	94·0	7·7	·65
		3	9·3	438	5·4	95·0	7·6	·72
		4	12·8	440	7·5	75·5	9·5	·79
		5	10·6	448	6·3	82·0	8·8	·72
	Single Motor.	6	13·9	418	7·7	72·0	10·0	·77
		7	13·5	410	7·4	70·5	10·2	·72
	Motors in Parallel.	8	21·6	415	12·0	61·5	11·7	1·02
		9	22·2	410	12·1	57·5	12·5	·97
		10	30·8	430	17·7	47·0	15·3	1·15
Rheostatic Controller.	Portion of Resistance in Circuit.	⅞	22·0	410	12·0	87·5	8·2	1·46
		¾	22·3	403	12·0	76·5	9·4	1·27
		½	24·4	400	13·0	63·5	11·3	1·15
		¼	24·3	385	12·5	61·0	11·8	1·06
		None. Full Field.	25·1	398	13·3	57·5	12·5	1·07
		None. Weak Field.	39·8	385	20·4	48·0	15·0	1·36

Table 2. Starting Tests. See Fig. 3.

Type of Controller.	Number of Test.	Amperes at Start and During First Fourteen Seconds.								
		Start.	2 Sec.	4 Sec.	6 Sec.	8 Sec.	10 Sec.	12 Sec.	14 Sec.	Mean.
S. P. Controller, 1st Position.	1	42·5	23·0	17·0	15·0	14·0	12·5	12·0	11·0	18·4
	2	43·5	25·0	18·0	14·5	12·5	13·0	13·0	12·0	18·9
	3	40·0	22·0	15·5	14·0	12·0	11·0	11·0	10·5	17·0
	4	45·0	25·0	20·0	15·0	13·0	12·0	11·0	11·0	19·0
	Mean	42·8	23·8	17·6	14·6	12·9	12·1	11·8	11·1	18·3
Rheo. Contr. ⅞ Resistance in Circuit.	1	43·0	40·0	37·0	35·0	33·0	32·0	31·0	29·0	3·50
	2	50·0	46·0	42·0	38·0	34·0	32·0	30·0	29·5	37·7
	3	50·0	48·0	43·0	40·0	36·0	34·0	33·0	33·0	39·6
	4	51·0	45·0	41·0	34·0	31·0	29·5	29·0	27·0	35·9
	5	44·0	39·0	36·0	34·5	33·0	31·0	30·0	29·5	34·6
	Mean	47·6	43·6	39·8	36·3	33·4	31·7	30·6	29·6	36·6

In regard to simplicity of mechanism and wiring, the series-parallel controller is inferior to the rheostat, but its somewhat greater complexity is not a serious objection and is practically of no importance as compared with its many points of superiority.

On the whole, the advantages of the series-parallel controller far outweigh its disadvantages, and it is undoubtedly the best method of electric car control in use today. It is not an extravagant statement to pronounce its introduction the most important single step in electric railway development since the trolley system became a practical success.

INFORMAL COMMUNICATIONS.

Mr. A. Raht made some remarks on the formation of slag-crystals; in which he said:

A great many metallurgists consider the form of the slag-crystals an infallible criterion of the chemical composition of a slag. While I am not prepared to deny that a certain composition has a tendency to produce certain crystals, I question the practical reliability of conclusions based thereon; since the associated physical conditions such as the original temperature, rate of cooling and hence the size of .the slag pot, play an important part in crystallization. These influential conditions are, I believe, frequently overlooked.

During August, 1892, we obtained from matte concentrating at the Philadelphia Smelting Works, a number of well-developed slag crystals, a short description of which may prove interesting in connection with the above; more especially the fact that we frequently found three entirely different forms of crystallization in the same piece.

Below I give the analyses made by our member, Mr. E. C. Eddie, of these three different forms obtained from the same piece of slag; and also the analysis of the fluid slag taken from the furnaces at the same time. The high lead percentage of 1·5, was the cause of the slag being "cold-dumped" and thus gave occasion for the crystals to form.

	Globular Radiated form.	Apparently Cubic form.	Prismatic form.	Liquid Slag.
SiO$_2$	36·5	36·6	37·1	37·2
Fe	20·3	20·0	20·4	22·1
Mn	2·1	2·2	2·0	1·8
CaO	23·1	21·0	21·9	18·0
Al$_2$O$_3$	7·8	7·4	7·2	Undet.
S	0 4	0·36	0·55	Undet.
BaO	0·52	0.66	0·92	1·3
MgO	Trace	Trace	Trace	Undet.
Pb	Undet.	Undet.	Undet.	1·5

What seems remarkable is, that the three forms of crystalliza-
tion should show so little difference in their composition, while
the liquid sample shows such a marked difference from these.

A REVIEW OF THE RUSSELL PROCESS.

BY L. D. GODSHALL.

The economic reduction of our low grade, dry silver ores is a problem which has been under consideration among our leading metallurgists for a long time. The recent great depression in the price of silver has reduced their production in some districts to a large extent, and, if not met by a lower cost in the reduction of the ore, promises, in the near future, to still further diminish the output of the majority of our silver-producing mines. The smelters of the West are now treating many of these ores at a surprisingly low treatment charge. Freights have also been slightly reduced, but, notwithstanding this, it is a well known fact that large quantities of such ores can be found throughout Colorado and many of the other Western States, which either do not pay to ship, or pay so little that the owner rather leaves the ore blocked out in the mine, trusting that some day some process will be devised which will solve the problem to his advantage. The establishment of local smelters for the treatment of such ores is often impracticable and frequently impossible. Much has been said concerning the availability of the lixiviation process for such dry argentiferous ores which cannot now be treated by smelting. Of such processes the one known as the "Russell" is pre-eminently the foremost. It is today in successful operation in three large mills, located in widely separated localities. In the following pages an attempt is made to give a fair and impartial review of both the good and bad features in this process and the extent of its adaptability. The statements made and the conclusions arrived at are based on the actual experience of nearly a year as superintendent of the Holden Smelting and Milling Company at Aspen, Colorado.

The various steps in the process are so well known that they scarcely need to be mentioned here. However, for the sake of reference, they will be treated under the heads of crushing, roasting, leaching and precipitating.

CRUSHING.

A few years ago it was almost the unanimous opinion that rolls were most suitable for crushing ore for leaching. One of the reasons for recommending the use of rolls then was that the crushed product would be more granular, of a more uniform nature, and consequently less liable to form slimes which might operate disadvantageously in the lixiviation. This idea has been abandoned almost altogether, as the great importance of very fine crushing is now more thoroughly realized. The very fact that rolls do produce a product coarser than that obtained by stamps is now used as a strong argument against them. The incessant break-downs occurring in so many of our dry crushing mills where rolls are used have proved very objectionable. It is true that much of this trouble could frequently be traced to incompetent workmanship, either in the manufacture or in the putting up of the machinery, or in the lack of care or knowledge required in operating the plant.

The only objection to stamps is the extra cost in the beginning. This is, however, often more than counter-balanced by the small amount of repairs and attention required after once in operation. The introduction of a pulverizer to take the place of either stamps or rolls is at all times hazardous, but it is much more so in a new mill or with a new process. There are, no doubt, certain ores which can be crushed more economically by pulverizers of the most approved pattern than either by stamps or rolls; the fact to be emphasized, however, is the danger of introducing such appliances to crush all kinds of ore, and the difficulty in determining just what ores are more suitable for them than for either stamps or rolls.

The question of the limit of fineness required in crushing an ore for lixiviation can only be determined by actual experiments. The following points must be taken into consideration: Cost of crushing, capacity of crushing machinery, and the subsequent

percentage of extraction.   Where the roasting furnaces have in-
sufficient dust chambers, the loss in dust ought also to be taken
into account.   With some ores, the difference between very coarse
crushing, say between 10 and 30 mesh to the linear inch, would
mean a considerable saving of time, and therefore of fuel in the
roasting, as well as a smaller loss of silver by volatilization.

ROASTING.

All ores treated by the Russell process should be first sub-
jected to a chloridizing roasting.   It is true that statements have
been made claiming this unnecessary with some ores, but such
statements so far lack a practical demonstration.   Even if in rare
cases the silver could be extracted from the raw ore, or from ores
roasted without the use of salt, the mechanical difficulties in the
leaching of such a product would probably more than offset any
advantage that might otherwise be gained.

The furnace best adapted for the most efficient and econom-
ical chloridization of any certain ore, or class of ores, is not at all
times as simple to determine as might appear to one not exper-
ienced in the roasting of such ores.   Even among those of the
widest experience in lixiviation there is a great difference of
opinion on this subject.   Generally speaking, in the lixiviation of
silver ores as well as the chlorination of gold ores, the reverbera-
tory furnace is the most reliable, but also the most expensive.   By
some the Stetefeldt furnace is regarded so superior to all others
as to be beyond comparison.   It is, no doubt, one of the most in-
genious and, at the same time, simplest of furnaces in existence,
and if used in the proper place, is undoubtedly the most perfect
furnace of today.   But the use of this furnace has certain limits
beyond which it is unwise to go.   Silicious ores carrying 6% or
more of sulphur can be chloridized better in some other furnaces.
Ores carrying a large percentage of lime, say from 15 to 20% of
CaO, are also very difficult to chloridize properly in the Stetefeldt
unless sufficient sulphur is present to combine with the CaO and
form $CaSO_4$; even then the chloridization in the furnace is fre-
quently very low and rarely exceeds 60%.

The writer has seen the furnace deliver roasted ore from cer-

tain mixtures high in lime and sulphur where not more than 15 to
25% of the silver had been chloridized in the shaft of the furnace,
where about 65% of the ore is roasted.   However, after the above
ore had been lying on the cooling floor for three days, fully 90%
of the silver was found to be chloridized.

The continuation of the chloridizing action on roasted ore
after leaving the furnace is not new; but so far as the writer
knows, no such great differences as the above have ever been noted
before.   The extremely low percentage of the silver converted into
chloride in the furnace was due partly to its having been crowded
beyond its capacity, but chiefly to the large percentage of sulphur
present causing such a strong reducing atmosphere of sulphur
dioxide that the effect of the chlorine liberated by the acid gases
was neutralized.   Frequently the odor of sulphurous acid escaping
from the roasted ore as it was discharged from the shaft of the
furnace was sufficiently strong to overcome all smell of chlorine
fumes.   The sulphur in the raw charge of the ore just considered
ranged from 8 to 10%, being about half that of the lime and mag-
nesia present.

The large percentage of sulphur in such an instance really
performs a dual function—that of making the lime and magnesia
inactive and thus preventing caustic solutions in the leaching
operations, and at the same time acting as a fuel in the furnace.
An increase of 1% sulphur in the ore would be almost instantly
noticed by the furnaceman on account of requiring less gas to
maintain the proper heat for roasting.

The roasted ore after being dumped on the cooling floor retains
its heat to within a few inches of its surface for several days, or
until all the available sulphur is consumed.   While on the cooling
floor for the first two days it really undergoes a heap chloridizing
roasting.   Inasmuch as the supply of free oxygen is extremely
limited, and repeated tests fail to show any presence of sulphate of
iron, it would seem to indicate that sulphurous acid might under
certain conditions have the power of liberating the chlorine from
the salt with the formation of sulphite of soda.   The writer freely
admits that he is ignorant of the exact chemical reaction which
occurs under conditions of heat and exclusion of air, between sul-
phurous acid and sodium chloride.   The fact, however, remains

that ores may be chloridized on the cooling floor if the above conditions are carried out.   Repeated tests were made to chloridize
this ore without resorting to this large percentage of sulphur,
which was chiefly furnished by pyrite ore brought from Leadville;
but such experiments did not prove successful.   The ore came out
of the furnace very dusty and in a condition very similar to that
in which it went in.   Even roasting a smaller tonnage and increasing the temperature did not suffice to effect a thorough chlorination.

The salt used in the roasting is intimately mixed with the ore,
generally in the conveyor, before it is charged into the furnace.
It is usually crushed separate from the ore.   By so doing it may
be crushed quite coarse, while if mixed with the ore it would have
to be crushed to the same fineness, and as the ore is generally
crushed quite hot the salt would have a tendency to bake and clog
up the screens.

The amount of salt used in the roasting varies according to
the character of the ore, ranging from a minimum of 5% to a maximum of 15%.   As a rule, the higher the percentage of salt, the
higher the chloridization of the silver.   An important fact not
generally known in this connection is that the higher the percentage of salt used in the roasting, the lower is the loss of silver by
volatilization.   The reason for this strange action will be given
further on.   The fact was first noticed by Russell and afterwards
confirmed by the writer by roasting different portions of the same
sample of ore with 4, 8, 12 and 16% of salt respectively.   All
other conditions were exactly the same.   Consequently, where
salt is reasonably cheap, its liberal use will be found to be profitable.   The reverberatory and Bruckner furnaces require a smaller
quantity of salt than the Stetefeldt, for the reason that they have
a longer time in which to accomplish their work.

About the time the Aspen works were first started, the writer
was informed by one of the leachers who had previously been connected with the leaching department at the Blue Bird Mill in
Montana, that much trouble had been experienced there on
account of the water rendering a considerable proportion of the
silver chloride insoluble in the sodium hyposulphite solution.
This water is used to dissolve and wash out the soluble chlorides

of the base metals, and is called the first wash water. The inform-
ation was received with a smile of incredulity, but in a very short
time it changed from a matter of amusement to a stern reality, as
it was discovered that this same trouble existed to an alarming
extent with the Aspen ores as then mixed and roasted, A sample
of the roasted ore charged into the vat would show a high extrac-
tion in the assay office with "hypo" or "ordinary" solution, as it
is generally termed. At times the extraction by the "ordinary"
would be almost as high as with the "extra" or Russell solution.
But after washing the charge thoroughly with water and removing
all soluble salts and then again taking and leaching a sample, a
vast difference would be found between the assay office "ordinary"
and "extra" extraction. The "extra" extraction on the washed
ore as compared with tests made on the dry ore differed somewhat.
but the "ordinary" extraction on the washed chloridized ore
would sometimes fall as low as the "ordinary" extraction on the
raw ore. Innumerable experiments were made to overcome this
difficulty, and various theories were suggested as the cause of it.
Ferrous sulphate was at one time supposed to be responsible for
the trouble, but repeated tests failed to show the presence of
either soluble ferrous or ferric compounds. The theory proposed
and still adhered to by the writer is that the variations noted are
partly occasioned by the fact that there is present in the roasted
ore a reducing agent in the form of sulphurous acid, either free
or combined. This reducing agent acting on the silver chloride
reduces it to a metallic silver, insoluble in sodium hyposulphite, but
slowly soluble in Russell's "extra" solution. This theory is
strengthened by the fact that when a maximum amount of the air
was admitted into the furnace, thus oxidizing more of the sulphur
in the furnace and allowing less sulphurous acid to be formed at a
lower heat on the cooling floor, the difference between the "ordin-
ary" extraction on the dry and washed ore samples was not so
great as before. The difference in the extraction of the two sam-
ples by the "extra" solution was also less.

   As the pyrites used at this time contained quite a large per-
centage of zinc and lead in the form of blende and galena, it was
thought possibly that all the trouble might be traced to these im-
purities. This supposition seemed to be confirmed when after the

introduction of a purer pyrite results were obtained which proved much more satisfactory; however, while the zinc and lead were responsible for the trouble to a great extent, they were so only in an indirect manner. It is a well known fact that it is far more difficult to roast zinc blende and galena than iron pyrites; consequently, when a large percentage of these minerals is present in the pyrites, more sulphur remains unoxidized in the ore after it has passed through the furnace, and the subsequent chloridizing action on the cooling floor under a limited supply of air necessarily produces a larger quantity of sulphurous acid.

The irregularities mentioned are also indirectly due to the conditions that obtain in the Stetefeldt furnace. If it were possible to obtain a perfect chloridizing atmosphere, or oxidize all of the available sulphur in the ore while in the furnace, the difficulty with the washed ore would undoubtedly be overcome, as there would then be no reducing agent present to affect the silver chloride. Such a condition it is impossible to obtain in the Stetefeldt furnace when roasting ores carrying as much lime as the average ores of Aspen do. The question then arises whether such ores can be roasted better with any other furnace. Metallurgically, the answer is "Yes." The proof of the above assertion with regard to Aspen ores has been demonstrated by the writer, by roasting in a reverberatory furnace ten lots of ore containing 25% of CaO (MgO not determined, but probably amounting to 10 to 12%) with less than 2% of sulphur and using practically the same amount of salt as in the Stetefeldt furnace. The chloridization was all that could be desired, and no trouble was experienced with the washed ore.

By referring to page 7, table 5, in a pamphlet on the Russell process by Mr. C. A. Hoyt, it will be noticed that the average extraction by the "ordinary" at the Blue Bird Mill on six charges of ore was 15·1% below the percentage called for by the assay office test made on the same ore. No doubt the result was due to the cause mentioned above. By referring to page 16, tables A and B, in a pamphlet on the Russell process by Robert F. Letts, it will be noticed that during an actual run of eight months at Yedras, Mexico, the extraction in the mill by the "ordinary" was only 4·97 below the percentage called for by the assay office test, while in a comparative run of three months, using the Russell pro-

cess, an extraction in the mill of 1·18% below that called for by
the assay office was obtained.   On page 6, table 6, of same
pamphlet a run of twelve months is given, constituting the year
1892.   During the last ten months of the run, it will be noticed
that the extractions in the mill were higher in every case than
called for by the assay office tests.   These results were due per-
haps to a better roasting, or possibly to a higher state of perfection
attained by the process.   Undoubtedly, similar conditions would
prove equally favorable to the old process were the comparative
tests to be repeated now.   The point to be established is not the rela-
tive merit of the two processes, but the possibility of obtaining the
same extraction in the mill with the old process or " ordinary " solu-
tion which the assay office test calls for.   The run of eight months
at Yedras, using reverberatory furnaces, has proven that it is pos-
sible to extrac by means of the old process within 5% of what
the assay office test demands.   At the Blue Bird Mill, under dif-
ferent conditions, it was impossible to come within 15% of the
same result, and at Aspen the differences were still greater.   The
only reasonable conclusion to be drawn is that these differences
must be due either to the manner of roasting or to the refractory
nature of the ores, the analyses of which are given below:

	SiO_2	$BaSO_4$	CaO	MgO	Fe	Zn	Pb	Cu	S	As
Aspen	21·7	20·9	11·	4·2	10·	2·9	2·3	0·16	8·1	....
Blue Bird*	64·4	......	......	......	3·7	12·8	4·2	0·20	5·	....
Yedras** ..	· 15·1	......	18·9	2·6	17·3	4·9	1·8	......	13·3	9·8

*C. A. Hoyt on Russell Process at Blue Bird Mill.
**R. H. Letts on Russell Process at Yedras.

The refractory nature of the Yedras ore together with the ex-
cellent results obtained would lead to the conclusion that the dif-
ficulties experienced in Montana and at Aspen ought to be
ascribed to the manner of roasting.

The interesting statement is made by Mr. Letts in the same
paper that the old tailings now being treated by the Russell pro-
cess give an extraction by the "ordinary" in the assay office of
about 35%, but when treated in the mill by the same solution, do

not give any extraction at all. This is probably due to the presence of sulphate of iron produced by long exposure of the tailings to the action of the atmosphere.

The loss of silver by volatilization is a very important item in all chloridizing roasting, but it is a very difficult matter to determine in which furnace such loss is the least, for scarcely any two ores even of the same chemical composition show agreeing results, even when roasted under precisely the same conditions. The results obtained by myself in the past show that the loss of silver by volatilization in muffle roasting cannot be determined by a knowledge of the chemical constituents of the ore.

Mr. Stetefeldt claims that the volatilization of silver is principally a function of time. If the above statement is true, it is one of the strongest arguments in favor of the Stetefeldt furnace. Experiments made to determine this point proved that time was an important function under certain conditions, but not at all under all conditions. There is another factor which, so far as I know, has never been mentioned in connection with the loss of silver in chloridizing roasting, which factor is air, or oxygen. That oxygen is one of the principal, if not the principal cause of the volatilization of silver in chloridizing roasting, is believed by the writer for the following reasons:

It is possible to volatilize from 40 to 60% of the silver contents, in an ore in a chloridizing roast conducted in a muffle at a low red heat, in fifteen to thirty minutes. The same ore roasted at the same temperature with the same percentage of salt on a commercial scale in a large furnace under the worst conditions would not show more than one-third of the loss sustained in the muffle, while under the best conditions the loss would in all probability not exceed one-tenth of that experienced in the muffle. The time required for roasting in any large furnace other than the Stetefeldt would be many times that required for the muffle roast. If it can be shown that, with only a momentary exposure of the ore, as is the case with the Stetefeldt furnace, the percentage of silver volatilized is as high or nearly as high as when the ore is roasted for eight hours with the same quantity of salt in a reverberatory furnace, it must be concluded that there are other influences more important than time governing such loss. This

has been found to be the case with the Aspen ores. The average loss by volatilization determined in roasting some twenty-ton lots of ore in a reverberatory was found to be less than that experienced at Aspen where the Stetefeldt furnace is used.

In the above cases the following conditions were the same: Character of ore, percentage of salt used and temperature of roasting. Those not the same were: Time of roasting and amount of oxygen in contact with the particles of ore during the time the chloridizing action was going on.

Time only increases the volatilization of silver when sufficient heat and air are present. The highest loss was sustained in the muffle where the amount of air used in roasting was greatest. The ore roasted in the reverberatory was just as well chloridized and gave fully as high an extraction as that treated in the Stetefeldt furnace.

It was also noticed at Aspen that some of the lowest losses in silver were experienced during the months when a heavy excess of sulphur had been used and only a limited supply of air allowed to enter the furnace; it was afterwards observed that additional air produced a higher chloridization of the silver, but that the losses by volatilization were also higher. Every indication pointed to the fact that the higher chloridization in the furnace was obtained at the expense of part of the silver. The fact of a smaller loss by volatilization when roasting with a higher percentage of salt can only be explained on the same theory, namely, that the atmosphere enveloping the ore is one of chlorine rather than oxygen. During the strong chloridizing action on the cooling floor, where the ore remains red hot to within a few inches of the surface for two and frequently three days, the loss by volatilization is not perceptible, and samples taken from different parts of the heap at different intervals show no variation in value. It is true that all fumes are condensed and prevented from escaping into the air by the cold crust of ore, and the volatilization might be prevented more by a mechanical than chemical condition.

In chloridizing roasting gold ores, the theory equally holds so far as the agency of air is concerned. The writer has roasted gold ores side by side in Bruckner and Howell-White furnaces with the

same percentage of salt in each. One of the Howell-White fur-
naces was built in front of the other and the ore allowed to pass
through both. Nearly all the sulphur was driven off in the first
furnace. The salt was added to the hot ore as it was being fed
from the first furnace into the second, where it was roasted for a
little over an hour. In the Bruckner the salt was added to the
raw ore and the charges roasted from 8 to 12 hours. The volatili-
zation of gold was the heaviest in the Howell-White furnace where
undoubtedly each particle of ore was more frequently exposed and
longer in contact with the air than in the Bruckner furnace. The
same ore, when roasted in the muffle with the same percentage of
salt at a low red heat for 15 to 30 minutes showed nearly ten times
as great a loss in gold by volatilization as was experienced in the
practical operation.

It is evident from the above statements that determinations
of the volatilization of silver and gold by chloridizing a few hun-
dred grams of ore in a muffle are not apt to be very reliable. Ac-
cording to Mr. Letts, Yedras ore is now being roasted in the rever-
beratory furnace at a loss of only $6\frac{1}{2}$ to 7% of the silver.

LEACHING.

After all the chloridizing action has ceased on the cooling
floor, the ore is spread out in a layer about a foot thick so as to
enable it to cool quickly. The temperature of the roasted ore as
it is charged into the ore vat should not exceed 300 degrees Fah-
renheit. At the Marsac Mill at Park City, Utah, this expensive
cooling of the ore is not necessary, as the chloridization is practi-
cally completed before the ore leaves the furnace. There, when
ready to charge a vat, the red hot ore is frequently wet down and
cooled by simply turning on the hose, without, according to state-
ments made, in the least endangering the subsequent extraction of
the silver. However, it must be remembered that the ore used at
the Marsac Mill is highly silicious, contains practically no lime or
magnesia and less than 1% of sulphur, thus making it possible to
obtain an ideal chloridizing atmosphere in the furnace whereby
no unoxidized sulphur can remain in the roasted ore to exert a
subsequent reducing action on the chloride of silver. At Aspen

part of the cooling floor is in the open air; a heavy rain penetrating only a few inches into the hot ore pile on several occasions caused quite a perceptible decrease in the subsequent extraction of the silver, part of which, however, must have been caused merely by a cessation of the chloridizing action' then going on. Steam, generated by wetting down red hot ore, has been thought to exert a reducing action on chloride of silver, but as such action has not manifested itself in wetting down the Marsac roasted ore, the theory is hardly tenable.

The mechanical difficulties in leaching chloridizing roasted ores have been successfully overcome. At Aspen in all probability the ore is crushed finer than anywhere else in the world where lixiviation is carried on. A mechanical analysis of the Aspen ore delivered from the battery usually shows from 85 to 90% finer than 150 mesh to the linear inch. The rate of leaching on this product after roasting is frequently from 12 to 15 inches per hour.

The operations of leaching by the Russell process may be summarized as follows: Preliminary washing of the ore to remove all soluble salts; first treatment with "hypo" or "ordinary" solution, followed by the Russell or "extra" solution, and again by another "ordinary" solution. With well roasted ores, such a treatment should be sufficient; a majority, however, require a second application of the Russell solution, followed by an "ordinary." Very poorly roasted ores may even require a third Russell solution, followed by an "ordinary." The last "ordinary" is always succeeded by water so as to displace and not lose the "hypo" solution remaining in the charge. The strength of the "hypo" solution generally used is from 1·5 to 2%. The "extra" solution contains from 0·10 to 1% of copper sulphate, according to varying circumstances.

The same Russell solution can be used with some ores a second time or "circulated," as it is termed; with others, again, the circulating is not only of no advantage, but a positive injury, as this solution has been known to redeposit in the charge part of the silver dissolved in the first application. In certain cases where deep and heavily alkaline charges are treated, it is sometimes found that a solution will dissolve a large part of the silver from the top of the charge, but before coming out at the bottom will

re-deposit it; this is evidently a clear case of precipitation as it is known that caustic lime, will, under certain conditions, precipitate the silver from solutions of "hypo" and "extra," and when once so precipitated, presumably as oxide of silver, the "ordinary" has very little dissolving action upon it. The Russell solution will, however, re-dissolve most of it if enough is used and sufficient time be given.

The time required to leach a charge of sixty tons, from the time the ore is charged into the vat until it is sluiced out as tailings, is generally from three and one-half to four days.

The writer discovered while at Aspen that the addition of a small quantity of soda ash (commercial carbonate of soda) to the first wash water produced a much better extraction of silver by the sodium hyposulphite solution. In explanation of this action it may be said that silver ores frequently carry from one to two-tenths of a per cent. of copper, part of which is soluble in water after roasting. In the ordinary preliminary washing of the ore, the soluble salts of copper are all removed, but if sufficient soda ash is present in the wash water, the copper is precipitated, to be again dissolved to a large extent by the "hypo," forming a cuprous hyposulphite or Russell solution.

Where lead is contained in the ore some of it will dissolve in the solutions and thus contaminate the silver sulphides unless previously removed by soda ash. The removal of the lead occasions no difficulty even if the solutions are saturated with lime; however, in such cases, the precipitation must be done carefully so as not to precipitate too much of the latter. A good fractional precipitation can be obtained by adding the soda ash by means of a sieve, and at the same time agitating the solution by passing air through it. In this way the lead is precipitated first, and if the precipitation is stopped at the proper time, very little lime will be thrown down.

PRECIPITATION.

The precipitation of the silver is effected by means of sodium sulphide. This can be made at the works from sulphur and caustic soda, or obtained from Germany, where it is obtained as a by-product. In case it is made from caustic soda and sulphur

according to the directions given by Mr. Stetefeldt, the compound sodium bi-sulphide is formed. The German product is practically pure sodium mono-sulphide. The mono-sulphide naturally pre-cipitates sulphides of higher grade, but on the other hand, seems to cause a greater consumption of "hypo" per ton of ore treated.

Mr. Stetefeldt claims that there is always a certain amount of sodium hyposulphite obtained as an oxidation product in the man-ufacture of the bi-sulphide. Careful tests made by the writer on several different occasions failed to confirm this assertion, but on an actual mill test of two weeks, the difference in consumption of "hypo" was decidedly in favor of the bi-sulphide or home-made product.

In the precipitation of the wash water a curious fact was noticed, which, while not new to chemistry, had probably never before been made use of in practice. The sulphides obtained from the wash water containing the soluble salts were of a very low grade, frequently not exceeding 2,000 ounces of silver per ton. The writer several years ago made a few laboratory experiments with the precipitated sulphides of copper, lead and iron on chlor-ide of gold solutions, and found that all three precipitated the gold in the form of sulphide. Percy states that certain of the base metal sulphides act in a similar manner towards chloride of silver. With this idea in view, the tanks containing the wash water sulphides were allowed to stand for six or seven weeks before taking out any of the precipitates. All the wash water during this time was precipitated in these tanks. After each precipita-tion the sulphides were allowed to settle and the solution carefully decanted off. When the sulphides were finally taken out, dried, sampled and assayed, they were found to contain nearly 7,000 ounces of silver to the ton, showing conclusively that a reaction had been going on by which part of the metals of base sulphides were gradually converted into soluble chlorides, for which an equivalent amount of silver was precipitated.

For the refining of the sulphides obtained by the Russell process three new processes have been recently devised—one by Stetefeldt, tried at Park City and abandoned; another by White-head, and the third by the writer while at Aspen, where a refinery has been built and the process given a practical demonstration.

Mr. Stetefeldt's process has been described in detail by him. The Whitehead process is an ingenious one, and is based on the stronger affinity of sulphur for silver than for copper. The distinctively new feature of the process is contained in the following reaction:

$$Ag_2SO_4 + CuS = CuSO_4 + Ag_2S.$$
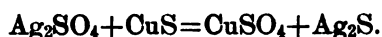
However, as only the copper is removed from the sulphides and the equivalent amount of silver required is very large, the economy of the process is somewhat doubtful.

The third process is based on the following reaction, which is also the only distinctively new feature in it:

$$2H_2SO_4 + CuS = CuSO_4 + SO_2 + 2H_2O + S.$$

Silver and lead sulphides are decomposed by sulphuric acid in a similar manner. These reactions, however, only take place when the sulphides are treated with concentrated sulphuric acid at or near its boiling point. A patent for this process has been applied for by the writer, but lately one has been granted to Mr. F. P. Dewey for the same thing. The future will probably demonstrate who is justly entitled to the priority of the discovery.

CONCLUSIONS.

The following conclusions have been formed with regard to the Russell process:

First: Fine crushing is in many cases necessary and always most desirable.

Second: Stamps are the most reliable and at the same time most economical for fine crushing; while rolls are generally preferable to pulverizers.

Third: The furnace best adapted for chloridizing roasting silver ores depends at all times upon the character of the ore. The Stetefeldt furnace is probably the most economical furnace for ores high in silica, free from lime and magnesia and low in sulphur, in other words, ores of the character of those roasted in the Marsac Mill at Park City. For ores containing from three to eight per cent of sulphur, the Bruckner, Pearce or Howell-White

are to be recommended. For ores containing over eight per cent of sulphur, unless accompanied by a large percentage of lime, the reverberatory or a combination of two furnaces, the first of which should be devoted exclusively to an oxidizing roast, will be found to be the most economical.

Fourth: The loss by volatilization is principally a function of time and amount of oxygen in contact with each particle of ore while in the act of chloridizing.

Fifth: The leaching of the ore depends to a great extent upon the roasting of the same. A poorly roasted ore may give a good extraction with the Russell process, but it is at the expense of a large consumption of chemicals and time. Different strengths of solutions and different methods of applying the same will also in some cases improve the percentage of extraction; but with good roasting and a sufficient amount of solution the extractions will be good, no matter how the solutions are applied.

Sixth: The precipitation of the silver by means of sodium sulphide presents no difficulty and is much to be preferred to calcium sulphide.

Seventh: The economical refining of the sulphides at the mill is a problem which is not yet satisfactorily solved.

Eighth: That the Russell solution is capable of dissolving certain compounds of silver which cannot be dissolved by means of sodium hyposulphite alone has been amply demonstrated. It is also known that the Russell process is capable of extracting from 90 to 95% of the silver in ordinary dry ores where the silver is not present in the metallic state; but that a high extraction of the silver will not necessarily make the process a commercial success in all cases is shown by its rejection several years ago by the Blue Bird Mining Company near Butte, Montana.

The greatest objection against the Russell process is the cost of treating the ore. A very expensive plant is always required. The loss in roasting is also a serious matter, but not any more so in this process than in any other where chloridizing roasting is required. Notwithstanding these objections, there is no question but that there are numerous localities in this western country where the introduction of this process would prove a profitable investment, the statement being based on a cost of treatment of $10

per ton for a mill of 100 tons daily capacity, and $12 per ton for a mill of 50 tons daily capacity, with a minimum extraction of 90% of the silver, in comparison with current smelting rates on dry ores with added freight charges.

CERTAIN DISSIMILAR OCCURRENCES OF GOLD-BEARING QUARTZ.

BY T. A. RICKARD.

COINCIDENCE OF THE PITCH OF AN ORE-CHUTE WITH THE INTERSECTION OF LODE AND COUNTRY.

No feature of vein mining offers more perplexing problems than the uncertain behavior of ore-chutes. Occasionally, the evidence obtained from underground surveys indicates the pitch in a particular direction of the successive ore bodies of a particular mine; but the deductions which are then made may prove as dangerous and delusive as they often are practically useful.

In a little mine among the Australian Alps there was afforded me a very striking illustration of the dependence of ore-deposition upon the geological structure of the country rock. At the "Shouldn't Wonder" mine, seven miles from Bright, Victoria, the country rock is of Upper Silurian age, and consists of altered slates and sandstones having a varying dip to the southwest and a strike 35° to 50° west of north. Though these rocks show the changes due to metamorphic action, and exhibit a well developed cleavage, yet the bedding has not been obliterated. The lode of the mine is a quartz vein, having a strike 28° west of north and a dip to the northeast of 75° to 78°. The width of the lode is fifteen to twenty-four inches, and consists of simple, gold quartz containing a very small but varying percentage of pyrite. Occasional faults occur, which are called "heads" by the miners, and have a throw to the left. The break which they cause is clean, and there is no difficulty in again picking up the lode beyond the fault.

The plane of the lode cuts across the bedding of the country

rock, and the vein is therefore what is commonly called a "true fissure." The examination of the foot-wall shows that the bedding planes are marked by lines having a dip 42° south. While the foot-wall is more regular than the hanging, and indicates this feature best, yet the face of the latter carries lines which correspond to those occurring on the opposite wall.

The sketch (on Plate I) will illustrate the face of the foot-wall. A A, B B and C C are the bedding-planes. A small quartz seam follows the parting at C C, while D D is a minute cross-vein traversing the country independently of its stratification.

The country has a dip 79° southwest and a strike 55° west of north. The line of intersection formed by the crossing of the planes of stratification and the lode-fissure was found to make an angle of 46° south, as indicated by the foot-wall. Upon referring to the longitudinal section of the underground workings, it was found that this angle coincided with the pitch of the ore bodies, as worked in the four successive levels of the mine.

At the "Myrtle" mine, a few miles further south, there was the same correlation between the pitch of the ore bodies and the line of intersection of the wall of the lode with the bedding-planes of the enclosing country. The stratification was distinct, the rocks consisting of altered, often very silicious, slates of a gray to gray-blue color. At the 700-foot level the country had a dip of 80° southwest and a strike 46° west of north, while the vein dipped 70° northeast and had a strike of 20° west of north. The quartz vein was two and a half to three feet wide. In the stopes above this level, the pay ore was separated from the valueless quartz by a small step, due to the irregular fracture of two beds of slate of unequal hardness. The miners had considered this a small fault. It marked the line of intersection between lode-plane and country bedding.

This particular ore-chute was eighty-five feet long and of variable gold contents. The quartz contained a large proportion of included fragments of country rock, giving the ore a mottled appearance. The gold was fine, often forming a gilded mosaic upon the faces of fractures.

In the different parts of the mine, the changing dip of the country produced variations in the angle of the lines of intersec-

tion, which varied from 35° to 55° south.   The general pitch of the ore bodies of the mine, as worked to a depth of 700 feet, was found to be 45° south.

THE OCCURRENCE OF ORE AT THE INTERSECTION OF BANDS OF DECOMPOSED COUNTRY ROCK.

I must ask you now to leave Australia and go to the north island of New Zealand. The gold mining district of Hauraki— also known as the Thames—offers many interesting studies in ore deposition.   The country rock of the mines is an andesite breccia.[*] It shows a certain rude stratification, and is characterized by the occurrence in it of bands of decomposed rock—often termed "sandstone" by the miners—in which it is difficult to recognize the true character.   In many ways the lode formation and mineral occurrence of this district resemble that of the gold fields of Transylvania (Hungary).

At the "Moanataeri" mine, at the 200-foot level, I obtained the sketch given on Plate I.   The structure of the country rock is indicated.   A B consists of a series of small quartz seams, called "leaders," overlaid by hard, reddish-brown andesite, and under-laid by a similar rock whose brecciated structure is more evident. C D is a band of soft, gray, decomposed rock which cuts across the structural lines of the country and contains a number of veins of quartz, but only near its crossing with A B.   The line of C D is parallel to that of a main fault seen in other workings.   The leaders in the band A B are gold-bearing, particularly near their intersection with C D.

In the main adit, 108 feet deeper, the lode known as "No. 9 Reef" presents the appearance shown in the upper drawing on Plate II.   This is taken in horizontal section as seen along the roof of the tunnel.   A band (D D) thirteen inches to two feet wide, of granular, gray rock, traverses a dark reddish-brown andesite whose brecciated character is more evident on one side (A A) than on the other (C C).   In this gray band (D D) which constitutes the lode there are dark seams of flinty quartz, accom-

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[*] Much resembling the enormous masses of andesite breccia characterising the geol-ogy of certain districts in the southwestern mining regions of Colorado.

panied by frequent cavities or vugs. In the encasing country there are numerous veins of zeolites.

The mine workings disclose a series of such bands of decomposed country, seamed with quartz streaks varying in width from that of a sheet of paper up to three or four feet. The gold is particularly patchy in occurrence, and is found in the form of filaments and threads of minute size distributed through a matrix of very hard, dark quartz, especially when the latter is cavernous.

At the "Saxon" mine, the main lode has a better definition, and a more regular course than is usual in this district. Its width varies from eight or nine inches to three or four feet. The cross section, given on Plate II, shows a certain laminated arrangement. B is the ordinary andesite country rock. A A is a white to yellow-white granular tufaceous material called "sandstone." It consists of much decomposed andesite. C C is the "motley" of the miners. It consists of andesite, altered, much brecciated and mineralized. A is altered andesite, with zeolite veins. D D is the main streak of pay ore, and consists of small veins of white cavernous quartz arranged in a general matrix of white sugary material.

At another mine, the "Waiotahi," we have another illustration of the vein structure. (See Plate III.) Here C is the ordinary country rock. B B is a band of the same, but much decomposed and altered to a gray, granular material. A A is the "main reef," consisting of a vein of quartz five to eight inches wide, characterized by cavities distributed along its center. D is also andesite breccia, which is traversed by a series of small quartz seams (E E), the largest of which are nearly at right angles to the "main reef." The formation resembles a "stockwerk," since the whole mass of country adjoining the more regular vein (A A) is streaked with quartz seams sufficiently auriferous to make it profitable to mine them.

In general it may be said of the main reefs or lodes of this district that they have a course similar to that of the mineralized belts of which they form a part. These belts are bands of soft, decomposed country having a variable width and hardness. The harder portions can not be said to be non-auriferous, but, as they are more costly to mine, they are left to one side. Where portions

of hard, less altered country meet the softer lode formation it is
not unusual to find that the quartz reefs deviate from their straight
course and go around, rather than through, the hard bar of coun-
try rock.

My investigations into the geology of the district were insuf-
ficient to permit of an attempt at any detailed description. But
the evidence obtainable in the mines, and the examination of nat-
ural sections along the sea shore, and in the gullies of the neigh-
boring hills, indicated that the prevailing country rock of the aurif-
erous area was an andesite breccia, and that it has been laid
down in water. It has a certain rude stratification and is overlaid
by mudstones and slates. It seems probable that the breccia
formation owes its existence to the fragmentary eruption of masses
of andesite, which, falling into a shallow body of water, such as an
estuary, became subsequently consolidated. The bands of "sand-
stone" and "felsite" found in the mines are probably volcanic tuff
and ash, which have also been deposited under water. The occur-
rence of overlying mudstones and slates is confirmatory of this
supposition. The later formation of the lodes of the region
appears to be due to the effects of lingering igneous agencies.
The belts of decomposed country, the character of the country
rock, the strongly mineralized underground waters, the behavior
of the quartz seams and the neighborhood of an active volcanic
region (at Rotomahana and Tarawera, further south), all suggest
the origin of the lodes as due to the work of solfataric agencies.

This gold field, though now no longer of any considerable im-
portance, must yet be ranked among the most extraordinary dis-
coveries of the century. The ore is often of very remarkable rich-
ness. At the "Moanataeri," in 1878, 5,400 pounds of quartz pro-
duced 14,600 ounces of gold, being at the rate of over two and one
half ounces per pound of ore. In the year 1871 the "Caledonia"
mine paid three million dollars (£600,000) in dividends, produc-
ing ten tons of gold in eleven months. These figures speak for
themselves. Later exploration has proved that the ore does not
continue so rich in depth as it was nearer the surface, and that
the horizontal development of the mines is more profitable than
the extension of the workings in depth.

OCCURRENCE OF A RICH POCKET OF GOLD ORE AT THE CROSSING OF A FAULT PLANE.

The "pockets," or extremely rich patches of gold-bearing quartz, which are found in certain lodes of the main Californian gold belt, more particularly in Calaveras and Tuolumne counties, offer many points of interest. The gold is often intermixed with so little quartz as to resemble a nugget; differing, of course, from the latter in the absence of water-worn edges and by its more filiform, spongy structure. It was long supposed that no gold had been found in quartz reefs in pieces such as would explain the derivation of the larger nuggets by the degradation of pre-existing quartz lodes. In these "pocket" mines, nevertheless, there have been found occurrences of gold quite able to account for the largest nuggets which have yet been found in California. It must not be understood, however, that in making this statement of fact I would wish to uphold the origin of nuggets as due to purely mechanical agencies.

At the "Rathgeb" mine, near San Andreas, there was found one of these "pockets." It may be premised that the main lode of this mine has an augite schist (a very beautiful rock in which the augite is porphyritically disseminated) on the foot-wall, and a more compact and massive rock, approaching a diabase, on the hanging.

The zone of oxidation has a depth of about 160 feet; below this, the lode is large and poor, consisting of white, massive quartz; but above the water level the vein is replaced by a network of quartz seams of varying sizes. Those having a regular strike to the northwest represent the main lode, while the smaller, more irregular cross-veins may be considered as "feeders." (See Fig. 2 on Plate III.) Where these veins intersect there have been found bunches of rich quartz containing gold in a coarse form. I will describe the mode of occurrence of the richest pocket which was found during my stay at the mine.

At the 120-foot level (south) and about 150 feet from the shaft there were some old workings, and upon an examination of these there was noticed a small cross-vein one-sixteenth of an inch thick, the red clay filling of which showed a great deal of free, fine

gold when washed in a pan. A miner, experienced in "pocket hunting," was put to work at this place. The small streak, while it was generally very "slim" in size, yet occasionally opened out into small lenticular openings, yielding a clay in which the gold was as the raisins in a pudding, though also mixed with quartz, some adhering, some merely fragmentary. Each pocket yielded gold worth from one to five hundred dollars. At length this cross-vein widened to six or eight inches and looked like an ordinary quartz lode of more than ordinary richness, but not up to "pocket" standard. The amount of red clay began to increase, it became daily more gold-bearing, and a rich discovery was hourly expected. It was duly found. The vein became faulted, and at the place of the fault there was a soft, spongy, wiry mass of gold and clay— more gold than clay. The first handful which I broke while yet the stope was obscure with powder smoke contained three ounces of gold. Within the next two hours that pocket gave us $3,000 worth of gold, and in the days that followed it yielded over $20,000, obtained at an expense of less than $200. When it had been worked out, it was easy to study its mode of occurrence. The sketch given in Fig. 1, Plate III, will explain. The vein had been faulted about its own width, namely, ten inches, and along the recess so formed the nest of golden material was found. A few feet overhead the vein met with another cross-vein which bounded its extent in that direction, while below it narrowed to the width of a knife blade.

The gold was spongy and accompanied by a certain amount of quartz which filled the interspaces. The clay which covered the gold and quartz was partly red, ochreous material and partly a gray, gelatinous, silicious matter. The gold, when washed, sold for $18 per ounce. The quartz associated with it carried pitch-blende (uraninite) in needle-shaped crystals, which, immediately adjacent to the gold, became yellow uranium ochre. The association of gold and uranium is uncommon.

ORGANIC MATTER AS A PRECIPITANT OF GOLD.

Leaving California, let us return to the southern hemisphere. In the colonies one often hears of the "indicator" of the Ballarat mines. In the underground workings of the "New Normanby," I

had an opportunity of examining it. The country rock is Lower Silurian, as proved by the *Graptolites*, and consists of slightly metamorphosed slates and sandstones, thinly bedded and having an easily recognized stratification. The strike is nearly due north, while the dip is almost vertical and to the east. The "indicator" conforms to the bedding, and consists of a thin seam of black slate. It has become a very notable feature of the mines of Ballarat East, because its crossing of other veins is frequently coincident with the occurrence of gold-bearing quartz of great richness.

At the 700-foot level of the "New Normanby" mine, the breast of the drift appeared as shown on Plate IV. The thick black line is the "indicator." It deviates from the vertical five feet in 100 feet, and separates a sandstone from a slaty rock. The adjoining country is "ribboned"—that is, it consists of closely alternating, thin beds of slate and sandstone of varying shades of color. Both country rock and "indicator" are disturbed, and slightly dislocated, by the crossing of certain flat veins, or spurs of quartz. Near the crossing, these veins are highly auriferous and consist of very white, brittle quartz carrying free coarse gold.

The thickness of the "indicator" varies; so does its composition. In the above mentioned drift it is about one-sixteenth of an inch, and carries pyrite and crushed, black slaty material. In the cross-cut, at the same level, it contains a small seam of quartz. In an adjoining mine—the "Prince Regent"—it is one-quarter of an inch thick and carries pyrite and black clay. When the black clay, or black slate, is replaced by quartz, the occurrence of rich ore has been found by experience to be less probable. At the surface this part of the Ballarat district was extremely productive. Between the "New Normanby" and the next mine to the north —the "North Woah Hawp"—the line of the "indicator" is crossed by an alluvial lead, known as the "Canadian," and near the crossing there were found a large number of the nuggets which made Ballarat so famous early in the "fifties."

The "indicator" may be considered as a bedded vein, in that it follows the stratification. An inquiry into the reasons which render its near neighborhood so favorable to the occurrence of highly gold-bearing ore would offer much matter for interesting discussion. It is probable that this thin seam of black slate, of

PLAN
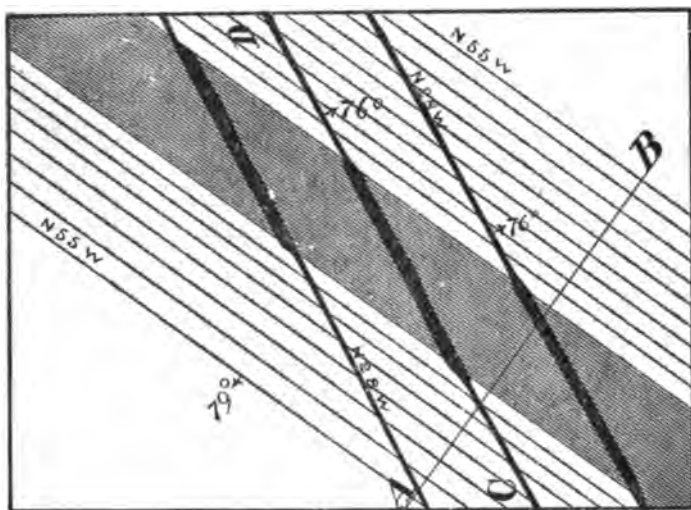
SEC.   **A — B**

which the "indicator" consists, represents a layer of fine silt, full
of the remnants of vegetable life which was laid down upon the
floor of the Silurian sea. The organic matter so derived afforded
a reducing agent for the precipitation of the gold from mineral
solutions circulating through the fissures and fractures which
traversed this particular part of the district.

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In presenting the foregoing brief notes, descriptive of certain
ore occurrences in the gold-bearing veins of mining districts so
widely separated, the writer has not aimed so much to call atten-
tion to any new economic features in this special class of ore de-
posits, as to afford evidence of the fact of the great variety of the
modes of occurrence of gold-bearing quartz, and to emphasize the
consequent danger of attempting to take a theory applicable to
one district and apply it to another region far distant and of
entirely dissimilar geological structure.

DISCUSSION.

Mr. Philip Argall:—The coincidence of the pitch of an ore-
chute with the line of intersection of the planes of stratification
of the country rock and lode fissure, appears to me to be an un-
doubted proof of the favorable influence of certain zones of coun-
try rock on the deposition of ore in veins.

Probably no phenomena of vein formation have been more
carefully noted or more often described than this "influence of
the country rock on the deposition of ores in veins." It may,
however, be permissible to quote briefly some authorities bearing
directly upon the subject.

Muller, describing the Freiberg ore deposits,* states:

"The lodes in general, without distinction in regard to the character of
the formation, have attained a development favorable to mining only within

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* Gangstudien 1, page 209; Von Cotta, pp. 50-59.

compact rocks, in which feldspar or quartz, hornblende, pyroxene, as also carbon (graphite, anthracite), form an essential ingredient."

W. J. Hemwood, in describing the metalliferous deposits of Cornwall,[*] states:

"The lodes are closely related to the rocks immediately adjoining them. Their structure, like that of the rocks, seems in some measure dependent on their mineral characters. * * * * * Most bodies (courses) as well of tin as of copper, have within their respective lodes an endlong dip or chute, which usually approximates to the contour and bedding of the neighboring granite, and to the inclination of the cleavage-planes in the adjacent slates. In each of our several mining districts, the lodes are productive on similar lines taken at right angles to their respective directions, hence the phrase, 'ore against ore;' but, as the direction of the lodes varies in different districts, the direction of these productive lines is not always the same."

Professor Moissenet, in his extremely valuable publication,[†] also gives this matter a careful analysis, terming the coincidences observed by him the "influence of parallelism, or *vis a vis* of riches in lodes nearly parallel."

J. H. Collins, in describing the lodes of Cornwall,[‡] states:

"That some lodes have copper ore only in slate, and tin ore only in granite and at the "Botallick" mine one of the lodes was found to pass three times from granite to slate, or the reverse, containing none but tin ore in the granite, and none but copper ore in the slate."

The classic example of the influence of the country rock on the deposition of ore in veins is found at the famous "Kongsberg" mine, in Norway, discovered in 1623, and worked almost uninterruptedly since. The silver veins are found most productive in certain belts of rock called fahlbands, which are irregular in their dimensions; the greatest thickness recorded being 1,000 feet. They are parallel in strike and inclination with the gneissoid and schistose strata in which they occur, and are subject to the same local disturbance of stratification. These fahlbands are traversed by fissure-veins containing silver ores, and long experience has shown that these veins are productive *only* where they intersect the fahlbands.

The example given by Mr. Rickard is interesting, inasmuch

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[*]Journal of the Royal Institute of Cornwall, No. XIII.
[†]Observations on the Rich Parts of the Lodes of Cornwall
[‡]Proceedings Institute of Mechanical Engineers, 1873, Penzance meeting.

as it shows that at least one of the observed laws relating to the deposition of ore in veins in the Northern hemisphere has a further confirmation from the antipodes. It also furnishes an excellent illustration that the aphorism, "ore against ore," is only true when the dip and strike of the favorable beds are taken into account.

To make this clear, I show in plan, Plate V, a series of slate beds and mineral veins having the direction of those indicated by Mr. Rickard as occurring at the "Shouldn't Wonder" mine, but I have marked in fine lines one particular bed, which we will assume to be a favorable zone for the deposition of ore in the veins; the ore-chutes will, therefore, be limited to this particular zone in which I have shown them as enlargements of the veins. Now, it will be seen from the plan and section A B that, if a cross-cut is projected from an ore-chute on one vein, on the theory of "ore against ore," it will reach the objective vein in an unproductive place. The section C D shows the dip of the ore-chute in the vein, as indicated by Mr. Rickard. This dip of 45° southerly is that of the line of intersection of the lode and the favorable zone of country rock.

I have seen many cases of "ore against ore" in parallel veins in eruptives, an example being the "Kapanga" mine, New Zealand. Here, two parallel veins have the same dip (33°) and are separated by eighty feet of tufa. The ore-chute in the "Kapanga" vein was found to fairly correspond with that in the parallel "Scotty's" vein, and what is more curious, the rich ore in both chutes ceased to exist at about the same depth from surface, thus, as it were, proving the correctness of the theory ("ore against ore") in both directions. I could not detect any change in the country rock along the course of the veins; the same rock formed the walls of the ore-chutes, and also the walls of the unproductive part of the veins.

The Gympie Reefing Fields, in Queensland, described by Jonathan C. B. P. Searer,* are remarkable for the fact that the lodes depend upon the character of different bands of rock they pass through for the extent to which they are auriferous. Bands

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* Origin and Mode of Occurrences of Gold-Bearing Veins. Journal of the Royal Society of New South Wales. No. XXXI, 1887.

of black slate occur with diorite and other rocks, and it is in the *black slate* that the lodes contain most gold, being comparatively poor in other parts. Four bands of this black slate are known to exist, and so dependent are the reefs on it that the miners first sink to cut the slate, then drive to where a reef passes through it and start to work the lode at that place.

While not able to discern many features in common between the lode formation of the Hauraki District of New Zealand and that of Transylvania (as described in the books), I recognize in the section of the "Waiotahi" mine a typical illustration of the veins of the Hauraki District. The reef A A is particularly good; the band B B is often in the nature of a gouge containing quartz fragments (auriferous when near a pocket) embedded in a soft, unctuous clay. The quartz seams E E are, however, not very common, and I have seldom seen them rich enough to pay for treatment.

I regret very much that Mr. Rickard has not called attention to the minerals associated with the gold in the reefs of the Hauraki District, particularly to arsenic, both in the native state and as arsenical pyrites; also to the tellurides. Had he done so, we might have learned something new regarding the occurrence of those associated minerals.

In the "Coromandel" mines the gold is extremely bunchy, the vein quartz seldom pays to crush unless free gold is visible, and when it is visible, the picked stone is usually estimated at ounces of gold per pound of quartz, instead of per ton; the two and one-half ounce per pound returns given in Mr. Rickard's paper are not at all unusual. I, myself, have seen many lots of picked quartz that ran from three to five ounces of gold per pound, and small lots that contained seven ounces. So coarse is this gold that the mill-dirt from rich pockets will seldom run over two ounces per ton of rock, showing how easy it is to pick out the gold by hand. The veins are perhaps best described as specimen veins.

Native arsenic occurs very frequently associated with rich gold-quartz in the Coromandel District, and arsenical pyrites is very abundant. Green chloritic minerals are also common in association with the richest gold pockets, particularly when the pocket is near a veinlet, dropping in from the hanging wall.

Arsenic in one form or another is concomitant with gold in all the deposits I have any knowledge of, and where arsenical and iron pyrites occur in a gold vein, the former is invariably richer in the precious metal.

Sometimes the arsenic minerals in gold veins are not at all apparent, as for example, in the Gilpin County ores. In this connection Mr. Richard Pearce, of Argo, states:[*]

" In an almost daily examination of these ores for eighteen years, I have never seen but one small characteristic specimen of arsenio-pyrite; nevertheless, in roasting Gilpin County ores an appreciable amount of arsenic is always found, so that arsenic may be said to be present in these ores in some form which does not make itself manifest as belonging to any mineralogical species, but rather as an accessory impurity."

Chlorite and chloritic schists are also closely associated with rich gold deposits, as, for instance, at the "El Callio" mine, in Venezuela. Telluride minerals are also found in most gold veins.

It is an undoubted fact that organic matter may act as a precipitant of gold, from its mineral solution. The example given by Mr. Rickard in the "indicator" is as instructive as it is interesting. I would particularly call attention to the enrichment of the quartz in the neighborhood of the graphitic clay seam, which is, I believe, rather unusual outside of Victoria. The series of lodes in California called by courtesy the "mother lode," do not, I believe, show any enrichment in the slates; they are, in fact, equally as rich and as poor in slates, in diorite or in serpentine. It has been observed, however, that in slate the lode is almost entirely composed of quartz, while in serpentine a considerable amount of gangue is invariably included in the vein.[†]

Professor Silliman has found tellurides of gold and silver abundant in some portions of the mother lode, while he gives the name "mariposite" to a green, scaly mineral which is very characteristic of the lode. Ribbon quartz—that is, quartz having alternating streaks of quartz and a dark-colored mineral, is usually richer in gold than the ordinary vein quartz. This dark-colored mineral is itself rich in gold, and is of varying composition. It may be a thin film of slate; very often it is graphitic material,

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[*] Transactions A. M. Institute Mining Engineers, Vol, XVIII, p. 448.
[†] Tenth Annual Report California State Mining Bureau.

while, according to J. A. Philips, it is, in the California quartz veins, sometimes roscoelite—a micaceous mineral containing over 28% vanadium oxide.

Black graphitic shale is sometimes, however, unfavorable to the enrichment of mineral veins, an example being the cupreous iron-pyrites lodes of Wicklow, Ireland, where the lodes are very bunchy and unusually unproductive in the "coal ground" of the miners. I have very often found pyrites in spheroidal forms in this graphitic shale, and occasionally native copper in the laminæ.† In this connection I made some experiments with the mine water (which held copper and iron sulphates in solution), looking towards the reduction of the copper by the shale. My experiments, however, were only successful when the pieces of shale were immersed in the mine waters in contact with pieces of metallic iron. Under these conditions I secured a beautiful deposit of metallic copper on the shale, due, no doubt, to the galvanic current generated.

Mr. T. A. Rickard:—In the course of his very interesting contribution to the discussion, Mr. Argall made reference to the mother lode of California, and he quoted a remark made by a writer (Mr. H. W. Fairbanks) in the Tenth Annual Report of the State Mineralogist. I do not know upon what facts is based the statement that the veins of that region are equally rich whether they traverse slate, diorite or serpentine; but a two year's acquaintance with the lode structure of the best developed portion of the gold belt—the counties of Amador and Calaveras—induces me to offer the following observations: There is a noteworthy relation —call it coincidence, if you will—between the character of the country rock and the richness of the quartz veins which it incloses. All along the series of extensive and productive mines, stretching for twenty miles from the Cosumnes to the Mokelumne River, the country rock is a black slate. The vein-filling is also of the same character. The lodes rarely occur in the diabase, but rather in the black slate at or near its contact with the "greenstone" dykes. On the table you will see a piece of ore brought by me from the "Wildman" mine at Sutter Creek, Amador County. It is quite

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† Scientific Proceedings Royal Dublin Society, 1879, p. 219.

typical of the low-grade ores of the mother-lode region, and exhib-
its the ribbon structures and graphitic slate casing, both thor-
oughly characteristic of the productive veins.

That "the lodes in the slate are almost entirely composed of
quartz, while in the serpentine there is a considerable amount of
gangue invariably included in the vein," is a statement which I
cannot corroborate. If the lodes of the main gold belt of Califor-
nia have one feature more marked than another, it is the inclusion
of country rock and the ribbon structure so produced. In this
respect, the lodes occurring in slate are certainly no exception.
May I mention a personal experience? A mine whose lode was
massive, white quartz, occurring at the contact of an augite schist
and a diabase, was found poor indeed; but another lode only a
thousand feet further east, occurring in a black slate and car-
rying quartz ribboned with inclusions of country rock, was found
to be far more gold-bearing than its neighbor. This one experi-
ence was confirmed by observations made elsewhere in the same
region since that time, and also by the experience of the oldest
mine managers with whom I discussed the matter. All veins in
black slate are not richly gold-bearing, but most of the rich lodes
are in black slate, and an unnumbered quantity of veins in green-
stone and schist have been found worthless. That is as near to a
generalization as I dare venture.

The Thames Mining District, whose lode structure I have
briefly described, has a geological connection with the Hot Lake
region of Rotorua, about forty-five miles distant. At Rotorua, at
one time famous for its lovely pink and white terraces, there are
numerous thermal springs, geysers and fumaroles. The surround-
ing plain is largely covered with fragmentary andesite and rhyo-
lite. This material is for the most part loose and unconsolidated.
Near the edges of the fumaroles, however, it has become cemented,
and then very much resembles the country rock of the mines of the
Thames. Further, the rims of the fumaroles show products of
decomposition identical in character with those observed near the
lodes, and which have been referred to as the soft and granular
material, often called "tufaceous sandstone" by the miners.

While at the Thames the andesites are usually brecciated, it
must be added that solid andesite rocks also occur occasionally.

The latter often gradate into the former, and appear to have penetrated through them, re-cementing them. This region very forcibly suggests the relationship observed elsewhere between young eruptive rocks, thermal springs and lode formations. The accurate study of this association of geological phenomena would do much to give us definite ideas on the subject of the genesis of ore deposits.

Turning to the note which I offered on the subject of the Ballarat "indicator," I would wish to refer to a description, which I only saw a few days ago, of a very similar occurrence in a neighboring mining district. In the Quarterly Report of the Victorian Mining Department, for December 31, 1888, there is a description by Mr. E. J. Dunn, a well known colonial geologist, of the "Champion Reef" at Wedderburn. Wedderburn is close to Dunolly and nearly fifty miles distant from Ballarat. This is a part of Victoria celebrated for the large nuggets which it yielded in the early days.

Mr. Dunn gives a vertical section which has many features resembling the sketch made by me in the "New Normanby" mine. He says that "it shows the influence of the band of country rock called the 'indicator' on the productiveness in gold of the intersecting quartz leaders." In parenthesis, I would say that the term "leader" as used here is unfortunate. A "leader" is a quartz vein or seam which "leads" a miner; in this instance, the "indicator" itself is the "leader," and the intersecting quartz veins can be better called "cross-veins." He continues,

"The country rock is of yellow and gray, soft sandstone and clayey beds, having a strike N. 5° W. and a dip 60° to 80° E. One of the beds of rock is of dark gray to black color and from five to seven inches wide, made up of thinly laminated unctuous clay. This is known to miners as the "indicator." At intervals of a few inches to several feet apart are flat leaders of quartz, from a quarter of an inch to one foot thick. These dip to the N. W. at angles ranging from 20° to 30°. Where they intersect the 'indicator,' the latter is generally displaced a few inches. At and near the intersections the quartz leaders become auriferous, and often richly so, the gold occurring in coarse nuggety pieces and frequently of crystalline character. The leaders are barren except at the intersections with the 'indicator,' or of nearly vertical thin quartz veins, called 'droppers' by the miners. A portion of the 'indicator,' on assay, gave only a trace of gold, unweighable, but this result is, nevertheless, regarded as important, showing the actual presence of gold, in however

small quantity, in a particular band of the country rock, in contiguity with which bands the quartz veins are found richly auriferous."

I must ask pardon for so long a quotation, which is only per-missible because the geologist quoted is one of the most accurate of observers, and because it very completely confirms the note which appears as a part of my paper. To that note I may make the following additions: Though at the level where I obtained my sketch the "indicator" is only slightly dislocated by the cross-veins of quartz, yet in other parts of the "New Normanby" mine there are floors or slides which throw it for from twelve to twenty-five feet. These faults have a strike and dip similar to that of the cross-veins. While the latter at the 700- and 800-foot levels have a flat dip to the east, yet nearer the surface they incline west. The "main lode" of the mine, a fissure-vein cutting across the bedding of the country rock, is less profitable to exploit at the lower levels than the line of the "indicator" where intersected by cross-veins, but at surface the fifty feet of country separating the "main lode" from the "indicator" was so richly gold-bearing as to have been all removed by open cuts.

The association of organic matter with ore deposits has been often pointed out. In this instance, the observations above recorded may be summarized by saying that both in the mines of Ballarat East and in those of Wedderburn, places nearly fifty miles apart, gold is found to occur in notable quantities wherever cross-veins of quartz intersect a thin seam of graphitic clay or slate which is conformable with and forms part of the bedded sedimentary rocks.

EVIDENCE BEARING ON THE FORMATION OF ORE DEPOSITS BY LATERAL-SECRETION.

THE "JOHN JAY" MINE, AT PROVIDENCE, BOULDER COUNTY, COLORADO.

BY P. H. van Diest.

About three miles southwest of Jamestown, in Boulder County, is located the "John Jay" mine, which has been worked at intervals with good results.

I desire to describe this vein, because my observations may be productive of an interesting discussion on the genesis of ore deposits.

Geology.

The Laurentian rocks of this region are, for the most part, essentially granites. A gneissic foliation is often apparent and frequently well marked. These rocks form a stratum of great thickness, and are more or less metamorphosed. This metamorphism is associated with extensive folding and with intersecting dykes; the latter occurring principally where contortion was the greatest.

A great anticlinal fold follows the continental divide, forming the west boundary of Boulder County. This fold is flexed, north of Arapahoe Peak, by a synclinal fold with an easterly-sloping axis. It is very prominent near Gold Hill.*

Along the North St. Vrain there is a large anticlinal fold also running easterly, and another occurs between Middle and South Boulder creeks. Diagonally between these main folds two prominent side folds appear; the one with a southerly-sloping axis runs

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*See Map of Boulder County, Proceedings, Vol. II, Part II, opposite page 50.

from Ballarat to Jamestown; the other with a northerly slope runs from Sugar Loaf Mountain towards Gold Hill. The telluride veins of Boulder County are located along the slopes of these sharp and much contorted side-folds; and dykes of pegmatite, or of porphyry, are observed principally in their neighborhood. Following the road from Jamestown to the "John Jay" mine, we cross the apex of the first named of these diagonal folds, and find the outcrop of the vein at its westerly slope.

OBSERVATIONS NEAR THE OUTCROP OF THE VEIN.

The vein has a course of north 30° east, and a dip of 70° towards the west, being very nearly coincident with the strike and dip of the country rock. This country rock is a fine-grained gneiss containing much dark mica (biotite) in layers between the feldspar and quartz. These layers have a foliated, and somewhat undulating appearance. The mass is cross-fractured, and shows in places little slip-planes which, as a rule, cross the stratification planes at a sharp angle. This micaceous granite, or gneiss, is cut by dykes, or veins, of pegmatite; a coarse granite consisting mostly of feldspar with some quartz and rarely a silver-white mica (muscovite). These pegmatite apophyses, the one westerly and the other easterly from the vein, have not the same course and dip as the micaceous country rock. The dip of the dyke running easterly of the "John Jay" vein is decidedly less steep, as is shown by the exposure in a small gully near the south end-line of the claim. The dykes are there about 80 feet apart, spreading as they course northerly, and with a tendency to unite or to cross each other towards the south.

Next to the outcrop of the easterly pegmatite vein, there is a cut made in the bank of the gulch, showing vein quartz and some ore along a fracture-plane. This cut is supposed to be on the "John Jay" vein; it is certainly on one of the many streaks which constitute the "John Jay" vein. This veinlet dips more steeply into the hill than the dyke by which it is apparently cut off. The pegmatite is there a more compact, a less porous and less fractured rock than the adjacent micaceous granite.

These surface observations led me to believe that the main shaft, following the dip of the vein, must intersect this pegmatite

dyke at a certain depth, and, furthermore, that this dyke must have had some influence on the process of deposition and of distribution of mineral in the vein under consideration.

UNDERGROUND OBSERVATIONS.

At the main shaft, the vein is about four feet wide, and was found to be very rich to a depth of 30 feet, and to an extent of 60 feet in a southerly direction.*

The character of the ore is sylvanite and native tellurium (always containing some gold), the latter showing, in cavities, tellurous oxide.

At a depth of 80 feet below the surface the vein splits into two streaks, the one following the hanging-wall side of the shaft and the other the foot-wall side: separated by what the miners call a "horse." I do not regard it as a keystone fallen in the crevice, but consider it rather a portion of the original country rock which was less altered and less mineralized by the solutions which, through existing fractures, found easier and wider channels around it.

The ore streak on the foot-wall side narrowed with depth; while the other streak, crossing the shaft, increased in width and value. In a southerly direction from the shaft the richer streak has been stoped above and below the 110-foot level, and below this 110-foot level to the north of the shaft. Access to these stopes is from behind the shaft on its east side. This rich streak narrows with further depth and pinches entirely still lower, where the first signs of the pegmatite dyke appear.

The west, or hanging side of the shaft, followed from the 110-foot level downward a small streak, which, on approaching the 160-foot level, became quite prominent, and was stoped out principally on the north side of the shaft. The ore on this streak between the 160- and 110-foot levels was very rich near the shaft, but northerly spread into several narrow streaks running in all directions through the altered country or gangue; the mineralized mass being in places eight to ten feet wide, but producing only concentrating ore. Native tellurium is not found much below the

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*See accompanying diagrams.

110-foot level; though iron-pyrites in minute crystals becomes more abundant.

Below the 160-foot level this streak, so rich near the shaft, loses itself against the pegmatite dyke. From that point down, the shaft is sunk through this pegmatite rock, without any sign of a vein below the 225-foot level; the present bottom or sump of the shaft passing through this dyke into micaceous granite.

In the 110-foot level, a little distance south of the shaft, a cross-cut is driven west, cutting at 21 feet from shaft a quartz streak, carrying in places telluride ores, which streak is followed by drifting about ten feet on each side of the cross-cut. The 110-foot level is driven southerly from the shaft about 100 feet along a streak, which is stoped overhead to nearly the end of the drift, where a raise is made easterly to the air-shaft. This air-shaft was sunk on another and more easterly running streak than the one followed in the drift. A cut made on the east, or foot-wall side, of this 110-foot level, at a distance of 65 feet from the shaft, shows a fairly good streak of ore. It is uncertain, and even doubtful, that this can be the same streak as the one the air-shaft was sunk on, as it shows, in the short drift on it, already a bending towards the west. In the stope above this 110-foot level south, slicken-sides or polished surfaces were observed on the foot-wall side; which tends to show that some displacement took place as the result of pressure, creating fracture- and slip-planes, distanced by comparatively unaltered rock. In the 160-foot level it was also observed that the clay selvage on the foot-wall showed polished surfaces.

In the 160-foot level, a cross-cut is made 12 feet southerly from the shaft in a westerly direction. The cross-cut is 32 feet long, and in that length cuts four distinct streaks separated from each other by relatively, little altered country rock. The first one nearest to the level is undoubtedly the same as the one stoped in a northerly direction, westerly from the shaft. The second one, five feet to the west of the first, is followed some ten feet north-erly, showing ore, but not in paying quantities. The third streak is small; but the fourth streak shows, for some distance, good ore and is about a foot wide.

In the 160-foot level south, 13 feet from its end or breast, a

feeder carrying some good ore crosses the level from foot- to hang-ing-wall side. I consider it to be a mineralized cross-fracture, along which solutions were guided from an easterly fracture-chan-nel to one more westerly from the interfering dyke.

At the breast of the 160-foot level is another cross-cut, driven westerly, intersecting two streaks about seven feet apart, both showing much iron- and copper-pyrites, and very little sylvanite. The gangue between these streaks contains considerable lime-spar.

In the 225-foot level, 35 feet southerly from the shaft, a cross-cut is driven westerly, which at 36 feet distance from the level cuts a quartz streak about two feet wide. This streak carries iron-pyrites, not in so minute a form as in the upper level, but in cubes often of pea size and larger; also calcspar, but very little tellur-ium ore.

From the foregoing observations I am inclined to draw the following conclusions:

The "John Jay" vein consists of a series of ore streaks occur-ring in a greatly altered portion of the country rock between two pegmatite dykes. These streaks were originally fracture- and slip-planes in the micaceous granite, formed by pressure and movement. These fracture-planes are limited in extent, princi-pally as to depth, and stop near their intersection with the easterly pegmatite dyke, but connect with each other by cross-fractures. These fractures were widened by the leaching action of circulating solutions; and later, filled by replacement with valuable minerals. Segregation of ores out of these solutions took place either by affinity for ingredients in the country rock or by crystallization where the solutions were kept to some extent stagnant by checked percolation, principally near the pegmatite dyke.

ORIGIN OF THE VEINS AND ORE DEPOSITS.

Although it is difficult to classify the Archæan rocks of Boulder County and to give their outlines with correctness, it ap-pears that the extensive structureless masses occupy the lowest geological position. On them are found more schistose rocks, especially in the direction of Caribou to Nederland. They appear again northwest of the Middle St. Vrain, with a forking towards Jamestown. A stratum of rather structureless granitic gneiss fol-

lows next; well observable where North and Middle Boulder join, and again along the South St. Vrain. An outcrop of an upper stratum of schists occurs both south and north of Gold Hill. They unite, and continue westerly south of Ward, appearing again north of Little Jim Creek, and extend for some distance beyond Ballarat.

It is possible that the lowest schists contain, finely disseminated through their mass, silver, zinc and lead sulphides; that the following more granitic strata contain, principally, gold-bearing iron and copper sulphides, while the upper strata are endowed, besides, with such elements as tellurium and selenium. The veins occurring between the horizons of these different strata would, in that case, be likely to carry, principally, the metalliferous compounds predominant in the enclosing rocks.

The resistance in folding, friction and crushing must have had as a consequence the forming of seams, cracks and fissures. It is admissible that the largest openings were filled by the intrusive matter of the original magma, softened by the heat accompanying extreme metamorphism, which intrusions now appear as dykes of pegmatite or of porphyry. Along in and near these dykes, along sharp demarkation lines of the granite and gneiss, along stratification-planes of the schistose strata, and along the joint-planes of the granite beds in the neighborhood of sharp folds, are found the valuable ores of Boulder County.

Percolating waters, becoming alkaline, dissolved the metalliferous contents of the rock. These solutions circulating along joints, shrinkage-planes, cracks, etc., filled these with the materials they held in solution. Possibly in some instances alkaline springs acted as carriers of vein material. Tame representations of such springs are still found, principally in the neighborhood of the so-called telluride belt.

A soda spring, known as the Fleury Spring, occurs in a gulch, about six miles from Boulder. An iron and soda spring is located one-half mile below the Boulder Falls, and a soda spring occurs at Springdale, a mile east of Jamestown, close to a telluride vein. It would be of interest to analyze the water of this last mentioned spring carefully to ascertain if it contains tellurium and selenium compounds.

Nevertheless, I am inclined to think that mineral springs have

had but little to do with vein filling in Boulder County. I cannot recall a single instance where a mineral spring was struck in sinking or drifting, or of water rising from below the water level. But several instances can be cited, which tend to show a lateral-secretion; the material for the filling being derived from the country rock, and the dissolved substances brought from both sides, to the fissure.

A sharp line of demarkation can be observed on Caribou Hill, between nearly structureless granite and schistose gneiss waving in an easterly and westerly direction. The veins on Caribou Hill contain exclusively silver ores (even the pyrites assay often high in silver), while the veins on Idaho Hill, one-half mile northeasterly of Caribou Hill, contain in the upper portions some auriferous pyrites. This is also the case in a group of veins situated one and a half miles more easterly, on Boulder County Hill, near Cardinal. Here a granular quartzite occurs reposing on gneissic schist. The kind of mineral in the veins changes in character when they pass through the upper quartzite streak.

In the upper or 40-foot level the "Trojan" vein on this hill carries gold exclusively. At 60 feet depth it enters a silver-bearing zone, coming in from the south side. At a greater depth it carries only argentiferous galena. The same is the case in the neighboring "Seek-no-Further" claim.

About the middle of the "Cash" lode claim on the south slope of Gold Hill, near the apex of a fold, a line of demarkation between gneissic and more granitic rock can be observed and followed for quite a distance in a northwesterly and southeasterly direction. In a tunnel driven near the "Cash" vein this demarkation is particularly sharp and well defined. The portion of the "Cash" vein northeasterly of this point carries only gold and telluride ores, and all veins north and northeast have the same character. The southwesterly portion of the "Cash" vein carries, mixed with telluride ores, much galena, and the veins located more southwesterly carry only silver ores.

The "John Jay" vein is also located near a demarkation line between a gneissic and an older granitic stratum, which has there been brought to the surface by a wrinkle, or local fold. This condition inclines me to think that the great amount of tellurium found in the upper part of the vein was derived by lateral-secretion

Outcrop of Vein

110 ft Level

East

ft Level
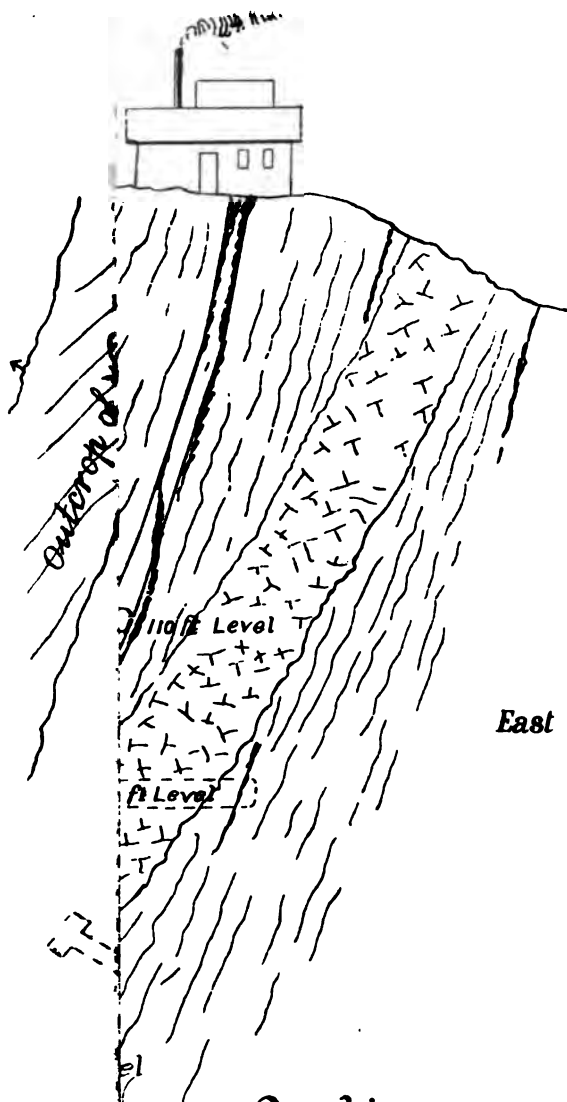
Section
across the Workings of the
JOHN JAY MINE
Boulder Co. Colo.
showing distribution of Orestreaks
Scale 48 feet to 1 Inch

ite Dyke ▨ Orestreaks

out of the upper gneissic strata containing that element, and that the rapid change from exclusively telluride to sulphide ores, as the vein obtains greater depth, is due to secretions derived from other strata which were to a lesser degree, or not at all, endowed with tellurium.

DISCUSSION.

Mr. Franklin Guiterman:—The thanks of the Society are due to Professor van Diest for the paper which has just been read; all the more so, as it brings up a subject not only of the deepest interest to economic geologists, but to every one connected with mining—namely, the origin of ore deposits.

In the case of the special deposits which have just been described, it seems to me that the evidence submitted is not sufficiently strong or positive to establish their origin on the theory of lateral-secretion, nor to invalidate the ascension theory, which might be applied with equal, if not more force.

Were the deposits confined to a zone lying above the intersection of the vein with the pegmatite dyke, and were it conclusively demonstrated that the vein did not continue below the intersection, their genesis might not unreasonably be ascribed to lateral-secretion, even without the positive demonstration, lacking in this case, that the enclosing country rock contained the metals which, passing into solution, were subsequently re-deposited in the vein. Beyond, however, the fact that the shaft in its downward course penetrated the pegmatite dyke and entered the granitic country rock without disclosing the vein, no evidence is offered.

The alteration of the country rock in immediate vicinity to ore-deposits is the usual occurrence, and can be rationally accounted for by the potent agency of thermal solutions which acted as mineral carriers. That the character of the mineral should change with the passage of the vein through different rock formations may be ascribed to the varying influences exerted by them on the precipitation of different ore-constituents, at different horizons, even from the same mineral solutions.

Professor van Diest has also alluded to the metalliferous lodes of Cornwall, England, calling attention to the well known transition of the ores from copper to tin, as the lodes in their downward course pass from one formation into another. This is held by him

to offer another striking evidence of the confirmation of the theory of lateral-secretion. I will ask Dr. Pearce, who is with us tonight, to give us his conclusions, founded on an extended study of the ore deposits in the lodes of Cornwall and also those formed by his examinations of the mines of Boulder County with which he is intimately acquainted.

Dr. Richard Pearce:—As far as my observations and investigations have extended, I may say that I have seen little which would incline me to the theory of the formation of ore deposits by lateral-secretion.

Such deposits as have been tonight described, I have met with in Cornwall as well as other mining districts, and have always come to the unvarying conclusion that it was the lode which influenced the encasing country rock, the alteration having been produced by thermal mineral solutions circulating in the vein. Not unfrequently the metamorphism and impregnation of certain zones of country rock can be traced directly to a small joint or fracture through which the solutions flowed. At Georgetown and in Gilpin County there are instances where, from small fissures, the enclosing country rock has been so mineralized as to constitute the lode itself, being worked as such. At the "Seven-Thirty" mine, at Georgetown, the rock in contact with the lode is found occasionally to be as rich as the lode proper.

In some of the mines of Cornwall, I have observed pseudomorphs of cassiterite after feldspar, and the alteration of feldspar and mica into chlorite, showing a mass of tin-bearing rock having the original structural characteristics of granite. The country rock as it receded from the veins passed into a clear granite of normal character. Numerous instances have come under my observation where the so-called vein was hardly more than an impregnated country rock, which gradually changed into a barren country as it left the source of mineralization. The mineral character of the ore deposits appears to be influenced not alone by the formation through which the veins may pass, but also by the action of cross-veins. In Cornwall, for instance, I have seen at the place of intersection of a vein with a cross-vein, native arsenic, arsenical cobalt, uranium (pitch-blende), native bismuth and other rare minerals, which were absent in other portions of the veins.

The late Captain Charles Thomas (the father of the present manager of the "Dolcoath" mine), who was a very clear observer, described two kinds of granite in the metalliferous districts of Cornwall, which he designated as primary and secondary, and which he held to be of different age. The secondary granite was merely the zone in which the copper and tin minerals were found in abundance. It is hardly probable that the two granites are distinct and separate rocks, but it is very likely that the secondary character of the one is entirely due to the metamorphism of the rock in the vicinity of the lodes.

Although the operations of thermal waters are rarely to be seen at the present time, it appears to me that they must, at remote geological periods, have exerted a most powerful metamorphic and mineralizing influence. At the "Clifford Amalgamated" mines in Cornwall there are at present strong evidences of thermal action. We find the porphyry in contact with the lode, where a hot spring of a temperature of 120° F. exists, undergoing rapid alteration, the feldspar being replaced by tourmaline. At Idaho Springs, Colo., there exists a hot mineral spring in the porphyry; the feldspar shows signs of decay, and probably furnishes the soda salts abounding in the water. The hot springs at Glenwood, Colo., which are so highly charged with alkaline chlorides, notably magnesium, have, in all probability, played an important part in the dolomitization and mineralization of the limestone along the fault which has proved so marvelously productive of mineral wealth at Aspen.

Recurring to Boulder, I may say that during the last twenty years I have had a general experience in regard to the character of the gold-bearing ores of that district, and, after a careful examination, I have come to the conclusion that the main bulk of the ore is an altered rock, principally porphyry. The original structure and character of the rock have in a measure disappeared, owing to replacement of feldspar by amorphous silica, showing here and there in spots undecomposed porphyry, sufficient, however, to demonstrate the original nature of the rock. The veins proper are extremely small, and can only be regarded as channels through which mineral solutions percolated, impregnating in so doing the rocks adjoining. The gangue associated with the very rich ores found in the seams consists, in many cases, of fluorite

and crystals of bitter spar, entirely different from the metamor-
phosed rock which is impregnated by mineral and which forms
the ordinary lode of the Boulder District.

Mr. T. A. Rickard:—The facts noted by Professor van Diest in
the "John Jay" mine are such as are often met with in mining
among the granitoid and gneissose rocks of Colorado.   In this
case, as in many instances described by other observers, I do not
see any immediate necessity for falling back upon the lateral-
secretion theory.

The veins are small, they are not continuous, they follow the
foliation of the country rock, they are connected by cross-fractures
which are also ore-bearing, the country rock separating them is
not notably altered save close to them, and the lode channel as a
whole is bounded by a dyke of pegmatite.

These observations would suggest to me the following more
ordinary explanation: The dyke marks a line of least resistance;
its contact with the gneiss became to the underground waters a
line of maximum circulation; it cut the foliation planes of the
gneiss, the solutions found a passage out of the main channel into
the adjacent country along the foliation fractures, and there depos-
ited their burden of metalliferous material whenever and wherever
conditions occurred compelling precipitation.   The system of
fractures, those along the leaves of the gneiss and those intersect-
ing ones which the author calls "slip-planes," may well be com-
pared to the joints of a more crystalline, structureless rock, like
granite.

That a change in the character of the country rock should be
accompanied by marked differences in the variety of the minerals
composing the ore is a fact that does not necessarily require for
its explanation the theory that the ores were obtained from the
leaching of the enclosing formation.   The character and composi-
tion of an ore deposit are determined no less by the presence or
absence, in the country rock which happens to be the place of
their deposition, of certain precipitating agents, than they are by
the substances in solution in the circulating waters.

That the veins of ore in the "John Jay" mine do not persist
in depth, but, on the contrary, appear to have an essentially
restricted extent, is no evidence of their being derived from min-
erals supposed to be contained in the adjoining country rock.   The

non-persistence of ores in lodes in depth is a fact of no rarity, and
is to be ascribed to other and simpler causes.   In this particular
instance the changes, both in kind and in quantity, of the ores de-
posited in the system of fractures described by the author, may be
explained in various ways.   They may be attributed to the vary-
ing distance from the main line of circulation followed by the per-
colating waters; they may be put down to the variations in the
structure of the gneiss itself, or to the effects of changing temper-
ature and pressure.

The lateral-secretion theory offers a wide field for pretty spec-
ulations.   In this connection I would instance the body of pyritic
ore found in the "Bright Diamond" mine, at Ouray.*   It occurs
in a bed of limestone, overlaid by quartzite and underlaid by a
series of beds of quartzite and sandstone.   A well marked fissure
cuts across the entire series, and is ore-bearing only in the lime-
stone bed just mentioned (and in other similar beds below it),
where is formed the body of gold-bearing pyrite above referred to.
The lateral-secretion theory would suggest that the pyrite was de-
rived from the leaching of the limestone or some adjacent rock
mass, while the ascension theory would lead us to suppose that the
solutions which found a passage along the line of that fissure
found no soluble rock in the sandstones and other underlying beds,
and had to wait until they reached the limestones in order to ob-
tain a place of ore deposition.   A soluble rock was required to
enable the carrying out of those chemical interchanges by which
certain minerals were removed and others laid down in their place.

Let me conclude these scattered remarks by saying that it
does not appear to me to have been proven that the "John Jay"
mine has any immediate need of the lateral-secretion theory.

Mr. R. C. Hills:—The arguments advanced by one side in this
controversy appear to be equally as strong as those advanced by
the other, and the facts usually cited in support of the ascension
theory may, when regarded from another standpoint, serve to but-
tress the theory of lateral-secretion.

In the course of the discussion here tonight, reference has
been made to the views maintained by Professor Posepny, of
Vienna, in his recent contribution to the subject of ore deposits in

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* For these facts I am indebted to Mr. Philip Argall.

the "Transactions of the American Institute of Mining Engineers."
I have read, somewhat hurriedly, Professor Posepny's remarkably
able paper, and may say that I find myself unable, in the majority
of cases, to harmonize the facts as I interpret them in the Rocky
Mountain region, with the conclusions therein set forth.

In his advocacy of the formation of ore deposits by hot
springs, assumed to derive their burden from deep-seated sources,
he adopts the theory advanced by Daubree, that deep circulation
is produced by capillary attraction, which exerts a greater force
against internal heat than does the head of water in the channel
of a hot spring. Some such ingenious explanation would be nec-
essary to harmonize the ascension theory with the conditions
under which ore bodies were formed in many of the summit dis-
tricts of the Mosquito Range, the Gunnison region and the San
Juan Mountains—elevations which since remote geological per-
iods have been, topographically speaking, what they are today,
and where the existence of hot springs, operating on the principle
of an inverted syphon, must certainly have been a physical impos-
sibility. Such springs always occur either in the valleys or not
much above the base of the mountain ranges, never near their
summits. Whereas, numerous and important ore-bearing veins
occur high above timber-line, where hot springs are unknown, but
where they should, nevertheless, be found—somewhere in this
highly-fissured region—if the theory of Daubree has any applica-
tion in fact. The truth is, hot springs occur under conditions
which admit of the flow being maintained on the inverted syphon
principle, and while capable, no doubt, of depositing ores where
such conditions exist, are evidently not responsible for the ore
bodies located on the summits of our mountain ranges.

Another point I wish to refer to, is this: Excluding those
springs which develop geyser action, the temperature observed is
seldom greater than is generally supposed to exist at a depth of
from 3,500 to 4,000 feet. Since vein-containing rocks of massive
eruption, as well as Archæan granites and schists, extend to much
greater depths, it does not appear that the ore deposited by hot
springs was, in all cases, necessarily derived from a source more
deep-seated than the enclosing formation.

Professor Posepny has presented, in a very interesting manner,
an imposing array of facts, but I question if he has succeeded in

proving the ascension theory of universal application. Ascension and lateral-secretion have, no doubt, both played their part in the formation of mineral veins. At the same time, the local evidence is not always conclusive, and the structural geology of a region must be carefully interpreted before we can decide in any case which theory is best supported by the facts.

Mr. Philip Argall:—I have not given the subject of the paper of the evening the consideration necessary to enable me to reach an opinion as to whether the ore was deposited from ascending currents or by lateral secretion, "so-called." I believe, however, that this latter theory, in its broader sense, is not by any means demolished by the able presentation of the ascension theory by Professor Posepny, in his recent paper to the American Institute of Mining Engineers. Lateral-secretion is applicable to many cases of ore-deposition to which the ascension theory cannot be applied.

In the San Juan region we know, that many of the mineral veins in the eruptives occupy fissures of contraction, and, consequently, do not extend deeper than the eruptive rocks. Here, then, the mineral solutions cannot have been obtained from vague and unknown depths, but from the surrounding rock-masses, and to such cases the lateral-secretion theory offers the only rational solution of the genesis of the ore deposits. I believe the great "Sheridan-Mendota" vein is simply a fissure of contraction, and that it will not be found to extend into the underlying conglomerates and sandstones; though I must state that this opinion is but a general one and is not based on a thorough study of this great vein.

Ten years' development at Leadville has not disproven the theory advanced by Emmons, much less established any basis for an ascension theory. All the ore deposits that I have seen at Leadville are the result of replacement; the deposition of ore extending from the porphyry downward into the limestone. This applies to the main contact and also to the intrusive sheets of gray porphyry in the limestone itself.

I have never heard any one dispute the finding of Emmons as to the sequence of events: First, the intrusion of the porphyry; second, the deposition of the ore; third, the faulting. The white porphyry has, in places, taken up with it sheets of limestone;

these we now find ore-bearing along their upper contacts.   Prob-
ably the best example is the "Mahala-Agassiz" sheet, which at the
"Mahala" shaft is 100 feet thick and is separated from the main
limestone by 600 feet of porphyry.   This sheet of limestone has
been extensively and profitably worked along its upper contact,
while the main limestone 700 feet below this contact is also richly
ore-bearing.

I cannot, however, avoid the conclusion that the gray por-
phyry at Leadville is no less intimately connected with the ore
deposite in the mass of the limestone in contact with it, than the
white porphyry is with the upper-contact ore bodies.   Further
researches may probably show this connection, not yet entirely
clear, owing to insufficient development.

On the other hand, we have in various mining districts in this
State ore deposits that, from the evidence at hand, may be
ascribed to the ascension theory   I mention particularly the Red
Mountain ore deposits, in the San Juan, and the "Bassick" mine,
in Custer County.

It seems to me, therefore, that the study of the genesis of ore
deposits should be approached with an unbiased mind, and the
conclusions should be formulated in favor of any given theory
only after an extended study of chemical and geological facts.

ON THE NATURE OF THE CHEMICAL ELEMENTS.

(SIXTH PAPER.)

BY CHARLES SKEELE PALMER,
Professor of Chemistry, University of Colorado.

THE DISTRIBUTION OF THE ATOMIC WEIGHT.

I. PRELIMINARY.

In the previous papers there has been outlined, the probable genesis of the chemical elements by a simple condensation of one kind of matter; the weathering-off of successive shells, each of which became a distinct series; the differentiation of each serial shell into its respective elements by a co-ordination of two opposite yet similar mechanical twist-structures, producing the opposite "kalidic" and "oxidic" properties of the elements as we know them—each series or shield having the basic elements on the outer part, and the acid elements in the inner part, the other members of a series being respectively intermediate in position.

Thus, we may say that the chemical "habit" or "facies" of an element is a function of (a) its automic weight; (b) its automic specific gravity and automic specific volume; (c) its polaric *oxidic* or *kalidic* structure, respectively.

All of the papers, thus far, have been purely speculative as far as any experimental work of the author is concerned. The present paper is a preliminary statement of experimental research to test the probability of the hypothesis. This work is now well under way at the laboratory of the University, and will be conducted by advanced students—Mr. Andrews and Mr. Stoddard—

under the personal direction of the writer   No definite results can be reached for months, and this paper is simply a statement to protect the writer in priority rights, should any publication appear from any other source during the period necessary for the work, and before definite results can be reached by the work at Boulder.   These ideas are the common property of science, and as they are in the air, surprising results may appear at any time from other laboratories.   At the same time, the work is entirely independent, and is being done nowhere else, as far as I know.

II. THEORETICAL.

The idea of evolution is familiar to us all.   It is not new, but has been grasped and applied in a new way by the present generation in biological lines.   In the application to the nebular hypothesis of astronomy it is a century old.   As yet, the idea has done almost no work in pure chemistry.   The "microcosmic hypothesis" of the writer is a crude and feeble attempt in this direction; but it is in harmony with the general idea of evolution, and, though only one of many possible forms, it is one of the first, probably the first *definite* formulation in this line.   Now let us notice how this idea must influence our conceptions of chemical fundamentals.

As soon as we admit the idea of evolution as a genuine working hypothesis in the origin of the chemical elements, we must also admit the concurrent idea of natural selection.   This means that present results are the fittest to survive under the circumstances, and that such resulting atoms represent the forms possessing the most stable equilibrium in enduring the strains and stresses from atomic bombardment and molecular friction.   In a word, all the mechanical disturbances implied in the long history of distinct pieces of matter, endowed with energy, and subject to collisions with fellow particles.

When one forms such a mental picture, he sees clearly that the *a priori* chances are against the view that all the atoms of any one element, so-called, could have exactly the same weight, the same structure, etc.   The chances on *a priori* grounds are, that the individual atoms of the same element may differ as much among themselves as the blades of grass on a lawn.   This is not the prevailing view, however, at present; it is too new and has, as

yet, too little experimental evidence. Thus, we find the statement in Richter's "Anorg. Chem.," 6th Auflage, p. 65: "Alle Atome aber eines Elementes haben dasselbe absolut Gewicht und sind einander gleich." This, no doubt, voices the prevailing belief among chemists. It is commonly supposed that the classical atomic-weight determinations, from Berzelius to Stas, Meyer and Mallet, are a final argument on this point. Thus, Stas found for the atomic weight of silver, as follows:

1st series, precip. by K Cl (dil).................	107·9401
2d series, Ag ClO₃, reduc. to Ag Cl..............	107·9406
3d series, Ag BrO₃, reduc. to Ag Br.............	107·9233
4th series, Ag IO₃, reduc. to Ag I.....	107·9371
5th series, Ag₂SO₄, reduc. to Ag.........	107·9270

These remarkably accordant results are always assumed as proof, that all the atoms of silver have the same atomic weight within the limits of experimental determination. So Professor Ostwald told me himself this spring in a conversation, in which he kindly, but decidedly, expressed himself as seeing but very little of value in any hypothesis of the evolution of the elements, including that of the writer, But notice: The new theory of solutions, which Professor Ostwald has done so much to develop and to prove, explains very neatly how, at the same time, the atoms of any one element may vary greatly, and yet these variations remain easily concealed even in an atomic-weight determination.

Thus, suppose, for instance, that we are dealing with a solution of K Cl; and further, suppose, for argument, that not all the atoms of K have the same weight, but that some are slightly heavier, and others slightly lighter than 39, the average atomic weight of K. Also, suppose a similar thing to be true of the atoms of chlorine, grouped about their average, 35·4. Now, suppose these atoms of K and Cl to unite with each other from ion to molecule as the solution is evaporated down; what would probably happen? The *most basic* K atoms would unite with the *most acid* Cl atoms, and the *less acid* K atoms with the *less acid* Cl atoms. But the most basic K atoms uniting with the most acid Cl atoms, would make an average molecule, which would be nearly identical in weight with the molecules resulting from the union of less basic K atoms with less acid Cl atoms; because the more basic K atoms would be *lighter* than the less basic, and the more acid Cl atoms

would be *heavier* than the less acid ones. This is illustrated by the following table, the figures being assumed for argument:

	Light Atoms.	*Average.*	*Heavy Atoms.*
Cl............	34·3 *(least acid)*	34·4	34·5 *(most acid)*
K	38·9 *(most basic)*	39	39·1 *(least basic)*

We would have Cl 34·5+38·9 K=73·4
Cl 34·4+39 K=73·4
Cl 34·3+39·1 K=73·4

Thus we see, in the typical case assumed, the molecule made up of most acid Cl and most basic K would equal the molecule made up of least acid Cl and least basic K, and also the molecule made up of the average atoms.

This is really startling, but there is no juggling and the logic is good. Similar reasoning applies to all other combinations. The work of Stas, then, and of all other good analysts, may prove nothing more than that, in the atomic union of unlike elements into molecules, the atoms tend to maintain an average.

It might also be shown on the ground of mechanics, on the basis of the tendency of unlike atoms and elements to unite with each other, that the *most unlike* would tend to unite with each other, and that in a solution evaporating from ion state to molecule, the equilibrium would not be well established till this had been done, and when this equilibrium had been established it would result in producing *molecules as nearly like each other in their total weight as possible.* As above, this would amount to concealing the possibility in any variation of the atoms, because the molecular weights would be the same.

Now the new hypothesis will in no way disturb the trustworthiness of quantitative analysis, because, in the first place, the atoms must tend to make the same average molecules; and, in the second place, this is all that ordinary quantitative determination can give.

III. SEPARATION.

Having thus shown, (*a*) that *a priori* argument makes the variation of the atomic weight probable, in the sense that not all of the atoms would have the same weight; and (*b*) that, if this is so, the ordinary quantitative and atomic-weight determinations would probably be powerless to discover it, from the necessary

tendency of the atoms to come to the most stable equilibrium in molecules of the same weight,—we next ask whether it be possible to separate the light from the heavy atoms in any case. The answer is, that it should be entirely possible by the simple yet powerful method of *fractionation*. This method is not new, yet it has thus far been applied only in the case of the *rare* elements where, from lack of material, the results are not sharp and convincing. Witness the almost wasted time of Crookes, Kruss, de Boisbaudran, Nilson and others, on the rare elements. We do not yet know the meaning of the alleged separation of "didymium" into "praeseo-dym" and "neo-dym."

But here notice, that we must take a common element, sufficiently abundant on the one hand to test all results, and sufficiently subject to all chemical processes. Such an element is silver. It is already classic ground. If any positive result be proven here, it will, in face of Stas' work, by analogy, challenge the whole question for all the elements. It can be dissolved, precipitated and reduced to the metallic state with the utmost readiness. If all of the molecules of any compound have the same total weight, resulting from the different partial weights of the atoms, these differing molecules should differ somewhat in solubility, specific gravity, refractive index, crystalline form, electrical conductivity, etc.

It only remains to fractionate a sufficiently large quantity into a series of precipitates; refractionate this series repeatedly till there shall be obtained a final series having a presumably sufficient differentiation to show some regular differences in combining weight, specific gravity, etc.

It is quite possible that the theory of the variation of the atoms about a mean value may be true, and that a genuine differentiation may result from the fractionation, and yet, that the variations may be too slight to be detected by our too cumbrous apparatus. This point will be referred to below in this paper. But it is probable that some means will be found to settle the question decisively by experimental measurement.

IV. The Kind of Variation to be Expected.

Assuming that, ultimately, the method of fractionation will yield positive results in experimentation, what kind of results can

we look for?   Let us notice the position of silver in the periodic arrangement, and especially in the curve tracing published in the first paper of this series.*   Silver lies on the retreating branch of the second long series; it is between palladium and cadmium.   In this part of the curve atomic weights vary *inversely* with the specific gravities; *i. e.*, as the atomic weights increase, the specific gravities decrease.   *This means that if silver has lighter and heavier atoms as regards combining weights, then those varieties showing a greater combining weight will show a lesser specific gravity, and those varieties showing a lesser combining weight will show a greater specific gravity.*   This prediction may be made with a large degree of confidence, and will be a very valuable check and criterion of the results; and particularly if they should indicate only slight variations.   There is another possibility regarding the distribution of the atomic weight, which may require a modification of the prediction.   Then the distribution of one element may resemble the distribution of the elements in any complete series.   If such should prove to be the case, then the varieties (of an element) having the lesser specific gravity would be of two kinds;   one, having the minimum atomic weight, and one, the maximum atomic weight; and the variety having the maximum specific gravity, would have a mean atomic weight.

V. The Kind of Distribution.

There are two possible simple modes of the variation of the atomic weight, supposing that each variation exists.   We will consider each of these in their bearing on the possibility of determining such variation.   But first let it be emphasized here that it is not supposed that in this separation of light and heavy atoms there is any *dissociation* of any atom into anything simpler, according to the views of Lockyer on the one hand, nor according to the hypothetical oxidium and kalidium of the writer, on the other. This latter hypothesis has been reduced to sub-elementary structure, but it is not the point in this paper and present investigation. This hypothesis has been held by Crookes, Mariguse and others, but I do not know that any experimental work has been done upon

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* Plate I.   Proc. Colo. Sci. Soc., Vol. III.

it: *i. e.*, the hypothesis, that the atoms of any one element are grouped about *the mean* value of the atomic weight.

The first possibility of atomic distribution is, that the atoms may be grouped about a *mean*, most of them being found *at* the mean, but some above and some below; the *number* of such atoms as are situated at a very considerable distance from this mean varying inversely with their removal from the mean. Thus, to reason from a particular case, let us take the case of lithium, and let us assume that it has an accepted atomic weight of 7; further assume, as the simplest case, that *most* of the atoms have atomic weights near 7, that being the average of all, and that all the atoms lie between the extreme limits of 6·5 as a minimum and 7·5 as a maximum; and assume that there are just as many atoms heavier and just as much heavier, as there are lighter and just as much lighter. (See Fig. 4.) The grouping about the mean is shown in the diagram, where distance on the abscissa represents variation of the atomic weight, and distance on the ordinate represents the relative number of atoms having the particular atomic weight in question. Thus, the product of the abscissa distance from the mean by one-half the heights of the plus and minus triangles, gives an area which represents the total weights of the atoms grouped, respectively, above and below the mean. If the methods of atomic weight determination involve no fractionation, it is possible to have light and heavy atoms so mixed that the results would appear that *all* the atoms have the atomic weight, 7. But suppose, from some failure to observe the customary care in quantitative work, or from some variation in the circumstance of the work, that this mean is not hit upon, but an empirical average lying one-tenth removed from the mean, at 0; and suppose that thus the portion in the triangle $-e$ is absent from the aliquot quantity whose average is taken. Then the total weight above the mean is the value of the area of the plus triangle, and the total weight below the mean of the area of the minus triangle, minus the small triangle $-e$; and one-half of the area of $-e$ is the displacement resulting from the displacement of the mean one-tenth towards the right; but the area of triangle small $e=0·05$. Dividing by 2 to get the average$=0·025$, a very small value.

That is, if the average of a group of atoms so varying between the limits of 6·5 to 7·5 were displaced one-tenth of the whole limit,

the apparent *average* would be displaced only 25-1000 (·025). *The result is, in a word, that a large amount of displacement of the average. would exhibit itself by a very small apparent displacement, such as would easily fall within the limits of experimental error.* Such accidental displacements would thus be overlooked, unless they were especially sought for. But by the method of fractionation the difference between the *average* of atoms falling in the limits of triangle −e would be very marked compared with the average of atoms falling in triangle +e, and both fairly distinct from the averages of the trapezoids +a and −a. Further, if the variation be regular, as shown in the diagram, or irregular, as in Fig. 5, the fractionation should show it in the regular, or irregular, variation of the successive members of the fractions, and in the number and quantity of the respective fractions so distributed.

Secondly, we may conceive that the atoms are not grouped *closely* about a mean, but that there are several maxima of distribution, the average of which would give the apparent atomic weight. Thus, suppose again, in the case of lithium, that three-fourths of the atoms were situated at ·1 of a unit above the mean and one-fourth situated ·3 of a unit below the mean. The mean would be the average accepted, as shown in Fig. 6.

A third and more complicated case would be a combination of the first and second methods. This, though more difficult, should still subject itself to the test of fractionation.

The second case just described at once suggests an explanation of a mystery of a well known science, viz., the multiplicity of the spectra of the elements. Of course, one line or set of lines may repeat itself again and again, as "over-tone" harmonic lines; but, assuming that we know the fundamental lines or sets of lines, why are these *multiple?* The explanation is, in a word, that each *independent line* may represent a maximum or grouping of atoms about one point, all the atoms producing one line having approximately the same atomic weight, and differing slightly, but decidedly, from the atomic weights of the atoms producing the neighboring line. This explanation may be new and may not be. It is, to the best of my knowledge, as the usual explanation is, to see in the independent sets of vibration frequency, so many "basal"

"sub-element" ingredients or components.   But I have not the latest spectroscopic work at hand, and cannot say as to its newness. It is, I believe, original with the writer, and, pending the results, I may say that it is the view which I anticipate will be some time found to be justified by experiment.   I look to find the fractions not regularly grouped, but irregularly, and tending to break up into a few principal groups corresponding to the principal lines of the element in question.   Of course, in the case of an element which, like iron, has *many lines,* the distribution of the fractions may appear regular and within wide limits.

The particular spectrum of silver will be discussed in a later paper.   A few remarks on the well known spectrum of a well known element will illustrate the conception.   Take the spectrum of sodium, and study it in the photograph of Professor Rowland. We assume that the sodium in the sun is still normal sodium, and that D_1 and D_2 are the two principal fundamental lines.   They are very different. D_1 is apparently *one* continuous *band,* about 0·3 ten-millionths of a *m.m.* in width, not a line, having both edges diffuse, not sharp and about equally diffuse on both sides.   The group of atoms producing this line (or band, rather) should not have the *same,* but approximately the same atomic weight, and perhaps too close ever to differentiate by any chemical fractionation. D_2 is a hazy, diffuse *band,* about 0·5 ten-millionths of a *m.m.* in width.

Regarding these lines, Prof. A. A. Michelson[*] says:

"Each component of the yellow sodium line is itself a double, whose components are in the ratio of 7 : 10, and whose distance apart is about one-hundredth of that between the principal components."

Michelson's statement is presumably based on the structure of interference bands, for light which is nearly mono-chromatic.

S. Higgs, the Liverpool student who has been so successful in photographing the spectrum, writes me thus: "I believe I can show that both are double, or that there is a bright rift in the center of each, but more decided in D_2.

Prof. H. A. Rowland writes me thus:

"It is true that D_1 and D_2 are different from each other, but I do not

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[*] Astronomy and Astro-Phys., Feb. 1894. p. 100.

think either is double.   Sometimes they are reversed and one reverses easier than the other.   In the electric arc they are always reversed.   In a Bunsen burner they can be reversed several times.   * * * The other doubles in the solar spectrum due to sodium, are the heads of *bands*, and are not reversible lines as D_1 and D_2."

These references are given to show, that it is a recognized fact that D_1 and D_2 are, at least apparently, double.   Moreover, D_2 is *wider* than D_1.   It is also nearer the violet end of the spectrum, and hence, if a repetition of D_1 should be slightly narrower.

If these bands both belong to sodium, it should be within the limits of fractionation to separate the atoms producing the D_2 as a group, from the D_1 as a group.   But this is only by way of illustration.

VI. CONCLUDING REMARKS.

This paper is a preliminary statement of anticipation of experimental work now in progress at the University at Boulder.   I am indebted for the opportunity to use a satisfactory amount of silver to our honored ex-President, Dr. Richard Pearce, who kindly loaned the writer the desired quantity, as a personal favor and in the interest of pure science.   Should negative results be obtained, the argument will remain with the old view as to the identity of all the atoms of any one element as regards the atomic weight.   But, should we obtain any kind of positive and definite variation of the atomic weight of silver, what will it indicate?   As previously stated, silver is a crucial and a classical element, and a blow here is a blow at all the elements by analogy; though, of course, they must be subjected to individual study.   And if the elements, each for itself, have their atoms grouped in sub-groups, what then?   It will argue for a genuine atomic evolution, foreshadowed by the grouping of the different elements of each distinct series.   It will not, of itself, be a certain proof in favor of the "genetic microcosmic" hypothesis of the author, to the exclusion of any other hypothesis; but as it has in the mind of the writer been a direct inference from his theoretical work, it may in fair justice be regarded as an argument for the special plausibility and worth of the microcosmic theory *as a working hypothesis*.   The experimental work will last months, but I hope within three months to have some indicative results, to show the tendency of the fractionation.   Other papers are in progress.

THE ERUPTIVE DYKES NEAR MANCHESTER, MASSACHUSETTS.

BY RICHARD PEARCE.

While staying at Manchester-by-the-Sea, in Massachusetts, my attention was attracted to certain geological features presented by the rocks of the coast, and in the following notes I have set down such observations as appeared most striking. The cliffs are, for the most part, composed of a coarsely crystalline granite distinguished by a splendidly defined, jointed structure. At the foot of one of the bold headlands I first noticed a large block of granite, the face of which was marked by a casing of black rock, and upon descending to the beach I saw that this same black material filled fractures along the joints of the granite. The cliff showed many of these thin veins, ranging from a mere thread a quarter of an inch thick to well formed dykes about a foot wide. The basic rock forming them had evidently sought out the lines of least resistance. It would follow a joint until it met with a cross-joint, when it would be diverted and often split up and ramify into small streaks.

My interest was aroused, for it seemed to me singular to find dykes of this character in a granite formation. Upon visiting Marblehead, distant about fifteen miles in an air line, I met with similar conditions to those described, but on a much larger scale. I found that Marblehead neck was crossed by a dyke of the same black rock, fully 40 feet wide on the land side, but on the ocean side, a distance of about half a mile, it lost its great width and was only from six to eight feet thick. It appeared to have broken up into a series of ramifications, the members of which exhibited a most interesting behavior. They would change their course sud-

denly, turning to one side and decreasing in size, then open out again as quickly—indicating that the original material must have been extremely mobile.

Further north on the coast, at Bideford, this rock appears in larger masses, penetrating the granite, and has a gray color. In this locality it has a most marked influence on the slates with which it here comes in contact; it twists and contorts them in a most striking manner. It has also caused changes due to heat, for the slates are baked and secondary veins of quartz have been formed.

At Marblehead, on the other hand, the granite shows no such effects as would be due to heat, the feldspar only is discolored and has a pink tint which may simply be due to water which finds its way along the joints of the rock.

A partial analysis of some chips of this intrusive rock gave:

SiO_2	CaO	FeO	Al_2O_3	MgO
36·85	15·73	17·50	15·46	5·60 = 91·14

It is therefore *extremely* basic (ordinary basalts carry 50% SiO_2) and would be molten at a *comparatively* low temperature.

THE SOLUTION OF THE EQUATIONS,
$X^2 + Y = 7, X + Y^2 = 11.$

BY FRANCIS T. FREELAND, ASPEN, COLORADO.

These equations, recently proposed in *The Colliery Engineer*, Scranton, Pa., appear to have presented a difficulty to some of its correspondents, and it may be of interest to briefly indicate the general method of solution.

Eliminating y between the two equations, we have

$$x^4 - 14x^2 + x + 38 = 0.$$

Following the method of Descartes, we assume the bi-quadratic to be resolved into two quadratic factors, and on account of the absence of the second term, we may put

$$x^4 - 14x^2 + x + 38 = (x^2 - ex + f)(x^2 + ex + g).$$

Expanding and equating similarly located coefficients, we have the following equations:

$$e^2 - f - g = 14, \quad e(f-g) = 1, \quad fg = 38,$$

for determining the assumed coefficients. Eliminating f and g, we have

$$e^6 - 28e^4 + 44e^2 - 1 = 0,$$

and this equation may be solved as a cubic one, for the powers of e are even. In order to suppress the second term let $e^2 = h + k$. Then substituting and collecting, and putting $3k - 28 = 0$, we have

$$h^3 - 652h/3 - 32{,}843/27 = 0.$$

To simplify this expression, let $h = j/3$, then

$$j^3 - 1{,}956j - 32{,}843 = 0.$$

This is the cubic resolvent of the biquadratic equation, and its solution may be had by Cardan's method or trigonometrically.

By Cardan's solution, if q be the second coefficient and r the third, then

$$-r/2 = +16{,}421{\cdot}5, \quad q/3 = -652 \text{ and}$$
$$\sqrt{(r^2/4 + q^3/27)} = +2739\sqrt{-1}.$$

Without going through the details of Cardan's solution, the root may be written at once from the known expression,

$$j = \sqrt[3]{[-r/2 + \sqrt{(r^2/4 + q^3/27)}]} + \sqrt[3]{[-r/2 - \sqrt{(r^2/4 + q^3/27)}]}$$

with some approximation, thus

$$j = 14[\sqrt[3]{(6 + \sqrt{-1})} + \sqrt[3]{(6 - \sqrt{-1})}].$$

We now see that the roots of the cubic equation are real and unequal, and that we have to do with what has been designated as the "irreducible case," for the result, although algebraically correct, is not in a convenient form for calculation.

However, to evaluate this expression, the two cube roots may be expanded by the binomial theorem into two converging series and summed to any required degree of accuracy. With these values we use the ascending powers of the imaginary, as that has the smallest coefficient. Thus, bringing the 6 from under the radical and putting i for the imaginary, the expression may be written

$$j = 14\sqrt[3]{6}[\sqrt[3]{(1 + i/6)} + \sqrt[3]{(1 - i/6)}].$$

But after expansion to six terms and reduction,

$$\sqrt[3]{(1 \pm i/6)} = 1{\cdot}00297 \pm 0{\cdot}05527i,$$

or say $a \pm bi$. Then the three roots are $2a$, $-a \pm b\sqrt{3}$ and

$$j = +51{\cdot}0134, \; -27{\cdot}9585, \; -23{\cdot}0649.$$

By trigonometry, for comparison, the three roots in the "irreducible case" are

$$2\sqrt{(q/3)} \cdot \cos(a, 60° \pm a) \text{ where } \cos 3a = r/2 \cdot \sqrt{(3/q)^3}$$

But when q is negative and $4q^3$ numerically less than $27r^2$,

$$j = \sqrt[3]{(-r)}[\sqrt[3]{\cos^2 a/2} + \sqrt[3]{\sin^2 a/2}]$$

in which

$$\sin a = 2/r \cdot \sqrt{(-\ q^3/27)}.$$

and when q is positive

$$j = \sqrt[3]{(-\ r/\cos a)}[\ \sqrt[3]{\cos^2 a}/2 - \sqrt[3]{\sin^2 a}/2\ ],$$

in which

$$\tan a = 2/r \cdot \sqrt{(q^3/27)}.$$

Here, $3a = 9° \ 28' \ 10''$ and
   $a = 3° \ 9' \ 23'', \ 56° \ 50' \ 37'', \ 63° \ 9' \ 23'',$
   $j = +\ 50·991, -\ 27·931, \quad -\ 23·060.$

As the square root may be plus or minus, the proper sign must be attached by a scrutiny of the cubic in j. The former result agrees fairly well with this one, but this is the more precise, as it is free from approximation. Now working backward,

$h = +\ 16·9970, \ k = +\ 9·3333, \ e^2 = +\ 26·3303,$

$e = \pm\ 5·1313, \ 1/e = \pm\ 0·1948.$ Hence $f = +\ 6·0678,$ and

$$g = +\ 6·2626.$$

These values of f and g satisfy the condition $fg = +\ 38$. The two other values of e, to-wit, $\pm\ 0·1516$ and $\pm\ 1·2829$, which may be obtained from the second and third values of j, are redundant, as they correspond to the two other arrangements of the four roots of the biquadratic in the two quadratic factors, and would lead to the same result.

Consequently the quadratic factors are

$$x^2 - 5·1313x + 6·2626 \text{ and } x^2 + 5·1313x + 6·0678.$$

Putting them equal to zero separately and solving, or remembering that if the three roots of the bicubic in e are a, b, c, then the four roots of the biquadratic will be $(\pm\ a \pm\ b \pm\ c)/2$, the signs being so chosen that abc is minus,

$x = +\ 2·0000, +\ 3·1313, -\ 3·2832, -\ 1·8481$

$y = +\ 3·0000, -\ 2·8050, -\ 3·7794, +\ 3·5845.$

The sum of the roots of an equation being equal to the coefficient of the second term with its sign changed, in this the sum of the x's must be zero, which it is; and similarly with the y's, for the

elimination of x would give a biquadratic in y lacking the second term. These values check to the third decimal place.

The work may be shortened with the data given by noticing that the biquadratic has a root $+ 2$. It may be depressed to a cubic equation by dividing by $x - 2$, and we then have

$$x^3 + 2x^2 - 10x - 19 = 0.$$

Put $x = l + m$, and let $3m + 2 = 0$, then

$$l^3 - 34l/3 - 317/27 = 0.$$

Put $l = n/3$, then

$$n^3 - 102n - 317 = 0,$$

By the trigonometrical method as before,

$$n = + 11 \cdot 3939, - 7 \cdot 8496, - 3 \cdot 5444,$$
then $$l = + 3 \cdot 7979, - 2 \cdot 6165, - 1 \cdot 1815,$$
and $$m = - 0 \cdot 6667, - 0 \cdot 6667, - 0 \cdot 6667,$$
hence $$x = + 3 \cdot 1312, - 3 \cdot 2832, - 1 \cdot 8482,$$

showing a close agreement with the determination above.

The methods referred to and their demonstration may be found in J. A. Serret, "Cours d'Algebre Supérieure," 4me ed., Tome 2, pp. 481, 451. I. Todhunter, "Theory of Equations," 3d ed., pp. 112, 99, 108. I. Todhunter, "Plane Trigonometry," 7th ed., p. 203.

Note 1.—Where

$$x^2 + sx + t = 0, \ x = [- s \pm \sqrt{(s^2 - 4t)}]/2.$$

Note 2.—Equations above the fourth degree, in general, cannot be solved algebraically. Certain forms, however, admit of a reduction in the degree. The number of *real distinct* roots can be found from Sturm's theorem, and their location by trial, and their approximate value to any required degree of accuracy by Horner's method. See Todhunter, "Equations," pp. 121, 150; Serret, t. 2, p. 497.

Note 3.—One solution may be quickly obtained by an algebraic device, thus:

Rearranging, $\qquad x^2 - 4 = 3 - y$
and $\qquad\qquad x - 2 = 9 - y^2 = (3 - y)(3 + y)$
eliminating $\ 3 - y, \ x^2 - 4 = (x - 2)/(3 + y)$
hence the common factor, $\ x - 2 = 0,$ etc.

Or arranging according to the powers of x and completing the square, the same result is obtained.

DISCUSSION.

Mr. R. M. Hosea.—In reading Mr. Freeland's paper, it has occurred to me that it may not be clear to all of us just why there are four values of x and four values of y with varying algebraic signs. I propose to illustrate this fact by a graphical method, and also show that there can be only four values of each.

If we examine the above equations, we see that in the light of conic sections, each represents a curve. That is to say, if we assume in each equation successive values of x, and solve the equation for corresponding values of y, and plot upon a system of rectangular co-ordinates the values thus obtained, the line joining the points so located will be a parabolic curve.

I shall of course follow the usual notation in considering algebraical signs, viz.: Distances measured to the right are regarded as plus; those to the left as minus; those vertically upward, plus; those vertically downward, minus.

In the equation $x^2 + y = 7$,

If $x = 0$, then $y = 7 \cdot$
If $x = \pm \cdot 2$ " $y = 6 \cdot 94$
If $x = \pm \cdot 4$ " $y = 6 \cdot 84$
If $x = \pm \cdot 6$ " $y = 6 \cdot 64$
If $x = \pm \cdot 8$ " $y = 6 \cdot 36$
If $x = \pm \cdot 1$ " $y = 6 \cdot$
If $x = \pm 2 \cdot$ " $y = 3 \cdot$
If $x = \pm 3 \cdot$ " $y = -2 \cdot$
If $x = \pm 4 \cdot$ " $y = -9 \cdot$
If $x = \pm 5 \cdot$ " $y = -18 \cdot$
    Etc.   Etc.

In the equation $y^2 + x = 11$,

If $x = 0$, then $y = \sqrt{11} = \pm \ 3 \cdot 3166$
If $x = -1$ " $y = \sqrt{12} = \pm \ 3 \cdot 4641$
If $x = -2$ " $y = \sqrt{13} = \pm \ 3 \cdot 6055$
If $x = -3$ " $y = \sqrt{14} = \pm \ 3 \cdot 7416$
If $x = -4$ " $y = \sqrt{15} = \pm \ 3\ 8730$
If $x = -5$ " $y = \sqrt{16} = \pm \ 4 \cdot 0000$
    Etc.   Etc.
If $x = 1$ " $y = \sqrt{10} = \pm \ 3 \cdot 1623$
If $x = 2$ " $y = \sqrt{9} = \pm \ 3 \cdot 0000$
If $x = 3$ " $y = \sqrt{8} = \pm \ 2 \cdot 8284$
    Etc.   Etc.
If $x = 11$ " $y = \sqrt{0} = \quad 0 \cdot 0000$

Plotting the curves represented by the above two series of values of x and y, the two intersecting parabolic curves on the diagram are obtained.

If these be drawn on a sufficiently large scale, we may measure at the points of intersection the values of x and y, thus approximately checking the results of Mr. Freeland's calculations.

Thus for a value of $x = +2$, $y = +3$; for $x = +3{\cdot}13$, $y = -2{\cdot}80$; for $x = -3{\cdot}28$, $y = -3{\cdot}77$; for $x = -1{\cdot}84$, $y = +3{\cdot}58$, the position of the points of intersection, indicating the algebraic signs.

It is shown in conic sections that the co-ordinates of points of intersection of curves must satisfy their equations. And hence to determine the co-ordinates of points of intersection, we must combine the equations of the curves in question. This is here done graphically, presenting to the eye the points where the relations of x and y are the same for both equations. This can only be at points of intersection or points common to both curves.

The diagram shows that there are four such points, and only four at which the values of x and y as deduced by Mr. Freeland can satisfy both equations.
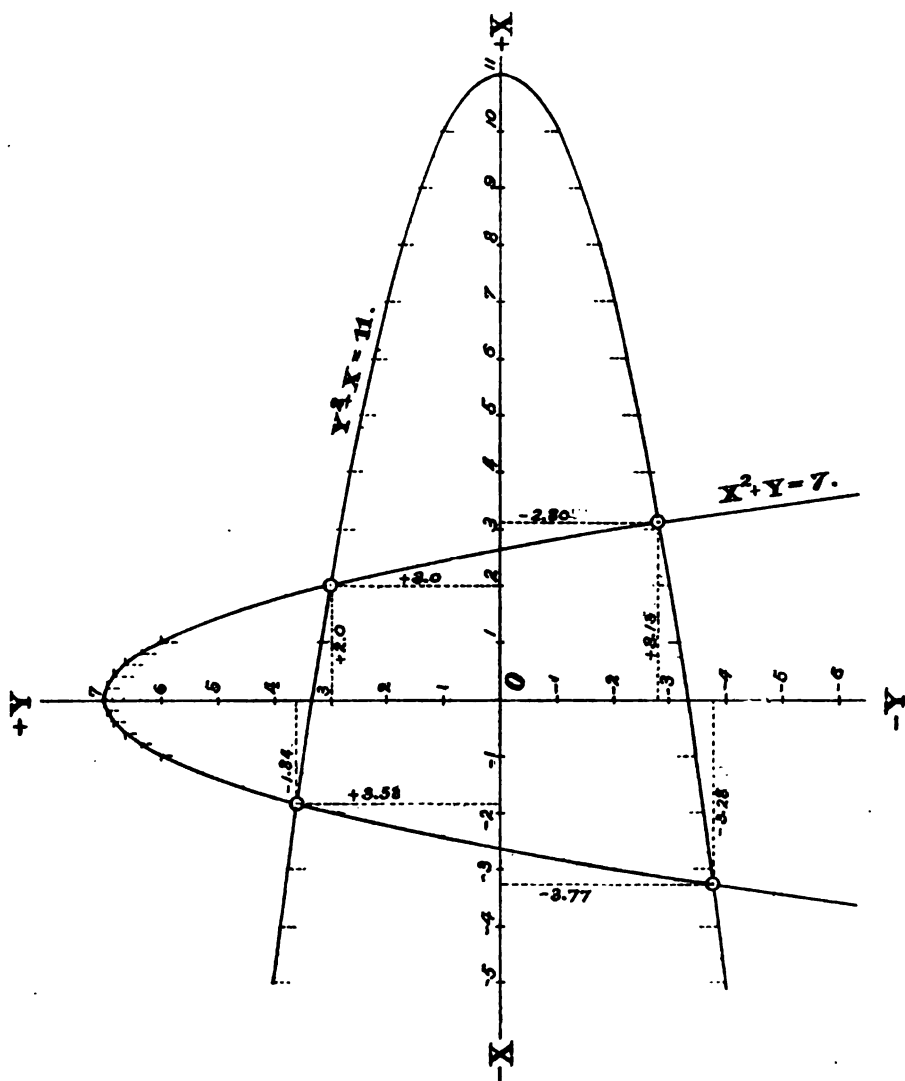
GRAPHIC SOLUTION

OF THE EQUATIONS

$X^2 + Y = 7.$ $Y^2 + X = 11.$

R.M.HOSEA

DECEMBER 1893.   SCALE

NICKEL

HISTORICAL SKETCH.

BY. W. L. AUSTIN, PH D., DENVER, COLORADO.

Introduction.—The world's production of metallic nickel has increased within the past ten years from one thousand tons per annum to over five thousand tons, while previous to 1876 not more than six hundred tons were produced in any one year. This increase in the consumption, coupled with the fact that we are aware of the existence of nickel deposits in this State, as well as adjoining Territories, is sufficient reason for drawing attention to this matter at the present time.

As far as our knowledge reaches today, the principle value of nickel seems to lie in the properties of its alloys. Mixtures of nickel with various other metals, which in some cases are probably actual chemical combinations, exhibit such desirable physical properties, that in the arts and manufactures they have largely usurped the places previously occupied by some of the better known metals. For instance, alloys of nickel and copper have to a great extent supplanted the smaller silver coins formerly current, and the well known compound German-silver, a varying mixture of copper, nickel and zinc, is of such general utility that articles manufactured from it are to be found in almost every home; while a small percentage of nickel incorporated into steel has provided the engineer with a structural material superior for many purposes to the best carbon-steel.

Contrary to expectations, nickel itself in the metallic form has not yet met with any extended application, if we except the nickel plating of other metallic substances and the recent issues of pure nickel coins by Switzerland and Austria; not that it cannot be advantageously used in various directions, as is evident from the number of small articles made from it, mostly in an experimental way, but because it is too expensive for general introduction.

From all appearances it will be upon the valuable properties imparted to steel by alloying nickel with it, that the future development of the metal will largely depend. This comparatively new industry has been instrumental in bringing nickel prominently forward within the past year or two, and has given a much needed stimulus to its exploitation. Failure to appreciate the true merits of this metal long retarded progress in the metallurgical treatment of its ores, and it was not until the recent demand for nickel-iron alloys instigated metallurgists to exert themselves, that some more or less novel departures were undertaken into fields but poorly explored heretofore. From the progress made along these lines valuable hints may be deduced by those engaged in allied branches of the profession, and it is proposed to lay before the Society in subsequent papers brief synopses of several of these novelties in nickel metallurgy, reviewing the subject tonight only in a general way.

Nickel has not received from scientific men the attention to which it is entitled, and the subtle influences exerted on the physical properties of its alloys by the admixture of exceedingly small quantities of other elements have mystified the practical man and kept him in the background. For more than a century nickel puzzled and perplexed all who had anything to do with it, and its history is a long story of contradictory statements and mistakes.

A cursory glance over the literature of nickel metallurgy will disclose an astonishing number of errors and many flat contradictions, and an attempt to look up the subject in the standard text books of the day will leave the investigator with very erroneous impressions, both as to the comparative values of known ore bodies, as well as methods of ore treatment. Judging from what has been written, or more properly speaking, what has not been written, on the subject, it would appear as though the odium originally attached to nickel ores had, in a measure, stuck to the metal itself

down to the present day, metallurgical writers casually mentioning its existence, as it were, because they could not exactly ignore it altogether. The information given in most cases either refers to a practice so antiquated as to be mainly of historic interest now, or is misleading altogether on account of being based upon insufficient data. One of our best authorities, even, is confused on its chemical formulas, using Ni_2O_3 where reference is clearly made to NiO, at the same time disseminating other extraordinary statements about nickel, furnishing thereby an unwitting illustration of what has already been said as to the carelessness of metallurgical writers on this topic.

A number of quotations might be cited covering the case in point, but any, even though it be a superficial examination, is sufficient to show that an unusual confusion exists on this subject in current literature. This can be mainly ascribed to the facts that neither has pure scientific interest been felt or exercised much in this field, nor have the properties of this metal been sufficiently studied by those who would naturally be expected to investigate them from an economic point of view.

Another reason for the shortcomings of our text books on this subject, is the secrecy* maintained by those manufacturing nickel products relative to their processes. From its inception the metallurgy of nickel has been surrounded by mystery, and therefore, to a certain extent, progress has been handicapped for many years. This policy must have been adopted to deter others from erecting refineries, but it has not in the least accomplished its purpose. Whether manufacturers are benefitted in such cases by jealously excluding scientific discussion of the methods employed is open to considerable doubt; while experience in the rapid development of the iron and steel trade goes to show, in one instance at least, the benefits which may be derived by adopting an opposite line of policy. A thorough and open discussion of scientific matters rarely, if ever, fails to be of advantage to all taking part in it.

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* Künzel, in "Amtlicher Bericht über die Wiener Welausstellung im Jahre 1873," page 859, says: " Die Fabrikanten von Nickel und Kobalt haben die Gewohnheit ihre Fabrikations-methoden mehr oder minder in Dunkel zu hüllen; meist erfahrt man über eine Fabrikations-methode erst dannetwas, wenn sie durch eine andere vortheilhaftere ersetzt worden ist oder wenn sine Fabrik die Erzengung von Nickel-U-Kobalt Produkten aus irgend welchem Grunde gänzlich eingestellt hat."

Until quite recently there was practically no advancement from the processes originally introduced for preparing the nickel used in the manufacture of the series of alloys of which German-silver serves as the type. Consequently high prices were maintained on an exceedingly limited consumption. The fact must not be overlooked, however, that only quite recently have extensive deposits of the ores of nickel been discovered, the original ore bodies of Scandinavia, Saxony, Hungary and the United States, which furnished material to the trade for so many years, being limited in extent. On the other hand it may be said, that just because nickel was so little understood and its physical and chemical characteristics so inadequately studied, for that very reason general interest in the metal was not enlisted and the deposits now known to exist remained so long undiscovered.

One of the results of the system of secrecy adopted by the metallurgical establishments engaged in treating nickel products has been, that information regarding processes employed by them has only made its appearance when they were superceded by better methods. An exception may be noted in cases where manufacturers have deemed it to their advantage to take out letters patent covering their improvements. From the patent specifications of these various new processes proposed or in actual use, some hints may be gathered as to the lines upon which the art is advancing. But this information is naturally of the most limited description. Taken, however, in connection with the writings of Schweder, Badoureau, Garnier, Levat, Vogt, Künzel, Riley, Emmens and others, which have appeared from time to time in the European and American periodicals of the day, a fairly good idea of the metallurgical status of the metal may be collected in the form of a scientific mozaic, so to speak.

Before it can be expected that nickel should occupy the position to which its qualities entitle it, its metallurgy must be taken out of the category of complex and semi-mysterious processes. The very number of the operations to which it is subjected before it becomes a marketable product, render its economical production impossible under the circumstances and the percentage of loss necessarily large. It is almost a surprise that any of the metal remains at all after the ore has been roasted, matted, bessemerized,

"top and bottomed," refined, reduced to oxide, and finally incor-
porated into the steel.   Yet this, the so-called "dry process,"
which includes at least seven distinct stages, not to mention the
many side operations necessary for working up the by-products
obtained, is the simplest and, at present, most direct method of
treatment.

    When ores are subjected to the wet system of treatment the
above mentioned number of operations is even exceeded.   It is
said that when the "Gap" mine in Pennsylvania was operated, a
year used to elapse from the time the ore came out of the mine
before the metal was ready for the market.

    Such methods may be allowable where it is intended to pro-
duce chemically pure metal, but they are far too complicated for
making commercial nickel-iron alloys and are a reproach to mod-
ern metallurgy.

    Nickel should be put into the form of ferro-nickel, suitable
for making commercial steel, in not to exceed three operations, and
without innumerable by-products being left over to work up after-
wards.   The writer ventures to predict that these results will be
attained within the next two years.

    Before taking up the specific object of these papers, the dis-
cussion of the lately appearing processes of nickel ore reduction,
a brief review of the history of the metal may be permissible.

    There have been four marked stages of development in the
modern history of nickel as a metal.   First came the century or
more, when the presence of some unusual metallic combination
was recognized to exist in some minerals, and during part of which
time the metal was introduced into the arts as an alloy under the
name of "white copper."[*]   The second period commences with
the manufacture of German-silver on a large scale at Berlin in the
early part of the present century, when nickel obtained a recog-
nized position among the useful metals.   This era extends up to
the time of the adoption of the metal for coinage purposes.   Until
1850 no other use was made of nickel than that of an essential
component of German-silver.   The third period begins with the
adoption of nickel by Switzerland for subsidiary coins early in the

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[*] "Pack-Fong" is the Chinese equivalent for "white copper;" see Roscoe and Schor-
lemmer, Vol. II, Part II.

fifties and ends in 1888, when it was first successfully alloyed with iron (steel) on a scale of commercial importance. So that the fourth periodic impulse given to nickel, which promises to exceed all the others in results, has only just been entered upon, and may be termed the era of nickel-steel.

First Period.

The Discovery of Nickel.—When Cronstedt[*] in 1754, definitely determined that the substance which he had discovered and described three years previously, was really a new element, he named it nickel, on account of its being a constituent of the mineral "Kupfer-nickel," which we call niccolite or nickeline. He did not look upon the new element as being a metal, but considered it what he termed a semi-metal. Cronstedt's attention was first arrested (1751) by the peculiar behavior of this substance in examining ore obtained from the mines of Helsingland, but it was not until the researches of Bergman[†] made their appearance in 1779, that it was shown what the former had only obtained in an impure state was really a new metal.

Origin of the Name.—The mineral "Kupfer-nickel" was described by Hierne in 1694, and the name bestowed upon it is characteristic of the low esteem in which the old miners regarded the ores of this metal. "Kupfer-nickel," very freely translated, means, "the-copper-of-the Old Nick," the term nickel probably having its origin in "nikker," which is Low-German for the hangman or devil. Tradition has it, that misled by the copper color of the niccolite, from which ore they vainly endeavored to produce copper, they applied the nickname "Kupfer-nickel" to it, just about in the way our miners would under similar circumstances today use the term "Devil's copper." Another version of the origin of the name refers it to the trouble it sometimes occasioned the manufacturers in the preparation of smalt. When the cobalt ores became over-roasted in the process of smalt manufacture the nickel contained in them followed the former metal into the combination with silica, in this way spoiling the blue color of the

[*] Transactions of the Swedish Academy of Science, 1751, p. 293 and 1754, p. 38.
[†] De Niccolo, in Opuscula phys. et chem., 1779 to 1790, p. 38.

glass and thereby naturally incurring the displeasure of the work-men. However the name may have originated, it clearly intimates that those who were first brought into contact with the metal were not pleased with the discovery.

Nickel Before the Christian Era.—Nickel was employed in the arts centuries before it attracted the attention of the Swedish savant, or reappeared to worry the worthy Saxon miners. The Bactrian King Euthydemos, who reigned 235 years B. C., em-ployed an alloy of nickel* for coinage purposes. An analysis of one of these coins, is given below:

Copper............	77·58 per cent.	
Nickel	20·04 "	"
Iron	1·05 "	"
Cobalt...........	·54 "	"
Tin	0·04 "	"
Silver............	trace	
Sulphur	0·09 "	"
Total..........	99·34	

The iron, cobalt, tin, silver and sulphur, aggregating only 1·72%, may be regarded as merely associated impurities in this alloy, and there remains a mixture of copper and nickel corres-ponding closely to that employed in coins used today, which are generally considered to be a modern innovation. It is strange that Euthydemos hit upon this particular ratio of copper to nickel for his purpose, as it was clearly intended to be 22 to 23% of the latter to 77 to 78% of the former; this very closely approaches the proportion of 25 to 75, which experience has taught us is the most desirable mixture of those metals for use as coins. Another note-worthy feature of the Bactrian coin is that the analysis given shows no arsenic, which fact debarred rich arsenical ores as a source of the nickel employed, and points to the use of the sul-phides, as the silicates could scarcely have been beneficiated at that time. If the sulphides were really the ores from which the nickel was reduced, it presupposes considerable metallurgical skill on the part of the early smelters, and considering the nature of the metals employed, it is hardly probable that the alloy was a

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* Numismatic Chronicle, VIII, p 305. Pogg. Ann. CXXXIX, p. 507.

haphazard mixture. A very interesting story is locked up in those old coins, and their existence robs Dr. Feuchtwanger, of New York, of any claim to priority of idea, when in 1837 he made his experimental "nickels."

Nickel in China.—Long before Europe awoke to the value of nickel, that enterprising people, the Chinese, who have antedated us in the application of the so-called modern improvements, such as gunpowder, bank-notes, etc., had been making an alloy of nickel and shipping it to Europe for a century or more, under the name of "Pack Fong,"* a variable mixture of copper, nickel and zinc. How long the Chinese had been manufacturing it before Europe heard of it there is no means of knowing. "Pack Fong" was analyzed in 1776 by Engstrom, and a similar alloy made.

SECOND PERIOD.

Rise of the German-Silver Industry.—Since the middle of the last century, at Suhl, in Hanneberg,† a white alloy had been prepared from old copper slag, which found its way into trade as "white copper." In 1823 Brandes showed that this alloy consisted chiefly of copper and nickel. Up to that time nickel had, in Europe at least, no value. The speise at the cobalt glass works, which was composed largely of nickel, was only used for the arsenic it contained, and the nickeliferous residue thrown over the dump. As soon, however, as it was learned that certain proportions of copper, zinc and nickel when melted together gave a beautiful white metallic alloy, closely resembling silver, tough, easily worked, and not tarnishable when exposed to gases containing sulphuretted hydrogen, the metal which had lain so long under a ban began to receive attention.

As already stated, nickel was employed in the manufacture of German-silver before the qualities of the metal were known, but it was not until 1824 that the nickel-copper-zinc alloys were made in Berlin on a large scale. That city has ever since been the center of this industry, whence the popular name for the alloy, German-silver.

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* Roberts-Austen. Introduction to Metallurgy, p. 90.
† Roscoe & Schorlemmer. Vol. II, Part II, p. 147.

The year following, Gersdorff began to make the same material in Vienna, and built nickel works at Reichenau, in Lower Austria. Soon other large commercial centers, Paris, Birmingham, etc., took up the business, and a number of alloys, differing mainly in the relative proportions of the three metals appeared under a variety of titles in the markets of the world.

It was an easy matter for the metallurgists to produce an alloy of nickel and copper out of the ores then worked, for the two metals were invariably associated, and as they approach each other so closely in many of their chemical and physical properties, they naturally remained together throughout all the metallurgical operations to which the nickel was subjected, and came out finally as an alloy suitable for the German-silver makers. This was rather fortunate, for had it been necessary to prepare a comparatively pure nickel, the early development of this industry would have found a formidable obstacle in its path. However, as long as its use was confined solely to German-silver manufacture, the alloy answered the purpose as well as though the metal had been reduced to the pure state.

Up to 1838 the source of the metal was wholly from its arsenide ores, and it was not until after the year mentioned when Berzelius is thought to have discovered nickel in the Klefva ores (Sweden), that Aschan made his first smelting tests upon the nickeliferous pyrrhotites and pyrites of that country.

The metallurgical losses were at first very heavy, but in 1849-1851 Berdberg made some experiments in which he laid down certain principles which have held good in nickel metallurgy up to the present time.

The Discovery of Nickel in the United States.—Nickel was probably first known to exist in this country when, in 1818,[*] Seth Hunt opened up the cobalt mines near Chatham, Connecticut, and shipped some of the ore to England, from whence a report was returned that it contained nickel. These same cobalt mines at Chatham were at one time the principal source of nickel in this country, at least they were so reported to be by Whitney in 1854, when at the same time he refers to the afterwards celebrated

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[*] Whitney, the Metallic Wealth of the United States. 1854, p. 497.

"Gap" mine as an unimportant copper deposit. Smaltite, a cobalt mineral, is prominent in the Chatham ore, and it is not unlikely that it was this glistening, silver-like mineral which attracted the attention of Governor Winthrop as long ago as 1661, and led him to obtain a grant from the inhabitants of Middletown, Connecticut, for the purpose of working those mines for the supposed silver ores, as nickel and cobalt were metals then unknown. These mines appear not to have proven very remunerative to their different owners, as they were taken up and abandoned, again and again, as the years went by. For instance, in 1762, we are told that a Dr. John S. Stephanney reopened the Chatham mines, and in 1770 associated several others with himself for the purpose of working them for cobalt. Again in 1787 a Mr. Erkeleus took out a quantity of the cobalt ore and shipped it to China. In 1853 attention was once more drawn to the mine by the Exposition held in that year in New York, where the Chatham Cobalt Mining Co. made a creditable exhibit of its ores and products.

The "Gap" Mines.*—The principal deposit of nickel ore opened up in the United States to date, was at the "Gap" mine in Pennsylvania. Tradition tells us that these mines were discovered in 1718.† At any rate, they were in operation in 1744 and were worked for their copper. They had passed through a number of hands when in 1849 the "Gap Mining Company" took hold of them and worked them until 1860, succumbing in its turn owing to inability to make a financial success of the enterprise. At the time this company took hold of the property it was valued for its copper only. Millerite was present in abundance, but nobody seemed to recognize it; it was called "mundic" and thrown over the dump. Finally in 1852 a new superintendent arrived at the mine who seemed to have had doubts about the yellow sulphide ore being "mundic," at least the kind of "mundic" with which he was familiar. He communicated his doubts to the company, and some samples of the ore were sent to Boston and Baltimore for examination, but the returns do not appear to have satisfactorily cleared up the uncertainty. Finally in 1853 some of the material

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* Berg und Hüttenmännische Zeitung, 1874, p. 142; 1875, p. 58; 1893, p. 454.
† Report CCC of the II Geol. Survey of Penna. 1880, p. 163 et seq.

came into the hands of Dr. Genth of Philadelphia, who pro-
nounced it nickel ore. It seems all the more strange that the dis-
covery of nickel in the "Gap" ores should have been so long de-
layed, because in 1846 Professor James C. Booth had already
established his nickel refinery at Philadelphia.

<div align="center">THIRD PERIOD.</div>

Nickel Coins Reappear.—With the rediscovery of the value of
nickel for coinage purposes and the introduction of nickel coins
by Switzerland in 1850, the metal obtained a further foothold in
the arts and manufactures. Different nationalties were quick to
perceive the advantages of nickel for subsidiary coins, and one
after another adopted the metal for that purpose until "nickels"
became a familiar feature in the monetary affairs of the world.
Considering what a radical step the introduction of a new metal
as a medium of exchange is, the reception which nickel met in this
direction was exceedingly flattering. The United States began
minting the "eagle" cents in 1857 in compliance with the act of
February 21st of the same year; the Belgians followed with their
nickel coinage in 1860, and many other governments, among
which were Germany, Servia, Brazil, Japan, Egypt, Ecuador, Ven-
ezuela, etc., subsequently took up the idea.

In November, 1862, Joseph Wharton acquired possession of
the "Gap" property and put it into operation as a nickel producer
in May, 1863, at the same time starting a refinery at Camden, oppo-
site Philadelphia. For a long time the "Gap" mine produced
most of the nickel used at our mints and in the nickeliferous
products shipped abroad. Some of the metal, however, came from
other points in the country, a small amount being furnished by
"Mine la Motte" in Missouri, where it was obtained merely as a
by-product from other smelting operations.

The spasmodic and temporarily heavy demands for the metal
caused great fluctuations in its price as the various governments
adopted it for coinage purposes. This was notably the case in 1837,
when the price rose from 4s to 16s per pound upon Germany
adopting the metal for this purpose. These commercial disturb-
ances were largely due to the fact that the production all told was
insignificant, and any unusual demand consumed the product of

all the mines, as long as the principal sources of supply were confined to the arsenide and sulphide ores.

Important Discoveries in New Caledonia.*—In 1867 Garnier first called attention to the existence of nickel ores in New Caledonia, but it was not until 1876 that these immense deposits of hydrated silicates of nickel and magnesium (garnierite)† assumed commercial importance and manufacturers of nickel products had placed at their disposal this exceedingly valuable material. These new ores contained the nickel in the form of the protoxide, free from cobalt, copper, sulphur and arsenic, and consequently required an entirely different system of treatment from that by which the sulphide, and sulpho-arsenide ores had been handled.

Many were the processes devised to treat the new material, both by dry and wet methods, or combinations of the two. Shipments of garnierite were made to France, Cornwall, Germany and elsewhere, and the rapid development of the New Caledonia mines with the possibility of producing a purer nickel from ores free from the usually accompanying deleterious substances, improved the quality of the metal offered in the markets, reduced its price, and extended its uses.

Several years previous to the appearance of the New Caledonia silicates at the metallurgical works of Europe, somewhat similar ores had already been worked at Ickatarinenburg in the Ural Mountains of Russia;‡ and others were known to exist in Spain,§ while since then further deposits have been discovered in Oregon and North Carolina in this country.

The New Caledonia ores proved to be a very disturbing feature in the established nickel industry, for in 1882 the world's production of that metal had approximated 1,000 tons of pure nickel per annum, thereby exceeding the demand, which lay between 700 and 800 tons per annum. In order to dispose of their product the New Caledonia mine owners began to force sales; prices naturally fell, and among others Wharton's Camden works suspended operations at the close of that year.

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* Bulletin de la Société de l'ind. minér. 1892, pp. 753-804.
† This name was given to the mineral in 1875 by Dana, who described it from samples sent to him.
‡ Wagner Jahres Bericht. 1876, p. 268.
§ Comptes Rendus, LXXXIII, p. 231.

Altogether the year 1876 was a memorable one to those inter-
ested in nickel, for at the same time that the announcements came
of the discovery of large masses of pure ores in New Caledonia,
Wharton showed the world what could be done with metallic
nickel in an industrial sense.

Wharton's Exhibits in Philadelphia and Paris.—At the Centen-
nial Exposition in Philadelphia in 1876,* Wharton made an ex-
hibit of nickel products such as had not been seen anywhere else
up to that time, but so little was known or understood about the
metal then that this remarkable display received scarcely any
attention. Again, in Paris in 1878, Wharton repeated his exhibits,
showing articles made of pure nickel both forged and cast. The
products were so remarkable that they excited the incredulity of
scientific Europe.

Production of the Norwegian Mines.—It was in 1876 also that
the Scandinavian mines reached the period of their greatest pro-
duction, yielding for Norway 360 metric tons of metal,† and for
Sweden probably not to exceed one-fourth of this amount. Since
that date the yield of these mines has very materially fallen off,
amounting in 1889, 1890 and 1891 to about the same quantity of
metal as produced in the United States in those years, which was
insignificant compared with the production of Canada and New
Caledonia.

Fleitmann's Discovery.—In 1804 Richter had succeeded in pro-
ducing malleable nickel, but subsequent investigators appear to
have obtained variable compounds, often brittle, according to the
amount of impurities left in the metal. The important part played
by small quantities of impurities alloyed with the nickel was not
then thoroughly understood, and it was not until Dr. Fleitmann,
of Iserlohn, Westphalia, in 1879,‡ found that the introduction of
small amounts of magnesium into the nickel just before pouring,
improved its quality greatly that it became possible to produce a
malleable nickel with any degree of certainty. It is to be noted,
however, that complete malleability of nickel had been obtained

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* Mineral Resources of the United States. 1882, p. 418.
† Vogt in Zeitschrift für prakt. Geology, 1893, p. 143.
‡ Berg- und Hüttenmännische Zeitung. 1880, p. 176; 1881, p. 76; 1883, p. 124.

at Wharton's works, in Camden, before Fleitmann's invention, but the latter is a more rapid and better method.

Garnier * subsequently accomplished the same results by the use of phosphor-nickel.

These discoveries were of great value and appeared to open up a new future for nickel as a metal apart from its alloys, for Fleitmann had at the same time shown that it could be welded. But the expectations raised were not realized, and during the years 1883 and 1884, the continued forced sales of the product of the New Caledonian mines brought the price of nickel still lower, averaging in the latter year only seventy-five cents per pound.

The Tariff.—Previous to 1883† there was an import tax of twenty-five cents per pound placed on nickel, but in the year named it was reduced to fifteen cents per pound. Subsequently, when the Canadian nickel mines began shipping their product into this country, this tax was made merely nominal,‡ and according to the revised tariff list (the Wilson bill), at the present time before Congress, it is proposed to remove the duty altogether from "nickel oxide and alloy."

Discoveries of Nickel on the Pacific Coast.—Nickel silicates were discovered in Douglas County, Oregon,§ in 1881, and have lately been considerably exploited by an Anglo-American company. In 1884 deposits of nickel ore were known to exist in Churchill County, Nevada, but these have only yielded experimental shipments to date. Distance from market, coupled with the forced sales by the New Caledonian mines, and the late discoveries of nickel in Canada, have militated against the coast mines. For these reasons, probably, capitalists have not been disposed to take hold of them, although they are the most promising nickel ore bodies at present known to exist within the boundaries of the United States. In 1885 about 90 tons of the Nevada ore were shipped to Europe, but in 1886 the price of the metal had fallen to sixty cents per pound, and nothing further was attempted in

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* { Berg- und Hüttenmännische Zeitung. 1881, p. 6.
{ Le Technologiste. 1880, Num. 142
† Mineral Resources of the United States. 1883-84, p. 538.
‡ Engineering and Mining Journal, XLIX, p. 378.
§ Clarke in American Journal of Science, XXXV, p. 483.

the way of shipments from those mines after that year.   Lately they have again shown symptoms of revival.

Discovery of the Canadian Nickel Deposits.—The presence of large deposits of nickel and copper in the districts of Algoma and Nipissing, in the Province of Ontario, Canada, has of late years attracted world-wide attention, first on account of their immense and apparently inexhaustible character, and lately because of the new applications of nickel in making nickel-steel.   The existence of deposits of copper in this region had long been an established fact, and in 1848 the "Wallace" mine,* on the north shore of Lake Huron (southwest from Sudbury), was opened and worked as a copper mine.   Even an earlier date has been assigned as the beginning of mining operations in that section.

In his report for 1856, Mr. Alex. Murray mentions the occurrence of a "dingy green magnetic trap" at a point which is ten miles southwest of what is now known as Sudbury.   This rock, upon analysis, showed small quantities of nickel and copper.   But the inaccessible nature of the country deterred prospectors, and it was not until 1883, when the Canadian Pacific Railway was in course of construction, that the first discoveries of any importance were made.   Early in 1884 the railroad mentioned made a cutting for its main line through a small hill about three and one-half miles northwest of Sudbury, thereby exposing the deposit of ore since known as the "Murray" mine; other discoveries followed fast.

In the spring of 1886 the Canadian Copper Company was formed to operate the "Copper Cliff," "Stobie," and "Evans" mines, but it was not until 1888 that the first furnace was erected by this company.   Shortly afterwards a number of other companies entered the field, among which was Vivian & Co., of Swansea, England.   When the writer visited Sudbury in the fall of 1892, there were already a number of furnaces at work there.

Nickel Mines Originally Opened as Copper Mines.—The Sudbury mines are to-day the largest producers of nickel on this continent, if not of the world, yielding in 1891, 4,626,627 pounds of the metal.   Since 1889 the mattes produced in the Canadian furnaces have been coming into this country in large quantities, resulting

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* Geological Survey of Canada, 1863.

in the closing of the "Gap" mine in 1891. This influx of foreign material, greatly facilitated by the practical removal of the duty in 1890, has had a detrimental effect on the exploitation of American nickel properties, and may partially account for the slight attention which has been paid them of late years.

The Sudbury ore bodies, like many other nickel deposits, were originally opened as copper mines, and it was not for some time that the presence of nickel in paying quantities was suspected. One is very apt to overlook nickel in its mineralized forms. The nickel ores of the "Gap" mine were not recognized as such until after that property had been worked on and off as a copper mine for over a hundred years. Several other cases could be cited where nickel ores have not been recognized at first, and have either remained unnoticed altogether, or else have been thrown over the dump for years. This unobtrusiveness of nickel, if such a word is permissible, the close resemblance of many of its ores to other minerals, and the unfamiliarity of the average man with the occurrences of the metal in nature, have all tended to keep it in the background. Besides those already alluded to, there is good reason to believe that what may later prove to be extensive deposits of the metal, exist in the United States.

FOURTH PERIOD.

The Era of Nickel-Steel.—Attention had long been directed to the unusual properties displayed by meteoric iron, both in regard to its extraordinary toughness as well as, in some instances, its non-corrodibility. Again and again during the present century, investigators appear to have returned to this subject in examining the physical qualities of these celestial visitors and by endeavoring to produce artificially similar alloys. Meteoric iron is never pure, but is invariably associated with nickel and other elements, and the desirable qualities attributed to it are ascribed to this fact. It became clear at an early date that iron alloyed with nickel acquires certain new and valuable properties, but obstacles were encountered in bringing these metals together, and even when this was effected the results were far from corroborating each other. Faraday* experimented in this direction by melt-

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* Quarterly Journal of Science, Literature and the Arts. 1820, p. 324.

ing horseshoe nails and pure nickel together in various propor-
tions, reaching finally only contradictory results. Berthier* also
made some alloys of the two metals, producing a mixture corre-
sponding to that of a meteoric iron found near Bogota. Liebig†
examined the same subject in 1832, and Mr. Fairbairn,‡ in 1858,
recorded the results of some experiments on alloys similar in com-
position to meteoric iron. In 1861, Longmaid patented (British
patent No. 1863, A. D. 1861) some alloys of iron and nickel, but
used only very small amounts of the latter metal. Boussingault,
as well, investigated the subject in connection with researches on
metallic meteorites, which in fact seem to have been the incentive
that urged on all early investigators of these alloys.

But all efforts to manufacture a commercially valuable alloy
of iron and nickel were in vain until a few years ago, the trouble
being that the tremendous influence of minute quantities of other
accompanying metals and metalloids was not understood nor sus-
pected. It is strange that the effect of impurities on the alloy
should have been unappreciated for so long a time.

Künzel, in his report on the Vienna Exposition,§ speaking of
the experiments made in 1860 at the Liege cannon foundry, in
which it was aimed to improve the quality of ordnance metal by
the addition of a little nickel, says the result was negative, and
declares he cannot understand what qualities of the iron (rohei-
sen) or nickel warranted the undertaking. Even Ledebur¶ him-
self has predicated that the new nickel-steel alloys belong to that
class of inventions which crop up at intervals finally to be buried
in oblivion because of their impracticability.

Probably the first appearance of nickel-iron alloys in the
United States was when Philip Thurber of Detroit, at the New
York Exposition in 1853, exhibited some products of the iron fur-
nace at Marquette, Michigan. This iron was made from a nickel-
iferous limonite and possessed some remarkable qualities, but it
was not until 1888, after experiments had been made first in France
with crucible nickel-steel alloys, and subsequently in England

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* Traité, p. 216.
† Annalen der Pharmacie, 1832, p. 237.
‡ Proceedings of the Manchester Philosophical Society, March 9, 1858.
§ Amt'l Bericht über die Weiner Weltausstellung von 1873, Bd. III, 1 Abth'l.
¶ Stahl und Eisen, 1889.

with similar mixtures produced in the open hearth, that the sub-
ject was brought to general notice.

In May, 1889, Mr. James Riley, at the request of the Iron and
Steel Institute of Great Britain, read a paper at their meeting in
Glasgow, in which he set forth the results of the experiments he
had been making with nickel-steel. Riley had been over in France
at the invitation of Marbeau, for the purpose of looking into the
claims made for certain crucible nickel-steels by that engineer,
and having satisfied himself as to their genuineness he returned
to his works in Scotland and began experimenting with similar
material, using an open hearth furnace in the place of the crucibles
employed in France. The results obtained by Riley are given
very fully in the proceedings of the Iron and Steel Institute.
Notable among them was one nickel-steel alloy containing 4·7%
nickel, which showed an elastic limit of 28 T. per square inch and
a breaking strain of 40 T. per square inch, whereas similar steel,
without the nickel, showed only 16 T. and 30 T. respectively.
The elongation and contraction of area of this steel were more-
over not materially impaired.

In August, 1890, the papers stated that the United States
Naval Board was about to test " a newly invented nickel-steel
plate" recently purchased by the Chief of the Bureau of Ordnance
from the Creusot works. On September 18th and 22d this plate
was tested at Annapolis, Maryland, together with other represen-
tative armor plates submitted for trial, to ascertain which style of
protective armor was the best for use on the new United States
men-of-war then building. At these competitive armor trials the
victory rested with the French nickel-steel plate, as against
another carbon-steel French plate and a compound one of Eng-
lish make. On September 26th, 1890, a bill was introduced and
immediately passed by the House of Representatives, appropri-
ating $1,000,000 to enable the Secretary of the Navy to purchase
nickel ore and nickel mattes for armor manufacture. It appeared
to outsiders as though the authorities were acting with undue
haste in the matter, and immediately stories began to circulate
detrimental to the new material, suggesting the possibility of a
"job" lying at the bottom of the hasty action on the part of Con-
gress. It was stated that the new steel became exceedingly brittle

when subjected to great cold; that its magnetic properties were such that ships' compasses under certain conditions could become totally deranged; in fact, that the new product was very unreliable and uncertain in its behavior. It appeared as though experience with alloys of iron and nickel on the part of experts had been for too long a period of a doubtful nature to admit of an opposite opinion being hurriedly reached.

Mr. Tracy, however, who was at that time Secretary of the Navy, decided to have very careful tests made of this armor before adopting any kind in the new navy, and proposed to employ for such tests plates that were to be made of American material by American mills. As a result of this decision orders were given to the Bethlehem Iron Company and to Carnegie of Pittsburg to prepare such plates, the government furnishing the necessary nickel for the work.

Shortly afterwards, Mr. W. L. Abbott, of Carnegie, Phipps & Co., in reporting to Mr. Tracy the progress in the manufacture of nickel-steel plates at the Homestead works near Pittsburg, showed samples taken from some of the material out of which the trial plates were being manufactured, and which had been rolled down to $\frac{3}{4}$ inch for experimental tests. These gave an ultimate tensile strength of 100,000 to 102,000 pounds per square inch, with an elastic limit of 59,000 to 60,000 pounds. The elongation was $15\frac{1}{2}\%$, with reduction of area of $29\frac{1}{2}$ and $26\frac{1}{2}\%$ respectively at fracture.

The toughness of nickel-steel is very great. During a visit which the writer made to the Bethlehem works last spring a large field was observed which was covered with blocks of nickel-steel that had been cut off during the process of manufacturing the armor plates. Many of these ingots weighed several tons. They had been set out in the open field adjoining the works because it was said that no profitable method of breaking them up into sizes suitable for returning to the furnaces had yet been devised. Attempts had been made to blast them with dynamite, but the explosive shot out of the holes as from a cannon, doing little execution on the blocks. Another illustration of the toughness of the metal is given in the late experiments by the German government, where shells were exploded in cannon, the one of ordinary gun steel, the

other of nickel-steel. The former was badly damaged, whereas the latter was only enlarged.

One by one the objections raised against nickel-steel have been removed. The effect of cold weather on the plates was experimentally demonstrated to be of no importance, and in April, 1891, the first nickel-steel plates of American manufacture began to arrive at the Washington Navy Yard for testing purposes. Plates of all descriptions, with and without nickel, were exhaustively experimented with. High and low carbon steels were shot at; plates just as they were rolled or forged, and others which had been surface hardened (Harveyized) were again and again subjected to the fire of the most formidable modern ordnance made, rifles as high as 12-inch caliber being used. These tests extended all through the summer, fall and winter of 1891 and 1892, and are still in progress, a plate being taken for testing purposes from each lot of material delivered by the works. The results have demonstrated beyond all doubts the superiority of nickel-steel for armor purposes. The tough, tenacious material flows under the impact of the shot, and in the case of the "Harveyized" plates, the extreme hardness of the exterior surface, reinforced by the tough, untreated steel behind, shatters the forged steel Holtzer projectiles, which have hitherto proved irresistible.

The World's Production of Nickel.—In the early eighties a yearly production of 1,000 tons of nickel swamped the markets of the world and sent the price of the metal down with a rush, the total annual consumption then being approximately 700 to 800 tons. In 1889 the world's production rose to 4,186,269 pounds, and reached in 1890, 5,299,429 pounds. In 1891 it was about 10,307,-275 pounds, which was not far from five times as great as it had been ten years previously.

There has been no material increase in any of the established channels of consumption, except it be for plating, consequently the large excess of metal produced must have gone into the manufacture of nickel-steel. Yet this alloy has hardly been introduced into what may be termed the peaceful arts up to the present.

Nickel-Steel in the Arts.—The price of nickel has been falling for several years, so that now, with the improvement in methods of producing the metal and its alloys, we can confidently expect

to see its cost steadily reduced until it finds a ready entrance into the steel trade for other purposes than making armor plates and guns.

There is naturally some hesitation in using it, as is the case with any untried material, in places subject to great strains and extremes of temperature, such as occur in boiler plates, bridge building and marine engineering. A great many experiments must precede its adoption for such purposes, but when it finally wins the confidence of the engineers, and some rational and cheap method of reduction from its ores has been introduced, we may expect to see the consumption greatly extended and the production keep pace with the demand.

Very little has been published regarding the use of nickel-steel in the arts and manufactures. It is, however, quietly being experimented with. Last year it was decided to place sections of nickel-steel propeller shafting in the United States protected cruiser "Brooklyn," and Battleship No. 1 (the "Iowa"). The ordinary carbon-steel used for such purposes has a tensile strength varying from 60,000 to 65,000 pounds per square inch, whereas the nickel-steel intended for the shafting spoken of will show a tensile strength of 90,000 pounds per square inch, the elongation being in both cases about the same, 20%. Using this stronger steel for the purposes specified will warrant removing the interior metal by boring, thus materially lessening the weight while preserving the efficiency. Such bored-out castings may in some cases be hollow forged, that is, when the hole is large enough to admit a mandrel, and when so treated they are essentially improved. Nickel-steel shafting will not be altogether a novelty, however, for during the past summer the Bethlehem Iron Works completed a spare crank shaft for the American Liner "Paris," using nickel-steel of about 90,000 pounds tensile strength, which is said to be 25,000 pounds in excess of any shafting made by German or English manufacturers. This statement is, however, open to some doubt, for an English firm which for a long time enjoyed an enviable reputation for the excellence of its shafting, owed its success, it is claimed, to the small quantity of nickel introduced into the steel used for that purpose. But this was before nickel-steel had begun to excite general interest.

The possibilities opened up before ship builders and architects when a steel is attainable by them with over 100,000 pounds tensile strength and an elastic limit in proportion, without seriously impairing elongation or reduction of area, have a tendency to lead into flights of fancy which it is premature to indulge in before this material has stood the test of prolonged usage.

By preparation for war the arts of peace are advanced, and to the navy department of the United States is largely due the practical development of the most valuable qualities to which the metal nickel can lay claim. In the probable extension of this, at present almost wholly war material, into the arts and manufactures lies the main hope of nickel in the immediate future.

I cannot close this article without tendering acknowledgments to Mr. H. A. Vezin for kindly allowing me access to his well filled library for consultation and reference.

NICKEL:

THE OCCURRENCE, GEOLOGICAL DISTRIBUTION AND GENESIS OF ITS ORE DEPOSITS.

BY PHILIP ARGALL, DENVER, COLO.

Read at Meeting, December 4th, 1893.

Native nickel is found alloyed with iron in meteorites and also in some ultra basic lavas, while the spectroscope reveals its presence in the solar atmosphere. We can therefore claim for metallic or native nickel both a cosmic and a terrestrial origin, though from neither source is it obtained in commercial quantities. Indeed, so little is known of the occurrence of native nickel that many text-books deny, or silently ignore, its existence except in meteorites.

I believe it is important to note that nickel shares with iron the distinction of being a connecting link, as it were—and a metallic one at that—between our world and those bodies in planetary space that have finished their careers as luminaries; that have become disintegrated, and the fragments of which, attracted by our earth, are being continually showered over its entire surface, at once brilliant and permanent witnesses of the "wreck of worlds," and of the common origin of the material universe.

As any article on nickel, however unpretentious it may be, must necessarily be incomplete without some reference to cosmic nickel, let us briefly review our present knowledge of those interesting messengers (the meteorites) from "worlds that were," and endeavor to see what they are and what they teach us.

THE METEORITES.

Meteorites may be divided into two primary groups, namely,

the metallic and the stony; but as these merge into each other by insensible gradations, it is best to follow the classification of Daubrée.

(1)   Holosiderites, composed entirely of nickel-iron.

(2)   Syssiderites, consisting of stony grains, disseminated through a metallic paste.

(3)   Sporadosiderites, consisting of metallic grains in a stony paste.

(4)   Asiderites, consisting entirely of mineral matter without metallic iron.

Holosiderites.—The holosiderites consist of metallic matter to the exclusion of stony parts; the metal is nickel-iron with chromium and cobalt.   The minerals troilite (FeS), schreibersite, a phosphide of iron and nickel containing magnesium and daubree-lite, $FeS.Cr_2S_3$, are sometimes found in these meteorites.   The latter mineral, it will be observed, differs from chrome iron ore in containing sulphur in place of oxygen.   These minerals—excepting troilite—are not known to occur in terrestrial rock masses. Another peculiarity of holosiderites is that when a polished surface is subjected to the action of an acid, part of the iron is left in relief lines parallel to two faces of a regular octahedron (Widmannstaetten figures).   (See Fig. 1.)

The average composition of these metallic meteorites is: Iron, 92·7%; nickel, 5·6%; chromium and cobalt, 0·9%.   The entire absence of oxygen in these meteorites will be noticed, while the following analyses will show that meteorites that have fallen at different times and in places widely separated, have nevertheless great uniformity in composition:

Source.	Zacatecas, Mex.	Lenarto, S. Amer.	Siberia (Pallas).	Bohumilits, Bohemia	Crosby's Creek, Tenn.	Cape of Good Hope	Pulaski, Virginia
Analyst.	*H.Müller*	*Wehrle.*	*Berzelius*	*Berzelius*	*Bergemann*	*Uricoechea*	*Eakins.*
Iron	90·91	90·83	88·27	95·25	91·89	81·20	93·59
Nickel	5·65	8·45	10·82	4·51	6·70	15·09	5·56
Cobalt	0·42	0·66	0·46	0·21	0·33	2·56	0·53

Syssiderites.—The nickel-iron in this class of meteorites contains silicates of magnesia and iron protoxide identical with olivine, and at other times a mineral resembling augite.   Here then we find mineral combinations resembling those so common in the eruptive rocks.

Fig. 2 shows a section of a meteorite, the bright markings being large and well-formed crystals of olivine embedded in a matrix of iron. This meteorite was found in the desert of Atacama, in South America.

A meteorite that fell in Montréjean, Haute Garonne, in 1858, was examined by M. Damour.   He found it to have the following composition:

Nickel-iron	11·60
Magnetic pyrite	3·74
Chrome iron	1·83
Peridot (olivine)	44·80
Hornblende and albite	38·00
	99·97

Some meteorites of this class are traversed by slickenside surfaces, which have apparently been produced before the breaking up of the original mass.   Slickensides have usually been attributed to the grinding of two rock substances upon each other and to be always the product of such movement.   Daubree[*] has, however, shown in his recent papers on "The Geological Work of High Pressure Gas," that a gaseous body under certain conditions of speed and pressure, can polish and striate rocks without the intervention of solid particles.   We cannot therefore accept striation as indicative of the movement of solid bodies in all cases.

Sporadosiderites.—Sporadosiderites are the most common variety of meteorites, occurring in the proportion of ten to one of the other kinds, according to the estimate of Prestwich.   They are usually of crystalline structure and contain nickel-iron, troilite, chrome iron, olivine, titanic and phosphoric acids.   M. Damour believes the Juvinas (Ardèche) meteorite closely resembles some of the Iceland lavas. ·Its composition is:

Pyrozine (augite) ....62·65
Feldspar (anorthite)...................34·56
Phosphate of lime...................... ·60
Titanate of lime....................... ·25
Chrome iron........................... 1·35
Magnetite .... 1·17
Magnetic pyrite....................... ·25
                                    _____
                                     100·83

A meteorite, probably of this class, which fell in Washington County, Virginia, June 25, 1890, weighed 184 pounds. It was examined and analyzed by L. G. Eakins, who observed pyroxene, troilite and nickel-iron.

The Metallic Particles Gave.	Proximate Composition.
Fe........86·76	Nickel-iron .... 7·7
Ni........12·18	Troilite.................................. 5·0
Co......... ·83	*Silicates, soluble in HCl.................46·0
	Silicates, insoluble in HCl..............41·5
_____	_____
99·77	100·2

Asiderites.—These meteorites do not contain metallic iron, but it is present as an oxide, together with nickel, cobalt and chromium. Asiderites are comparatively rare, and are especially distinguished by the presence of hydro-carbons.

A brief glance at these four classes of meteorites shows a gradation from almost pure metal containing, as we have seen, over 98% nickel-iron, to a stony mass closely resembling some basic lavas. We also find common minerals in these meteorites, the more important of which are olivine, pyroxene, feldspar and troilite. Diamonds have been found in a meteorite discovered at Canyon Diablo in Arizona. Here then we have not only the same elements that occur in the earth, but also the same mineral combinations that are so abundant in basic igneous rocks. There are some other peculiarities in meteorites which may be noted in passing—for instance, the absence of oxygen in holosiderites, the low degree of oxidation of the component minerals in the others, the absence of quartz and highly silicated feldspars, and that when feldspars do occur they are chiefly anorthite.

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*Olivine and troilite.

TERRESTRIAL NICKEL.

It is well known that the density of the earth is about 5·41,[*] while that of the crust to which our limited observations extend is but 2·4. Many theories have been advanced to account for this great variation. The best thinkers have, however, suggested that the heavier metallic ingredients might possibly be found to predominate in the nucleus. These suggestions were based on widely extended observations of present and past volcanic action. It was found that, once the acid stage had been passed, lavas become more basic; and while each succeeding flow from any one vent might not show a more basic lava than the preceding one, yet the tendency was in that direction, until finally ultra basic lavas were extruded from the seats of intense and long continued activity. Notwithstanding that the seat of volcanic activity is continually shifting, the same average order almost invariably attends the extrusion of lavas at every point on the earth's surface, provided the volcanic forces continue active for a sufficient period of time to reach and eject the ultra basic rocks.

The ultra basic igneous rocks have many points of similarity with some of the meteorites to which attention has been called. Take dunite, for example, which is a crystalline granular aggregate of olivine and chrome iron. This rock passes by alteration into serpentine. We have also picrite, nearly one-half of which is composed of olivine, associated with hornblende, diallage and magnetite. Lherzolite is another of these peridotites, consisting of olivine, enstatite, diopside and picotite (a black spinel containing over 7% sesquioxide of chromium). Olivine is the dominant constituent of this rock, and is frequently altered into serpentine. Von Lasaulx gives the following analysis of Norwegian lherzolite: SiO_2, 37·42%; Al_2O_3, 0·10%; MgO, 48·22%; FeO, 8·88%; MnO, 0·17%; NiO, 0·23%; H_2O, 0·71%.

These peridotite rocks have the highest specific gravity, 3·3 to 3·5, as well as the lowest oxygen of any known rock.

Some of the basalts, notably those of Antrim, Ireland, as pointed out by Professor Andrews, contain metallic iron (probably niccoliferous) in microscopic particles. To Professor Norden-

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[*] This is the latest determination by M. Alphonse Berget. Compt. Rend., July, 1893.

skiöld, however, belongs the distinction of having—·without know-ing it—placed the conjecture of a metallic nucleus for our earth beyond reasonable doubt, by the discovery in 1870, at Ovifak, on the shore of the island of Disko, off the Greenland coast, of fifteen blocks of nickel-iron within an area less than half an acre, the two largest being twenty and eight tons weight, respectively. Further observation in the same locality showed that the basalt contained lenticular and disc-shaped blocks of precisely similar iron. Nor-denskiöld, however, arrived at the peculiar and apparently impos-sible explanation of these phenomena, that the nickel-iron blocks were meteorites that fell in a shower at the time the basalt was in a molten condition. The difficulty remained, to account for the iron masses found in the basaltic dyke in the vicinity of the blocks of nickel-iron, while the microscope revealed in this basalt the presence of minute particles of iron moulded around crystals of labradorite and augite associated with viridite. These facts lead Froqué, Lévy, Daubrée, Judd and others, after careful study, to decide that the large masses of nickel-iron at Ovifak, together with the metallic iron diffused through the surrounding basalt, were of terrestrial origin. This Ovifak iron contains from 0·5 to 6·5% Ni, and varies in specific gravity from 6·80 to 7·46. A nickel-iron "awaruite" is found in the drift of the Awaru River, New Zealand, in association with gold, platinum, cassiterite, chromite, etc. This nickel-iron has been traced to its source, in a mountain of peridot-ite, and is beyond all doubt of terrestrial origin. The following analysis of awaruite has been published: Ni, 68%; Fe, 31%; Co, 0·7%; specific gravity, 2·1. Other blocks of nickel-iron, notably those of Brazil and the Argentine Republic, may upon investiga-tion prove to be of similar origin. In the Ural Mountains plat-inum is found alloyed with nickel-iron in association with olivine.

A nickel-iron "josephinite" is found in the form of pebbles and smooth boulders in considerable quantities in the placer grav-els of a stream in Josephine County, Oregon. They are supposed to have been derived from some dyke of ultra basic rock at present undiscovered. Melville has described this alloy,[*] which is strongly magnetic. The pebbles are in color greenish-black, with bright

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[*]American Journal of Science, Vol. XLIII, p. 509.

areas of a grayish metal. The greenish-black portion consists of silicates, some of which are insoluble in hydrochloric acid. The analysis is as follows:

	Insoluble.	Soluble
SiO_2	45·63	38·23
Al_2O_3	6·58	2·34
Fe_2O_3	8·77	15·88
$(Ni,Co)O$	Undeterm'd.	2·49
CaO	11·03	12·14
MgO	28.01	19·85
Na_2O		0·35
H_2O above 100 C		8·72
	100·02	100·00

Two analyses of the metallic portions of these pebbles gave the following result:

	First.	Second.	At. Ratio.
Fe	23·36	23·09	0·41
Ni	60·47	60·43	1·03

The differences in composition of the various nickel-iron alloys will be best seen in the following comparison:

	Ovifak.	Ovifak.	Awaruite.	Josephinite.
Fe	90·17	88·13	31·02	23·22
Ni	6·50	2·13	67·63	60·45

The fact that etching with nitric acid will not develop the Widmannstaetten figures in terrestrial nickel-irons and the invariable presence of phosphorus combined with nickel and iron in the mineral schreiberite in meteoric iron—though never found in terrestrial irons—serve as important distinguishing points between meteoric and terrestrial nickel-iron.

We are now in a position to summarize and compare the various meteorites with the eruptive rocks, and for this purpose I shall, with some modifications, use the table adopted by Prestwich, who took the mean densities of the several classes of meteorites given by Daubrée:

Meteorites.		Terrestrial Rocks and Metals.	
	Specific Grav.		*Specific Grav.*
Nickel-iron, solid	7·1	*Probably*, awaruite	7·1*
" considerable	6·8	† Nickel-iron in basalt (Ovifak)	6·8*
" medium proportion	3·5	Basalt, gabbro, lherzolite, etc	
" small quantity	3·1		3·0 to 3·5
Stony	2·7	Trachyte and dolerite	2·7 to 2·9
		Rhyolite, petrosilex	2·6

From an examination and comparison of this table with the analyses and description of the meteorites it will be seen that there are rocks and metals in the earth which compare in density and in composition with them; and, furthermore, we may admit that the earth as a whole—judging from what we know of its composition and density—does not essentially differ from the average density and composition of meteorites, while there are good grounds for assuming at least that it has a semi-metallic nucleus.

There remain some other comparisons to make, namely, the invariable presence of cobalt with nickel, not only in the metallic alloy, but also in the minerals found in the meteorites; that chromium is but little less persistent, while troilite is almost invariably present. We shall subsequently find that the same association holds good in the majority of cases where nickel occurs throughout the world, and that to the ultra basic rocks and their derivatives, serpentines and magnesium silicates, we can in many cases trace the genesis of nickel deposits.

CLASSIFICATION OF THE ORES OF NICKEL.

MINERALOGICAL CLASSIFICATION.

In the following table, compiled chiefly from Dana, I have set forth the principal ores of nickel, their chemical formulas and percentage of contained nickel.

Sulphides.

Millerite, NiS, containing	64·6%	Ni
Polydymite, Ni_4S_5, containing	59·4	Ni
Beyrichite, Ni_3S_4, containing	54·2	Ni
Pentlandite, $(FeNi)S$, containing	34·0	Ni

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*Approximate.

† Daubrée examined some of the masses of nickel-iron from Ovifak and found that two might be classed as syssiderites and one as sporadosiderite.

Arsenides and Sulph-arsenides.

Niccolite, NiAs, containing ....43·9% Ni
Gersdorffite, NiAsS, containing ....35·4   Ni
Rammelsbergite and Chloanthite, NiAs2, containing ....28·1 Ni

Sulph-antimonides.

Breithauptite, NiSb, containing ....32·8% Ni
Ullmannite, NiSbS, containing....................................27·8 Ni
Wolfachite, Ni(AsSb)S, containing ....29·8 Ni
Coryite, Ni(AsSb)S, containing....................................28·8 Ni

Silicates.*

Genthite, 2NiO.2MgO.3SiO2.6H2O, containing.......................22·6% Ni
Garnierite, H2(NiMg)SiO4 + aq, containing........................25·0 Ni
Connarite, H4Ni2Si3O10, containing................................31·4 Ni
Rewdanskite, (NiFeMg)3Si2O7 + 2H2O, containing ....28·1 Ni

Sulpho-Bismuthide.

Kallilite, NiBiS, containing ....19·0% Ni

Telluride.

Melonite, Ni2Te3, containing.... ....23·8% Ni

Oxides and Salts.

Bunsenite, NiO, containing..78·5% Ni
Nickel oxide, Ni3O4, containing...................................73·1 Ni
Cabrerite, (NiMg)3.As2O8 + 8H2O, containing ....25·1 Ni
Forbesite, H2(NiCo)2.As2O8 + 8H2O, containing ....14·4 Ni
Morenosite, NiSO4 + 7H2O, containing..............................20·9 Ni
Lindackerite, 3NiO.6CuO.SO3.2As2O5.7H2O, containing..............12·9 Ni
Annabergite, Ni3As2O8 + 8H2O, containing.........................29·4 Ni

Carbonate.

Zaratite, NiCO3.2Ni (OH)2 + 4H2O, containing......................46·8% Ni

GEOLOGICAL CLASSIFICATION.

With Types of Ore Deposits.

The ores of nickel are usually divided into three main groups —the arsenides, sulphides and silicates,   Vogt† has employed this

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*These silicates are of variable composition. The above formulas are simply given as types, and the percentage of contained nickel that which is ordinarily found.

†"The Formation of Ore Bodies by Differentiation in a Basic Eruptive Magma." by J. H. L. Vogt, Zeitschrift fur Praktische Geologie, 1893.

subdivision as a foundation for a genetic classification. His groups are:

(1) Arsenides and sulph-arsenides, which include the antimonous-sulphide and combinations of nickel with sulphur and bismuth.

(2) Sulphides (without arsenic), such as niccoliferous pyrrhotite and pyrite, millerite, etc.

(3) Silicates, garnierite, genthite, etc.

Group I.—The arsenides and sulph-arsenides are usually found in veins; as, for example, the Dobschau type of nickel veins in Hungary, and in the so-called Kobaltrücken veins, as exhibited by the type, "Riechelsdorf Bieber" veins. They occur also as subordinate minerals in the silver-bismuth-cobalt veins; for instance, in Schneeberg, in the ordinary silver-lead veins at Freiberg; and in the "Gem" mine, in Fremont County, Colorado. Von Groddeck shows that the typical Dobschau veins contain nickel and cobalt ores of different kinds accompanied by copper ores. These veins occur in massive rocks, principally olivine and gabbro. The olivine rocks and serpentines which result from them carry together with copper always more or less nickel and cobalt. The same holds good also for the older eruptive lime-olivine rock, in one of which, near Dillenberg, in Nassau, there is found from 0.162% to 0.666% Ni accompanied by copper, cobalt and bismuth. This explains the occurrence of nickel ore bodies in these rocks. They are, however, only found in very much decomposed portions of the rocks and never in the fresh, unaltered rock. Von Groddeck describes a vein of this class which is found near Dillenberg, in Nassau. It occurs in picrite changed to serpentine, and contains millerite, bismuth-glance, pyrite and other sulphide minerals. This vein was only found productive inside the serpentines, and became wholly barren upon passing into other rock ("Schaalstein"). A similar ore body is that at Belluhausen, in the Grand Duchy of Hesse.

The veins that occur near Dobschau, in Hungary, are found, as has been mentioned, in the gabbro. This rock, partly changed to serpentine, is surrounded by a peculiar green quartzose clay schist lying on gneiss and granite. The veins occur on the borders of the gabbro, and lie between it and the green schist. They

evince the character of composite veins; show no sharp boundaries against the adjoining rock, and reach a width of eight metres. The principal metals sought for in these veins are nickel and cobalt.

The Schneeberg veins carry cobalt and nickel ores rich in silver. They occur principally in crystalline schists and but rarely in the granite.

The "Kobaltrücken" type is characterized by cobalt, nickel and bismuth ores, which occur in veins in stratified rocks.

Group II.—The true deposits of nickel sulphide ores, such as those of Sudbury, Erteli, Piedmonte, Varallo and other places, are classed by Vogt as a "world group," sharp and defined both in a mineralogical and geological sense. He believes that this class of deposits is generally formed by the magmatic differentiation process within the basic eruptive rocks. Pyrrhotite is everywhere the characteristic ore or mineral that carries disseminated through it the ores of nickel, such as millerite, polydymite and pentlandite. Chalcopyrite and titaniferous iron are usually associated minerals. Possibly the largest and best known deposits of this class are those of Sudbury, Canada. There the ore occurs in irregular lenses in the Huronian rocks, apparently conformable to the bedding, but invariably in close proximity to somewhat extensive dykes or tilted beds of greenstone (diorite). But it also occurs at times disseminated through the greenstones themselves, with which Merritt[*] thinks it has undoubtedly been brought up.

The region in which these immense nickel deposits occur is much faulted and is traversed by numerous dykes of diabase. In places the pyrrhotite and chalcopyrite form a breccia in a black diorite matrix. The ore at Sudbury has been followed on its dip to a depth exceeding 600 feet without showing any sign of falling off in the value or in the quantity of the ores. According to Mr. D. H. Browne,[†] it appears that in some mines the ore changes in character from a distinctly copper ore at surface to a distinctly nickel ore on the lower levels. He gives the "Copper Cliff" mine as an example, stating that on the fourth and fifth levels the ore carried 4% copper and 4·5% nickel, while on the seventh level

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[*] Transactions American Institute Mining Engineers, Vol. 17, p. 295.
[†] Engineering and Mining Journal, September 16, 1893.

many stopes show an average of 0·5% copper and 8% to 10% nickel. It remains to be seen whether this is an exceptional occurrence, or one characteristic of all the mines as they are developed in depth. It appears to me, however, that in such immense deposits occurring under the geological conditions that obtain at Sudbury, any such enrichment with depth could scarcely be expected to occur generally.

The bulk of the Sudbury pyrrhotite contains from 1% to about 5% nickel and from 1% to 4% copper. Cobalt and traces of gold, silver, and platinum in the rare form of the mineral sperrylite (an arsenide of platinum), are also found in this ore.

The following analyses of an average month's output of three of the Sudbury mines are interesting as illustrating the ratios between the copper and nickel contents of the ore:

	Copper Cliff.	Evans.	Stobie.
Cu	4·31	1·43	1·92
Ni	5·57	3·74	2·36

In screening the "Evans" mine ore the following division of values are found:

Coarse ore	Cu—1·62	Ni—3·45
Raggings	Cu—2·99	Ni—3·90
Fines	Cu—3·78	Ni—5·04

The ore is sorted by hand into four grades: 1st, the average mixed copper-nickel ore; 2d, the copper pyrites; 3d, the pyrrhotite or nickel ore; and, 4th, the gangue rock, or diorite. How closely this separation can be accomplished is seen by the following table:[*]

	Cu %.	Ni %.
Copper Cliff mixed ore	5·69	4·75
Stobie mixed ore	2·21	2·28
Evans mixed ore	2·60	4·00
Copper Cliff picked copper ore	14·13	2·74
Stobie picked copper ore	15·71	1·28
Evans picked copper ore	13·86	1·34
Copper Cliff picked nickel ore	0·80	8·12
Evans picked nickel ore	0·49	5·36
Average diorite rock	0·80	0·70

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[*] David H. Browne, in Engineering and Mining Journal, December 2, 1893.

This table shows that the pyrrhotite carries the principal nickel value, in comparison with which the chalcopyrite is quite lean, and that these ores are not intimately mixed.

Some difference of opinion exists regarding the mode of occurrence of the nickel in the pyrrhotite. Mr. Browne, however, shows that pentlandite of the composition (NiFe)S, is the principal nickel mineral, and in this form about two-thirds of the nickel in the "Copper Cliff" and "Evans" and one-third of that metal in the "Stobie" ore seem to exist. He ascribes the increased richness in depth to the increasing amount of pentlandite found in the pyrrhotite of the deeper levels.

Vogt believes that the Sudbury pyrrhotite separated from a basic magma by what is called the "differentiation process." Merritt also advances the theory of a molten origin to account for these deposits. Others have taken somewhat similar views. Mr. Browne, however, says that he believes

"it is universally granted that the Sudbury ores are of intrusive volcanic action, having been in most cases thrust up between diorite and syenite or other similar igneous rocks. The ore must therefore have contained both nickel and copper in solution in the molten iron sulphides. * * * It would seem that near the surface, and where the nickel-copper ores occur as an overflow of an eruption, the nickel exists mainly as an element replacing iron in pyrrhotite. The finer grained the ore, and hence the more rapidly it has been cooled from its original fused condition, the more nickel exists in this condition. The coarser grained the ore, on the other hand, and the deeper it lies below the surface, the more nickel exists as pentlandite separated from the pyrrhotite."

I have quoted Mr. Browne verbatim, so that there can be no misunderstanding the extraordinary theory put forth of an eruption of molten pyrrhotite. Assuming that the nickel originally existed in the diorites or diabase—as in all probability it did—it appears to me that a leaching of these rocks by solutions potent to dissolve the nickel and concentrate it along lines or zones favorable to precipitation, is the more rational view to take. On such ground it is simple to account for the formation of these very remarkable and instructive deposits, which now yield at least one-half the world's supply of the metal.

The mine at Lancaster Gap, Pa., though not strictly belonging to this class of deposits, might conveniently be described at

this point.   The "Gap"[*] mine at one time produced one-sixth of the world's supply of nickel, and its total production is given at 4,000,000 pounds—scarcely more than one-third the present annual production of the metal.   The deposit has been described as a lenticular mass of hornblende rock embedded in mica schist. The ore, principally millerite associated with pyrrhotite, was found impregnating the hornblende, at or near the contact.   It has been suggested that this hornblende may prove to be an altered eruptive rock, while it is not unlikely that an adjoining trap dyke had some influence on the formation of the deposit. This mine has been worked intermittently for over two centuries, but it has only been worked for nickel since 1852. The ores, according to Blake, run from 1·5% to 2% nickel, while Wharton gives a series of analyses that show an average of 3·6% nickel and cobalt and 0·75% copper. The mine of late has not produced much ore.

Vogt endeavors to trace a constant ratio between nickel-pyrrhotite and chalcopyrite occurring in the ore deposits in certain rocks. He states that, while in each mine the ratio may vary considerably from day to day, that the average ratio over a long period of time will give constant results. He gives a table showing the ratio for eight of the more important Norwegian and Swedish mines.[†]   In them the copper contents corresponding to 100 parts of nickel vary from 20 to 80 and average 43, while the nickel and cobalt contents in 100 parts of pure pyrrhotite vary from 2·5 to 7·5 and average about 3·8. Thus, he claims for ores that have been produced by a segregation process from one and the same eruptive (norite or uralite-norite), there exists a ratio between the proportion of nickel to copper on the one side, and the absolute nickel contents of the pure pyrrhotite on the other.

"The higher the nickel contents of the pyrrhotite, just so much lower is the ratio of copper to nickel. This phenomenon cannot have occurred arbitrarily nor by chance, but results probably from the relation existing between the small contents of nickel and copper held in the silicates of the original eruptive magma."

On referring to Plate II. it will be at once seen that the Norwegian pyrrhotite deposits shown there occur chiefly at the con-

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[*] Pennsylvania Geological Survey, Lancaster County Survey, CCC.
[†] See Plate II. for types of these deposits.

tact of the eruptive norites with the schists, and are to that extent comparable to many deposits of precious metals found in the Rocky Mountain region, where the ore occurs in the contact plane between an eruptive and sedimentary, or metamorphic, rock. It has often been pointed out by Emmons[*] and others that the plane of contact between eruptive and other rocks offers a favorable passage for mineral solutions. Turning to the detailed section of the "Minkjar" mine—disregarding the particular rocks—it will be seen that it represents a familiar type of ore deposit, such as we usually assume to have been deposited from circulating mineralized waters.

The norite body shown on the left side of Plate II. is 80 metres long by 45 wide, and it is almost entirely surrounded by an irregular band of pyrrhotite from one to two metres thick, which forms a circle enclosing the eruptive field. The detailed profile of the "Minkjar" mine on the same plate illustrates the transition from a normal norite into, first, pyrrhotite-norite and afterwards into almost pure pyrrhotite, which is concentrated at the immediate boundary of the gneiss; from this contact ore body small veinlets occasionally branch off into the latter rock. Ore bodies are also found in the norite along the contact of included masses of schist.

The theory of the process of differentiation propounded by Vogt, as applied to pyrrhotites, is not only new but may prove of great importance. Its confirmation by further research will be awaited with expectant interest.

In the Piedmontese deposits, which Vogt also considers a segregation out of norite rocks, he shows the same relation between nickel and copper, as above described in the Norway deposits; that is, 100 parts Ni to 40–50 parts Cu. The Sudbury deposits, which are connected with a different petrological group of basic eruptive rocks, contain more copper than do the corresponding Scandinavian and Piedmontese ore bodies, as will be seen by comparison with the table on pages 12 and 13.

The limits of this paper will prevent further descriptions of any of the other deposits that come under the classification of

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[*] S. F. Emmon's "Structural Relations of Ore Deposits." Transactions American Institute Mining Engineers, 1888.

this great group of pyrrhotiferous nickel ores.   I will therefore at once pass to the silicate ores comprised under Group III.

Group III.—As nickel silicates are best known in connection with the New Caledonian deposits, which for some years produced the principal supply of nickel, and are even now the largest producers of nickel-silicates in the world, it may be permissible to give at once a description of these important deposits.

M. Garnier discovered nickel in New Caledonia in 1867.   In 1873, however, M. Heurteau made a voyage of mining and geological exploration, the result of which will be found in detail in the "Annales des Mines."   Since 1873 active mining has been conducted on the island, and for some years our principal supply of nickel came from there.

The geology of New Caledonia can be briefly described.   A light-colored schistose rock, non-fossiliferous, forms the base of the island, resting on which are found secondary and tertiary rocks. On the eastern and southern portions of the island massive serpentines occur, which alone cover nearly one-third of its area, and in the heart of which are found the famous nickel deposits.

According to M. David Levat,[*] whose paper is made the basis of this sketch, the nickel is met with solely in the form of magnesian hydrated silicates—of beautiful apple-green color when pure—as coatings or concretions in the fissures of the serpentines. As neither arsenide nor sulphide of nickel has been found in New Caledonia, it is the opinion of Levat that the manner of occurrence clearly indicates the deposition of the ore from solution in the same state in which it is now found.

The pure mineral often averages 26% nickel.   The average ore, however, does not contain after sorting over 10% of nickel in a gangue of serpentine.   In addition to the nickel ores proper, it is found that the massive serpentines nearly all contain nickel in proportions varying from 1% to 3%, and in some instances 5%. Levat inclined to the belief that protoxide of nickel had partly replaced the protoxide of iron of the serpentines, because the iron

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[*] "Study of the Deposits of Nickel, Cobalt and Chromium in New Caledonia."   Association Francaise pour L'Avancement des Sciences; Paris, 1887.

contents of the serpentines diminish as soon as the nickel appears in them, and the total of the two metals remains constant.[*]

The nickel ores are found exclusively within the serpentines, but are not distributed there in an arbitrary manner. They always occur at the contact, or in the neighborhood of the contact of the serpentines with certain beds of red clay, but never in the clays themselves. The existence of these basins of red clays forms the most curious phenomena of New Caledonia geology, as much by their extent as by their importance from a mining point of view. The clays are supposed to be the products of the hydrothermal decomposition of the serpentines, as they contain all the elements of these rocks in addition to iron manganese, chromium and cobalt. Numerous fissures running at right angles to the general direction of the island have, it is assumed, afforded vent for numerous iron and manganiferous springs, which corroded the serpentines, producing a trimming of half-dissolved rocks, more or less embedded in the clayey mass which forms the center of the basin. The ferruginous water finally predominated, producing numerous masses of hydrated iron oxide, which in the form of oolitic iron ore eventually crowned these overflows. (See Fig. 3, Plate III.) Veins of chrome iron occur in the hard, unaltered serpentine, and rounded grains of chrome iron are also found in the red clays. (See Fig. 4, Plate III.)

The cobalt ore is always found in the red clays, and its origin is considered by Levat to be essentially hydrothermal. The chromium, on the contrary, pre-existed in the serpentine and was derived from it, while the nickel solutions, he considers, came after the solidification and contraction of the clays. These solutions circulated not only in the contact, but also in the cracks and joints of the adjacent serpentine, depositing hydrated silicate of magnesium and nickel in the form of a "stock-werk." The nickel ore is principally found in the roof and in the walls of the basins or pipes, and is invariably more plentiful in the roof. Figs. 3, 4, 5, 6 and 7, Plate III., give sections of different deposits of nickel in the New Caledonian mines. Fig. 5 is an example of the type

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[*] Levat had not had the advantage of a microscopic examination of the serpentines when his paper was written.

called symmetrical, the axis of the basin' being vertical, the ore being of equal thickness on the roof and on the walls. Fig. 6 is a type of roof deposit. The mine from which it was taken consists of an enormous stock-werk in the serpentine worked as an open quarry. Fig. 7 is a vein-like deposit. The serpentine which forms the roof is fissured at some points, producing cracks of several metres in width which are filled with rich nickel ore. This mine is also worked as a quarry. These nickel deposits are situated near the summit of the mountains at altitudes varying from 400 to 600 metres.

The nickel districts are distributed over a series of northeast and southwest lines, starting from the east coast and extending toward the interior. These lines are generally 600 to 800 metres wide; outside of them there are only local enrichments which lack continuity. With regard to the persistence of the nickel ore deposits themselves, Levat concluded, although at the time of his examination, in 1887, the deepest workings were only about 275 feet below the outcrop, that in depth they would lose their thickness, basing his opinion on the theory that the clays which caused the nickel deposits diminished at the bottom of the basin. He summarizes the deposits as having the following general characteristics:

First, the ore is essentially dependent on the serpentine rocks of the east and south parts of New Caledonia; second, the ores of cobalt associated with manganese occur in beds or deposits on the edges of basins of clay which traverse the serpentine in a great number of places. These cobalt ores do not contain over 2% to 3% cobalt, but they are very extensive, being mined very often by simply scraping up the mineral; third, the deposits of chromium are of two kinds, either in veins in the serpentine or in stratified beds in the clay basins; fourth, the nickel deposits are of a later formation than the two preceding ones. They are situated exclusively at or in the neighborhood of the contact of the clays with the serpentines and never in the body of these clays. They are united in certain number of northeast and southwest lines, the width of which generally does not exceed 600 metres. These lines are persistent in all the serpentine region of New Caledonia. Finally, the formation of these deposits being due to the shrinkage of

the clays settled in the basins, their continuity and their extent in depth seems to depend on that of the red clay which gave them birth.

The output of nickel and cobalt ores from New Caledonia was, in 1890, 22,690 tons of say 10% nickel ore and 2,200 tons of 3% to 5% cobalt ore. The output of nickel ore in 1891 was 35,000 tons.

Somewhat extensive deposits of silicate of nickel were discovered at Riddles, in Douglas County, Oregon, in 1881. The minerals are in appearance identical with those of New Caledonia. The Riddles deposits all lie at or near the surface, and occur in beds from 4 to 30 feet in thickness. The ore is found either as boulders disseminated in a highly ferruginous earth, or apparently in beds underlaid by serpentine and associated with chrome iron.

F. W. Clarke[*] has compared a series of New Caledonia silicate minerals with those of Webster, N. C., and Riddles, Oregon, and found them all very similar in appearance and composition, while the microscopic examination of these specimens by Diller is even more conclusive as to their apparently common origin. The purest specimen of Riddles ore gave the following analysis, with which are compared some New Caledonian specimens analyzed by Hood:

	CLARKE.	HOOD.	HOOD.
Loss at 110°C	8·87% ⎱	6·63%	7·00%
" in ignition	6·99 ⎰		
$Al_2O_3 + Fe_2O_3$	1·18	1·38	1·33
SiO_2^7	44·73	48·21	40·55
MgO	10·56	19.90	21·70
NiO	27·57	23·88	29·66
	99·90	100·00	100·24

Clarke shows that the many published analyses of nickel-magnesium silicates display great variations in their composition, the nickel protoxide contents in them varying from 0·24% to 45·15%, the differences in the percentages of silica and hydration being also very marked. These variations preclude the idea that the nickel is present to any great extent in these minerals as hydroxide.

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[*] American Journal of Science, Vol. 35, p. 483.

A fresh specimen of country rock surrounding the Oregon beds was analyzed, and some olivine was separated from this rock. The rock contained 0·10% NiO, the olivine 0·26% NiO. This, Clarke states, suggests a probable source of derivation for the nickel in the altered beds of ore, and this view is maintained by the microscopic investigation made by Diller, who described the ore-bearing rock of Riddles as belonging to the peridotites. It is a holocrystalline, granular rock composed essentially of olivine and enstatite, with a small percentage of chromium and magnetite. Olivine predominates, enstatite forming less than one-third of the rock mass. Quartz occurs from metasomatic change, and whenever genthite appears it is always associated with quartz or serpentine. Diller states: "The genthite occurs in the serpentines directly connected with the grains of olivine from which the serpentine has been derived, and there is every reason to believe that the genthite came from the same source."

Concerning the nickel silicate from Webster, N. C., Diller says:

"It is almost identical with that from Oregon, excepting that it is not so thoroughly intermingled with quartz. The relation of the genthite to the serpentine and the olivine at the Webster locality is exactly the same as at Riddles."

The Webster rock, however, differs slightly from that at Riddles in containing less enstatite. It belongs to the class of peridotites called dunite. Of the New Caledonian genthite, he says:

"Like that of Oregon, it is disposed in layers and cavities thoroughly intermingled with quartz, and in the same thin sections may be seen serpentine with traces of olivine and enstatite so disposed as to clearly indicate that the serpentine, noumeaite and other secondary products have resulted from alteration of peridotite."

As regards the nickel deposits of North Carolina, Stephen H. Emmens * states that the workable deposits

"occur in the form of veins, and are of three distinct species. First, we have what I regard as right running veins, occupying fissures the strike of which is more or less normal to the planes of division that give a bedded aspect to the chrysolite rock mass; secondly, there are numerous counter veins with a strike oblique to that of the first series; and, thirdly, there are bedded veins

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* Engineering and Mining Journal, April 30, 1892.

located in planes of division. I am of opinion that the counter and bedded veins will not be found very productive, and that the right running veins alone will yield any considerable supply of ore."

With this review of the ores of nickel, and having given a few examples of the principal types of nickel deposits, together with a description of the rocks in which they are found or occur in close association, I will proceed to consider briefly the genesis of some of the deposits.

The Genesis of the Ore Deposits.

We have seen that nickel is associated with olivine and other magnesian silicates not only in the ultra basic rocks of the earth, but also in the various meteorites. It has also been shown that the great nickel deposits of the world are found in rocks in which olivine is the predominant mineral. While these facts by themselves do not prove that the nickel of these great deposits was derived from the accompanying olivine, it will be of interest to note the conditions under which the olivine was formed, and to see in how far it is in itself niccoliferous.

The ultra basic rocks that we have been discussing have no doubt come from great depths in the earth's interior. It has also been pointed out that there are good grounds for the assumption of a semi-metallic nucleus for our earth, and that in this nucleus, iron and nickel are apparently the predominating metals as they are in·meteorites. Under such conditions it would not be remarkable for silicates forming or crystallizing out of the magma to contain such metals, especially when we consider that the latter were possibly undergoing the process of oxidation, and in a condition well adapted to further chemical change.

The microscopic study of igneous rocks has thrown much light on the order of the crystallization of the component minerals, so much so, that a fairly uniform and definite order has been established. The first minerals to form appear to be the oxides magnetite and ilmenite, sometimes chromite and picotite; next come such silicates as occur in minute quantities, as zircon and titanite. Pyrite and pyrrhotite usually follow, and next after the metallic oxides and sulphides we find the heavy dark-colored basic silicates, such as olivine, augite and hornblende, make their

appearance.   Olivine is the first of the rock-forming silicates to crystallize out of the basic magma.   Rosenbush states:

"The outline of the olivine crystal sections often exhibits a decided rounding with variously shaped loops, the result of corrosion by the magma out of which they crystallized.   *   *   *   The olivine of the granular eruptive rocks, as it occurs in diabases, olivine gabbros, olivine-norites and peridotites, and as it is found in the older segregations of the volcanic rocks, exhibits no perfectly regular crystallographic boundary.   It is always evident that it is older than the other silicates accompanying it."

According to Rutley,* olivine sometimes contains traces of titanic, phosphoric and chromic acids and the protoxides of nickel and cobalt.

Sandberger's † experiments with rock silicates almost invariably gave traces of nickel, copper and cobalt from olivine and augite.   In fact, he claims to have traced the small quantities of copper and cobalt in the fumerole product of Vesuvius to the olivines and augites of its own lava.   A. W. Stelzner, however, does not agree with Sandberger's conclusions, but holds that the metals found in such silicates occur as inclusions and are not combined with the minerals.   His views may be correct, as the microscope reveals many inclusions in olivine.   Rosenbush, for example, mentions magnetite, ilmenite, apatite and chromite as such.

It is immaterial whether the nickel found in association with olivine occurs in chemical combination or is mechanically included.   It is enough to know that the metal is within the olivine in quantity sufficient to form, when dissolved and re-precipitated, rich and extensive ore deposits.   That nickel does exist in some olivines to this extent cannot be doubted.   We have seen that the olivine in the Oregon rock gave over 0·25% nickel, while the serpentine from Dillenburg gave 0·66% nickel; and lastly, much of the serpentine in New Caledonia contains over 1% of the metal. Serpentine rock is, however, a product of decay.   It is never a primitive rock, but is formed by the decomposition of olivine, picrite, gabbro or even hornblende rocks.   Von Cotta states that it was at one time supposed that all the Dobschau veins were closely connected with the gabbro occurring there.   He then

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* "The Study of Rocks," p. 117.
† Utersuchungen über Erzgänge,

shows that "it is not the case with all, but certainly is so with the ore deposits containing nickel and cobalt." Von Groddeck admits that the presence of from 0·16% to 0·66% nickel in the Dobschau rock explains the occurrence of nickel ore bodies in these rocks. Lastly, Fuchs and de Launey, in their recent work on ore deposits, state: "Nickel, which is analogous to iron, appears to have its origin for the most part in a basic magma from the earth's depths."

After a careful review of the foregoing facts, one can not, in my opinion, avoid the conclusion that the nickel of at least the serpentine deposits has been derived from the olivine and basic magnesian silicates of the original rock masses. The pyrrhotite deposits in basic eruptives may possibly have a different origin, as advanced by Vogt. It has been shown that pyrite crystals are about the first to form in a molten magma (after the oxides magnetite and ilmenite), while Vogt shows that from the study of slags it is known that the lime, manganese and zinc sulphides are segregated before the spinels; that pyrrhotite has its own peculiar position, at least in the norite and pyrrhotite-gabbros of Norway, and that it comes after the iron and manganese silicates and the feldspars.

An examination of the norite rock "shows that the magnesian-iron silicates, namely the rhombic mono-symmetrical pyroxine-olivine and mica, as well as the plagioclase, occur segregated in the pyrrhotite in very well preserved crystals of idiomorphic contour, which are only a little rounded on the edges and corners."

Vogt considers the fact that many crystals of plagioclase are fractured, split and punctured by fine veins of pyrrhotite is proof that the pyrrhotite was in a fluid and molten condition after the consolidation of these crystals.

Workable deposits of titaniferous iron appear to have been formed in certain basic eruptives in Norway and Sweden by the differentiation process, or by the segregation of the iron ores to the center of the eruptive field. (See Fig. 8, Plate I.) That this same process, "differentiation in basic eruptive magmas," may possibly account for the segregation of the pyrrhotite is probably within the bounds of possibility, but on the evidence at present obtainable, I cannot see my way to accept it. It has been pointed out that the pyrrhotite deposits occur along the boundary or con-

tact of the eruptive rock with the gneiss and schists. (See Plate II.) Therefore, if these deposits have been formed by segregation from a molten magma, the segregation has been from the center towards the periphery of the eruptive field, or in reverse order to the segregation of the iron ore shown in Fig. 8. Comparison has also been made between these Norway pyrrhotite deposits and ore deposits associated with eruptives in the Rocky Mountain region, and we have seen that on the evidence at present obtainable these ore bodies can be best explained as having been deposited from circulating mineralized waters.

I am aware that there are some geologists who must necessarily derive from vague and unknown depths through the agency of circulating waters, the minerals now found in veins, in apparent disregard of the facts that fissures cannot extend to indefinite depths, nor can water circulate to any considerable depth in the earth's crust. While their views deserve some attention, it might be well to note, before adopting an "ascension theory" *ad libitum* for the formation of nickel deposits in basic eruptives, that these rocks came from much greater depths within the earth than in all probability circulating waters ever could have reached, certainly much deeper than any vein fissure could extend. Finally, it should not be forgotten that it is through volcanic forces and not by means of circulating waters that metals are brought from the great depths and placed within the reach of what can be termed surface agencies. I therefore submit that it is to the leaching of these basic eruptives at or near the surface our principal deposits of nickel are due.

THE DISTRIBUTION OF NICKEL ORES.

I believe I am quite safe in stating that nickel ores occur far more plentifully and are much more widely distributed over the globe than is generally supposed. That workable deposits of nickel are not more plentiful in the United States is, I venture to say, not because they do not exist, but because they are not known, and have not been looked for with that energy and perseverance which characterizes the Western prospector in his search for other and better known metals.

Sterry Hunt has shown that nickel occurs in moderate quan-

tities associated with chromium in the magnesian rocks of the Quebec group. At Orford, Quebec, a vein between serpentine and limestone holding green chrome garnet and chromite has been worked for nickel. This metal has also been found at Silver Islet in Huronian talcose schists as well as in some other places in that district. Egleston has shown that it is present in minute quanti- ties in the Lake copper. We have already seen that the mine at Lancaster Gap, Pa., was at one time a great nickel producer. There appear to be extensive deposits of nickel in North Caro- lina. At Chester, Conn., nickel has been found in pyrrhotite deposits which would appear to be at least worth developing. This metal is again found in the sedimentary beds of the mineralized limestone of the Mississippi Valley, at Mine la Motte, for example. Some important deposits of nickel have long been known to exist in Nevada, and that they are not more extensively worked seems curious. The occurrence of nickel has been reported from several points in California; for example, at the "Kelsey" mine, Los An- geles County, nickel and cobalt ores are found in the form of arsenates together with silver-glance and native silver in a fissure vein, in close relation with dyke rock, probably diorite. The assorted ores contain 7% to 15% cobalt and 2% to 3% nickel and 1,000 to 1,400 ounces silver per ton. It is also reported to occur in Arizona and New Mexico. Rich nickel ore has been found in the "Gem" mine, Colorado, associated with cobalt, arsenic and sulphur, and it is also known to occur in other localities in the State; for example, in the hornblendic rocks near Salida, associ- ated with copper, and also in small quantities in some of the ores from the Leadville region. The greatest North American deposits of nickel ore known at present are those at Sudbury, Canada, which have been previously described. Reference has also been made to the Oregon deposits, from which there is every reason to suppose large returns will soon be obtained.

Turning to foreign localities, we find that Norway, Sweden, Hungary, Italy and Germany are producers of the metal. Norway has extensive deposits of niccoliferous pyrrhotite, but the output has fallen off from 360 tons in 1876 to an average of 105 tons for the last six years. The ore is mostly low grade, but could no doubt be worked profitably if the more recent metallurgical im-

provements were introduced.   Nickel is also found in the Urals at Rewdinsk, for example, in veins two metres wide between chloritic schist and serpentine, and in many other localities.   The serpentines of the West of Ireland and those of Cornwall, and indeed almost all serpentines, contain a little nickel.   Australia, New Zealand and South Africa have also nickel deposits; but it is from New Caledonia that the great bulk of foreign nickel is produced. The nickel output of the world in 1891 was about 5,000 metric tons.

In submitting to the Society the foregoing facts and theories concerning nickel, its origin and the geological distribution of its ore deposits, the aim has been to present a composite picture of the subject, portraying the knowledge which has up to the present time been accumulated, and which may not inappropriately serve as an introduction to the series of papers on metallic nickel, its history, metallurgy and use in the arts, which are to be read before the Society by Mr. W. L. Austin; nor can I close without expressing my acknowledgments to Mr. H. A. Vezin and Mr. W. L. Austin for the great assistance rendered me in the translation of the French and German works which have been consulted.

DISCUSSION.

Mr. Thomas Charlton.—Among the sources of nickel ore in the United States, Mr. Argall has mentioned the "Gem" mine, of Fremont County, Colorado.   As this mine has been, to my knowledge, the only producer of nickel in this State, and possessing perhaps a more intimate acquaintance with this property than others of our members, a more detailed description of the mine may be of interest.

The vein of the "Gem" mine is in hornblende schist.   At the surface the ores were principally copper, but nickel soon made its appearance, and at a depth of fifteen to twenty feet became quite prominent, the nickel minerals occurring as the sulphide and sulph-arsenide.

From the surface down to a depth of about 75 feet the vein had an average width of three and a half to four feet.   At this

Fig 1

After Sir William Thomson

Fig. 2

Fig. 8

Plan of the deposit at Taberg illustrating the transition of the Olivine-hyperite on the periphery to a magnetite-Olivine in the centre of the eruptive field. After Vogt.
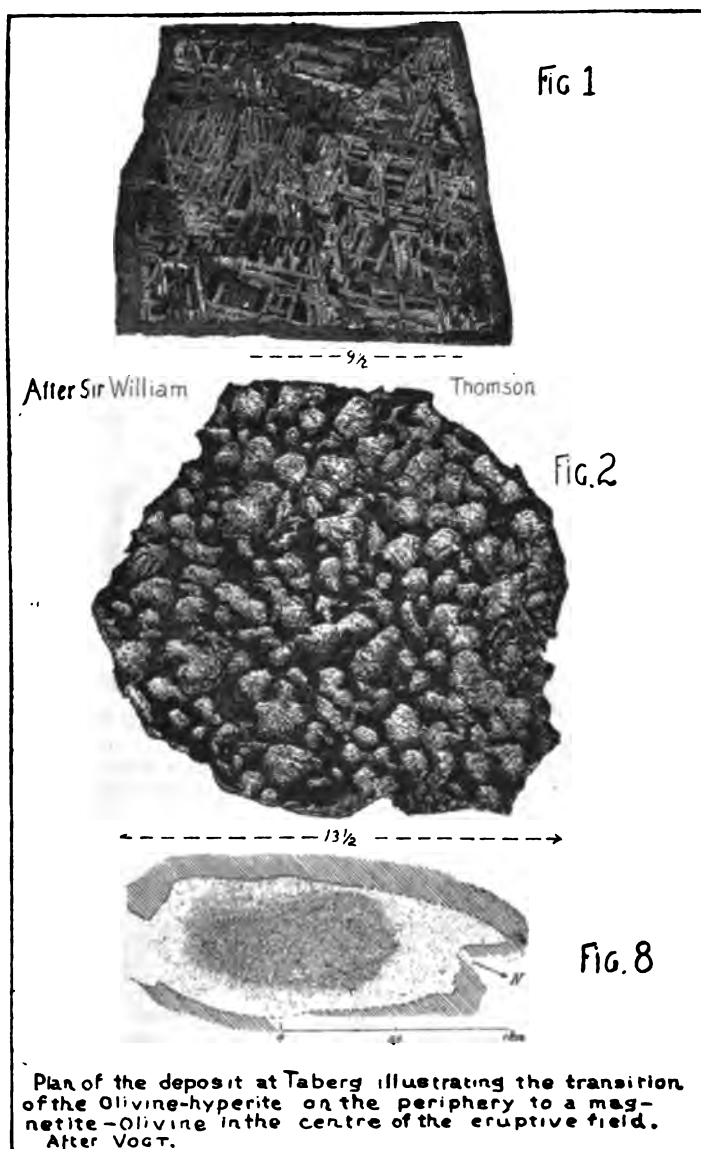
Plate I.

depth, however, it pinched out entirely and was lost. A cross-cut of a few feet to the east was made from the point where the vein was lost, and sinking resumed. Soon a narrow streak of ore was encountered about 18 inches in width. This streak contained the same nickel and cobalt minerals which had characterized the original vein, and conformed with the latter in its general dip and strike, at least to a considerable extent. In consequence of this agreement, it has come to be considered the continuance of the same vein, but I may say the proof of this has not been altogether clearly established.

It is noteworthy that at times the nickel-cobalt ores of this mine are accompanied by native silver, some of the mineral specimens being occasionally so permeated by fine wire silver as to be broken with difficulty. As a rule, however, the ores carry but little silver and only a mere trace of gold.

In 1882 there were shipped from the mine some twelve tons of ore, which contained 12% nickel and 2% to $2\frac{1}{2}$% cobalt, associated with considerable copper, chiefly as chalcocite. Another shipment of about one-half ton of selected ore was made at a later date to Swansea, England, which contained 34% nickel and 3% to 4% cobalt. The nickel ore in this shipment was mostly niccolite.

Owing to the mine being involved in litigation, but little work has been done upon it for some time. Apart from this, however, it must be said that the ore streak is narrow, the wall rock very hard, and, in consequence, the ore difficult and expensive to mine.

Note by the Secretary.—The foregoing paper was illustrated by a complete exhibit of nickel minerals from the famous nickel-producing mines of the world.

INFORMAL COMMUNICATIONS.

Mr. T. E. Schwarz, in a few informal remarks, described the ore occurrence at the Independence mine on Battle Mountain at Cripple Creek. The ore occurs on either side of a fissure, or crack, in the granite near its junction with the overlying porphyry. The peculiar features of the deposit are:

1. The entire absence of any vein-filling or gangue.

2. The fact that the ore consists of a mineralized granite extending from the fissure for two to five feet on each side; the mica of the original granite being dissolved out and replaced by the gold-bearing minerals, while the other components of the granite are but slightly, if at all affected.

3. The presence of a porphyry dyke, which strikes into the granite apparently from the adjoining porphyry mass, and, after following the fissure for a short distance, swings off into the granite and continues parallel to the fissure and within fifty feet of it.

4. That the ore appears to occur entirely independent of the dyke, except for the short distance that the latter follows the fissure.

Mr. Schwarz called attention to the excellent opportunity this property presented to study the relation of the intrusive dyke to the ore occurrence.

THE QUESTION OF A STANDARD OF VALUE.

BY O. J. FROST, DENVER, COLORADO.

The gold dollar at the standard weight of twenty-five and
eight-tenths grains was made the unit of value for the United
States by the act of Congress of February, 1873, revising the
coinage laws. The financial systems of most of the advanced
nations of Europe similarly depend upon a unit containing a
definite amount of gold. In gold standard countries silver coins,
whether of limited or unlimited legal tender quality, owing to the
fall of silver in gold price, are now merely "token" money in the
sense that they are legally current for more than their bullion
value. Any inquiry, therefore, into the question of a standard of
value may properly be first directed to the suitability of gold for
that purpose; and, in view of the unsatisfactory financial condi-
tions existing, such an inquiry is especially pertinent at this time.
A wide-spread disbelief in the stability of gold has grown up of
late years, but so many able men contend that it is unfounded that
the public mind is in doubt.

OPPOSING VIEWS.

On the one hand, declining commodity prices as they average,
are cited to prove the appreciation of the standard. Among the
advocates of this view are bi-metallists generally. They explain
the apparent fall in the value of silver, chiefly, as they do, if they
are consistent, that of average commodities, wholly, by the appre-
ciation of gold. On the other hand, the decreasing cost of pro-
duction is held to be a sufficient explanation of the decline of
commodity prices, while the fact of the increase in wages is fre-

quently used to clinch the argument against the view that gold has appreciated.

The advocates of either or of both these views are usually gold mono-metallists. Mr. J. Laurence Laughlin, now Professor of Political Economy in the University of Chicago, in the preface to his "History of Bi-metallism in the United States," clearly inclines to the opinion that "improved processes of manufacture, the introduction of labor-saving machinery," etc., are pertinent to an investigation regarding the suitability of gold for monetary uses. Mr. David A. Wells, eminent as a student of industrial and trade statistics, is positive that decreased cost of production and increased wages furnish sufficient answer to the "appreciation fallacy." The weight of the name of Professor Soetbeer, a great authority on average prices, seems also to be with the same side, as he deems it important in connection with the standard of value to point out the rise in wages.

Fortunately, first principles are so definite that they may be confidently appealed to for aid in clearing up the question at issue.

VALUE.

Value in economics is a relative term. The value of a thing means its "power in exchange." Economists are agreed that there can be no such thing as a general rise or fall of values. The proof is simple: If any single exchange, compared with previous exchanges, results in a rise in value, it can only apply to one of the valuables exchanged, and the other valuable must show a corresponding fall. This being true of each and of every exchange, there must be a constant average level of values.

From these fundamental considerations it follows that, under the present system, a prime requisite for a standard of value is that its supply shall so balance the demand for it, that it may bear the nearest possible constant relation to the general level of values. This is the stability requirement for a standard of value. Whatever other essentially distinct functions money performs need not concern us here, but under the current system it certainly performs the standard of value function, the importance of which we all more or less distinctly realize.

The necessity for a stable standard of value becomes evident,

not only in connection with the debtor and creditor relation, but in order that production may not be disturbed, and in every-day transactions to render experience in prices a guide to seller and buyer. As price is value expressed in money, with a money system perfectly answering the stability requirement there could be no such thing as a general rise or fall in prices. Such a system, however, if ever devised, has never been adopted. At various times in various countries, various commodities have been used to perform the standard of value function of money, but never, so far as I am aware, has the use of more than two commodities been attempted for this purpose at the same time and place; and now, as stated at the beginning of this address, the single commodity, gold, has come to be the basis of the money systems of advanced nations.

In becoming money no mysterious change happened to gold. It was a commodity before and it remains a commodity since it became money. The fact that it performs the money function does not relieve it from the fluctuations in value incident to every commodity. To say that the result of successive exchanges of any given commodity for gold has been a fall in the value of the given commodity is to say that gold has correspondingly risen in value, so far as concerns that commodity; and to say that *average* gold prices have risen or fallen is to say that gold itself has depreciated or appreciated, that there has been lack of conformity in its value to the average level of values.

Mr. Wells holds that there is not a single commodity that has notably declined in price in regard to which it can not be proven:

"That its decline has been due to decreased cost of production or distribution, or to changes in supply and demand occasioned by wholly fortuitous circumstances."

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"How great has been the average saving in the world's work of production and distribution (within the last thirty or forty years) cannot perhaps be accurately stated; but few investigators place it at less than forty per cent, and in some great branches of industry it has certainly amounted to seventy or eighty per cent. We have here, therefore, a natural, all-sufficient, and non-disputable cause of the remarkable decline in prices under consideration, and also of its continuance; and the only assignable and probable reason why the decline experienced has not been greater, is that decreased cost has occa-

sioned increased demand and consumption, which to a considerable extent has antagonized the natural tendency to decline." (October "Forum," pp. 132 and 133.)

This argument implies that decreased labor cost and decreased money cost are equivalent, a view inconsistent with conditions of free labor. As Mr. Wells' argument is typical of the reasoning to prove that gold has not appreciated, it will be worth while to show the bearing upon it of the fundamental principles above briefly outlined.

Value being merely a relative term, there being no such thing as a general rise or fall of values, because conditions which force the value of one thing down must force the value of something else up at the same time, it follows that only relative changes of value can result from changing conditions of trade or production. Therefore, price being value expressed in money, from the point of view of a stable standard deduced from the general level of values, such conditions as supply and demand, and decreased labor cost of production and distribution, could not explain decreased *average* prices. Although highly interesting as indicating the degree and extent of possible improvement in social conditions, and as partially explaining the causes of needful changes in the aggregate supply of money to maintain stability in prices, they are without special application, and not of direct importance to a test of the stability of a standard of value. The investigator must look elsewhere for the cause of decreased average prices. *In order to entitle such considerations even to an equitable bearing on the standard of value, it must be proven that unproductive members of society, namely, lenders as such, contribute to the causes of the increased productiveness of labor* beyond what supply and demand grant as interest.* The standard of value to be sought, as the term implies, is a standard or measure to facilitate the exchange of valuables, and to dispense justice between debtor and creditor.

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* " Labor," in this sense, of course means personal services of every grade. The term " increased productiveness of labor " is preferable to that of "decreased cost of production and distribution " because it is more definite, and because the latter expression is inconsistent as a general term except in the sense of decreased labor and abstinence cost.

WAGES NOT PERTINENT TO THE DISCUSSION.

The same writer states the argument from rising wages against the appreciation of gold, as follows:

" And then in respect to the one thing that is everywhere purchased and sold for money to a greater extent than any other,* namely, labor, there can be no question that its price *measured in gold* has increased in a marked degree everywhere in the civilized world during the last quarter of a century. Had the purchasing power of gold increased during this period, a given amount would have bought more labor and a fall of wages would have been inevitable. And if wages under such circumstances have risen, the cheapening of commodities could not have been due to a scarcity of gold. Measured by the price of labor, therefore, gold has unquestionably depreciated; and can anybody suggest a better measure for testing the issue?" (October " Forum," p. 136.)

At first thought this appears to be a serious matter to believers in the appreciation of gold, but the difficulty is dispelled by an examination of the economic differences between personal services and commodities.

First: While commodities and personal services have the common characteristic, exchange value, the causes for it are different. In the case of the former, exchange value is due to the desire for commodities themselves, while in the latter it depends, not upon the desire for labor itself, but upon the fact that labor is productive of desirable things, which for present purposes are covered by the term commodities. Commodities, therefore, are the primary object of exchange, and labor is merely secondary and incidental. If, then, as will probably be granted, labor receives wages because of its products, which in turn are bought and sold because of the desire for them, wages, if considered as the laborer's share of the joint product of capital and labor, must rise, when measured by a unit of time, with the productiveness of labor, unless we assume that capital is to get all the increase. That is to say, the inference must be that wages depend primarily on the productiveness of labor. The productiveness of labor

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* Labor, though " purchased and sold for money to a greater extent than any other " one thing, never has exchange value merely as labor. The labor expended in digging a hole in the earth without purpose, or in trying to bale out the sea, would not be exchangeable; but when so applied as to be productive of commodities, it is entitled to and receives wages.

being low, wages will be low. With highly productive labor wages will be high.* It must follow, then, that if they are to be included along with commodities in getting at average prices, the basis should be a comparison of the wages accorded for given units of product (for piece-work) instead of for a given unit of time; but, as commodities would still be the real basis of such investigation, the only result attained would be duplication, unnecessary and complex. Unless this view is fallacious, it proves nothing regarding the stability of gold that wages per unit of time have risen in this age of improvement. Wages per unit of product, however, have, without doubt, on the average declined; and part of such decline is due to the increased use of machinery which generally accompanies the increasing productiveness of labor, by cause of which, with every improvement, capital cuts a relatively larger, and therefore labor a relatively smaller, figure. Comparison of present wages per unit of product with past wages per unit of product would therefore indicate greater appreciation than has actually occurred, and it would introduce unnecessary error without affording any elements in addition to commodities. In the interest, therefore, both of simplicity and of accuracy, wages should be omitted.

Here, to avoid misunderstanding, a digression will be necessary. The objection may be interposed that wages are determined by supply and demand, or by the relative necessities of the laborer and the capitalist. But it must, on the one hand, be conceded that to furnish capital an inducement to continued production, at least a minimum profit must be available for its compensation out of the joint product of capital and labor; and, on the other, that laborers must live. In general, then, wages must fall considerably within the total product, and they must be sufficient to afford laborers subsistence. Constantly improving modern condi-

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* A relation of cause and effect once established between the increasing productiveness of labor and increasing wages, establishes an inverse relation between increasing wages and the expenditure of labor required to produce commodities. Obviously the accuracy of a balance could not be tested if the manner of loading one pan were to unload the other, and equally futile is any attempt to test the stability of gold by offsetting the decline in commodity prices by the rise in wages. As an appreciating standard tends to cause a decline in nominal wages, unless wages are for once and all rejected, their rise can be pointed at as proof that no appreciation has taken place until it is at a rate to overtake the rise of wages due to improvements in production.

tions of production afford a larger and larger margin above both the minimum profit for capital and mere subsistence for labor. The share of this margin which labor secures is the resultant of many tendencies, but a few hints may here be thrown out as to the *prevailing* tendencies. The first result of improvements in the production of any commodity is to increase profits in the industry in which the improvements occur. With profits increasing, the employer enlarges his operations aad employs more labor, with the natural result of a rise in time wages. Then, the increase of supply lowers the value of the given commodity and thereby raises the value of other commodities. Assuming that the commodity is one of great importance, if the money supply increases to meet the demands upon it resulting from the increase in commodities which have to be exchanged, that is to say, if the money supply conforms to the average level of values, the prices of commodities to which improvements in production have not been applied rise, and their production is directly stimulated, as in the case of the given commodity, with the result of a rise in general wages. With an appreciating standard, however, average prices fall, and the rise in the wages of the laborer may be confined to real, as distinguished from nominal wages. As improvements in production become more general, the rise in real wages becomes more noticeable. Also, owing to the fact that every increase in the productiveness of labor increases the wealth of the world without involving decrease in wealth-getting propensity, every increase in the productiveness of labor really increases the capital of the world, so that every undertaking promising a profit is the more readily set on foot with corresponding increase in the demand for labor and resulting increase of wages. It is to be expressly understood that this does not purport to be a complete statement of possible occurrences; but tendencies of the kind described prevail, under effective competition, as a result of improvements in the production of commodities, the consumption of which increases with the decrease of labor incident to their production. Labor organizations no doubt play an important part in hastening the rise in wages. When secured, higher wages, in connection with increasing and diversified product, lead to higher intelligence, and, in general, to a higher standard of living or sub-

sistence, which, as above indicated, becomes a new lower boundary of wages.

It is thus seen that the productiveness of labor governs supply and demand, and that it is the cause, working through competition among capitalists, of rising wages, a rising standard of living, and of the amelioration of human conditions. Labor organizations, the rising standard of living, and a condition of supply and demand becoming more favorable to labor, are often taken to be the causes of rising wages, but the more correct view evidently is that they are incidental in their nature to the underlying cause, improvements in production, which increase the effectiveness of labor.

To verify the deduction that wages depend primarily on the productiveness of labor, by reference to actual facts, let us connect the increase of forty to eighty per cent in the productiveness of labor indicated by the former of the foregoing quotations from Mr. Wells* with the wages indicated by European and American data. Professor Soetbeer gives carefully gathered data proving an increase of wages in Europe; and Carroll D. Wright, Commissioner of the Bureau of Labor at Washington, is authority that American statistics prove (October "Forum," p. 227) that nominal wages "stood at 168·6 in 1891 relatively to 100 in 1860." Taking into account the decline in commodity prices, he shows the increase in real wages to have been greater even than these figures indicate. Any one can also verify the connection where it is most striking by observation within the limits of any given trade or profession. Even the most ignorant laboring man knows that so far as employers can discriminate, his wages will be low or high in proportion to the value of the services he renders, subject, however, to the arbitrary interference of labor organizations. It by no means follows, though, that wages actually increase throughout different occupations to correspond with average increased productiveness. The connection seems to be opposed by other tendencies, among which may be mentioned the

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* Mr. Wells himself elsewhere recognizes the connection of rising wages and increasing productiveness of labor ("Recent Economic Changes," p. 417), but he fails, in considering the problem of the standard of value, to connect it with the fact deduced from the average level of values, that average commodity prices should be a constant, and, therefore, wages a variable, element, instead of both being variable as under an unstable standard.

constantly increasing share going to the land-owning capitalist as
a result of increasing population. Owing also to other opposing
tendencies which need not be taken into consideration here, as
they only partially offset the connection between increasing pro-
ductiveness and increasing wages, and do not affect the principles
contended for, wages increase less than the productiveness of
labor.

Thus, it appears, as before, that an attempt at a test of the
stability of the standard of value by comparison of present wages
per unit of product with past wages per unit of product, would
indicate a greater appreciation than has actually occurred. It,
then, being unfair to include wages either per unit of product or
per unit of time, and there being no other way to include them,
the conclusion is obvious that they are not pertinent to the dis-
cussion. Such is the conclusion which has been elucidated from
the fact that commodities are the real object of exchange, and that
the exchange value of labor depends not upon the desire for labor
itself, but upon its being productive of commodities.

Second: Wages are also rejected on other most conclusive
grounds. In the problems of production and distribution, the
causes, broadly speaking, are only two: Capital, including land;
and labor, meaning personal services of every grade. The effects
are the commodities produced, and the only claimants in their
distribution (ignoring government) are the laborers and the capi-
talists who furnish the labor and capital. Any attempt, then, to
test the stability of a standard of value by averaging the wages of
labor with the prices of commodities involves the bad logic of
mixing up cause and effect.

DECLINE OF PRICES.

Having eliminated wages, as not being pertinent in an inves-
tigation of the stability of the standard of value, we may pass on
to the evidence rewarding the course of the gold prices of com-
modities. Mr. Wells (October "Forum," p. 131) is authority for
the statement that, " taking the average prices of staple commod-
ities in the London market, the decline from 1867-77 to 1886 was
about thirty-one per cent." He then points out the fact that re-

cently "cotton, wheat, iron, copper, wool, leather and petroleum have touched the lowest general prices of the century."

Edward Atkinson was commissioned by President Cleveland during his first term, under provisions of successive acts of Congress, "to visit the financial centers of Europe in order to ascertain the feasibility of establishing, by international agreement, a fixity of ratio between the two precious metals in free coinage of both." With his report, made in October, 1887, Mr. Atkinson submitted a copy of the statistical work of Professor Soetbeer, who, before giving the results of his own investigations, quotes conclusions from other European sources, in substance as follows:

Statistics carefully gathered by the London "Economist" with regard to twenty-two representative commodities, and official French trade statistics with regard to a similar number, each taking the average prices for the years 1865–69 as par, indicate a decline of twenty-four to thirty per cent. down to 1885, and a decline of twenty per cent. down to 1883, respectively. Soetbeer's own investigations are brought down in the mentioned translation to 1886. He derives his data regarding prices of commodities from complete and trustworthy official trade statistics from the free port of Hamburg. His conclusions, taking the average prices for the years 1871 to 1875 as a starting-point, with regard to the prices of 100 leading commodities, which he divides into seven groups, are as follows:

Agricultural products had declined in 1886, 31 per cent.
Animal   "   "   "   "   "   23   "   "
Southern   "   "   "   "   "   7   "   "
Tropical   "   "   "   "   "   12   "   "
Minerals and metals   "   "   "   "   40   "   "
Textile materials   "   "   "   "   24   "   "
Miscellaneous products "   "   "   "   32   "   "

"For all the 100 articles the comparative prices show a fall in 1886, compared to 1871–75, of twenty-two per cent."

As the evidence is all in the direction of, and conforms with, the decline every observing man has noticed, there is no need of multiplying authorities.

THE APPRECIATION OF GOLD PROVEN.

The serious appreciation of gold has now been conclusively

proven, because, with wages eliminated, proving the decline in commodity prices is proving a corresponding appreciation of gold. In other words, in just the degree that other commodities have on the average declined, the production of gold has failed to respond to the increased productiveness of labor, and in just that degree its supply has fallen short of the demand for it as a stable standard of value.

W. S. Jevons appears to have been among the first of the standard writers on economics to enter upon detailed investigations to determine the degree of the instability of gold. From careful comparison of the most trustworthy data regarding the gold prices of commodities from 1789 to 1869, Jevons found that the highest prices of fifty leading commodities prevailed in the year 1809, the lowest prices in the year 1849. Compared with the price level of the latter year taken as 100, average prices at twenty-year intervals were as follows:

1789	1809	1829	1849	1869
133	245	124	100	119

Striking proof of the appreciation of gold has occurred in the Rocky Mountain region the present year. Capital and labor, throughout Colorado and other mining states, have turned in a remarkable degree toward gold mining in the past six months. A principle long ago pointed out is that capitalists and laborers, always seeking their own interests, leave industries with declining or vanishing profits for more profitable ones. The movement toward gold mining began in midsummer, just after the panic, when, as now, money was the only commodity in great demand, and it cannot be said to have been connected either with noticeable improvements in producing gold or at the time with any noteworthy discoveries in the mines, although, fortunately, it has since led to them. In the gold-mining counties of Colorado numerous abandoned mines were reopened. As the labor came not only from silver mining, but from every other branch of industry in the state, the enhanced value of gold obviously explains the un-

precedented movement toward prospecting for that metal and toward the reopening of old mines hitherto unprofitable.

For twenty or twenty-five years following the gold discoveries of California and Australia the range of commodity prices proves that the gold production exceeded the demand for it as a stable standard; but for the last twenty years the demand for gold has been in excess of the supply, as shown by constantly falling commodity prices. The wide-spread and increasing use of the various forms of bank credits is often cited as a factor in the question of the supply of the precious metals required for monetary purposes, and as tending to offset the effect of the reduced gold production of the past twenty years. Aside from its weakness in a time of need, as exemplified throughout the United States the past summer, whatever bearing this element has, it has proved to be insufficient by the ultimate and practical test of stability in commodity prices. It is evident that exact statements cannot be made as to the amount of gold required annually to render it a stable standard under the present system. It can, however, be said that it should be such an amount as will keep its value in a constant relation to the average level of commodity values.

The statement advanced by Mr. Wells in the October "Forum," that, "The decline in prices, although extensive, has fallen far short of embracing all commodities, and has not been manifested simultaneously," is explained by the influence, already pointed out, of the other variable wages, the rise of which is not confined, in progressive countries, to the labor employed in the production of commodities to which better methods have been applied. In such countries rising wages extend to the labor employed in unprogressive industries, owing to reduced competition resulting from the development of other more attractive fields for labor; and rising wages tend to raise the price of each commodity until better methods of production are applied to it—a tendency far less evident than it would have been under a stable standard of value. Doubtless the relative changes of price among commodities are mainly due, directly or indirectly, to improvements in production and distribution; a fact, however, which, as above made clear, has no bearing on the existence of the general level

of values, and on the requirement of conformity to such level in the standard.

No example has occurred to me that seems to fail to admit of explanation on the basis above outlined. Commodities to which improved methods of production have been applied have declined at the greatest rate. Part of the decline in the price of most of the metals and their manufactures, and in manufactured goods generally, is thus explained. Some farm products have declined to a less degree for the same reason. But all commodities have either declined or shown less tendency to rise, in proportion to the appreciation in the standard; and we look in vain, as the appreciation of the standard proven would lead us to expect, for rising prices in any great class of commodities, which, owing to lack of improvements in their production, ought to have been forced up in price by the improvements in general production. It is true that such tendency to rising prices may not have been entirely overcome in products in which labor is the principal element of cost, such as hand-woven lace; but the appreciation of the standard has been so serious that in relation to the whole number, comparatively few such commodities can be cited.*

THE CASE OF SILVER.

There is an impression, general in many parts of this country and of Europe, that the decline of silver measured in gold has exceeded that of other commodities. It had declined from an average of $1·298 an ounce in 1873 to an average of $0·871 in 1892, or 33%; and a considerable degree of this decline can certainly be ascribed to the lessened demand resulting from demonetization in this and other countries, as strikingly shown by the further fall occasioned by the closing of the Indian mints last summer.

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* The editor of the "Century," replying to a correspondent, in the June number of the current year, to prove that gold has not appreciated, cited the following valuables as having risen in price: Horses and other domestic animals, cigars, hand-woven lace, cut-glass, pictures, diamonds, malt liquors and house rents. It will be seen that these examples are valuables to the production of which machinery is either inapplicable or applicable only in a limited way. House rents depend, as stated by the "Century," largely upon the price of land. The revenue tax cuts a great figure in the price of malt liquors. Diamonds are in fashion and of limited production. The application of machinery to making cut-glass cannot go beyond a certain point, and the labor involved accounts for continued high cost. The other commodities cited continue to be produced, as they always have been, without the application of machinery.

The quotation from Mr. Wells, already given, that the decline of commodity prices from the average of the prevailing prices in 1867–77 had amounted to 31 per cent. in 1886, corresponds with the data of Sauerbeck, taken from Munhall's Dictionary of Statistics (p. 491), as follows:

Year.	1867-77	1878	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889
Index Number	100	111	87	83	88	85	84	82	76	72	69	68	70	72

If therefore, the figures of Sauerbeck, brought down to 1892, are used as a basis, a decline of 32 per cent. is indicated. This result not only negatives the impression of the excessive decline of silver, at least until the closing of the Indian mints, but indicates that if it had been retained as standard money by the countries using it twenty-five years ago, its value would have actually appreciated, compared with the average level of values, and gold would have simply appreciated in a less degree than has been the case. That this conclusion is a conservative one is indicated by the course of prices in silver basis countries. Mr. Jamieson, English Consul-General at Shanghai, is quoted by the press as reporting that the purchasing power of silver in China has risen 9 per cent. in the past twenty years, and that it has remained stationary in India.

Under present financial systems, a stable standard being the object in view, it must now be clear *that the proven instability of gold and the relative stability of silver point to the need of enlarged instead of to restricted use of the latter metal.* A consideration which has doubtless influenced public sentiment against it is the inconvenience of silver coin for money transactions, except for small amounts, due to the fact that it is so much more plentiful and so much less valuable than gold; but this consideration loses weight in view of the conceded greater convenience of certificates than either gold or silver coin.

CLASS LEGISLATION.

It is thus seen that the charge often made against bi-metallists, as being parties to class legislation favoring the "silver

kings," will not hold.   Doubtless the advocacy of silver as a money metal by the silver producer has a selfish basis, while the broader and the only sound basis for enlarging the use of silver as a money metal must be that of the general welfare.   Having conceded this much, the same concession must be demanded with regard to the money lender, that he is entitled to no more favors than the silver producer.   To the end that the established standard may be just for all classes, class legislation in the settlement of the financial question should be studiously avoided.

It would seem as if no one could question that the appreciation of gold, when considered from any point of view except that of the money lender, is of itself a "calamity," interfering with the distribution of the benefits of the increasing productiveness of labor.   The credits of the gold-standard countries, many billions in the aggregate, have so greatly increased in value in the last twenty years, as proven by the decline of commodity prices,* that (making all due allowance for such other causes as incompetence and speculation) there is abundant proof of the existence of a relation of cause and effect between such enhancement and the centralization of wealth on the one hand, and the unending list of business failures on the other.   The panic of 1893, if attributable to a collapse of credit, can in turn with much reason be ascribed to an inadequate supply of gold; and it illustrates the outrageous interference of an appreciating standard with all branches of production.

INTEREST IS COMPENSATION IN FULL TO THE LENDER FOR THE USE OF HIS CAPITAL.

Prof. F. W. Taussig, of Harvard University ("Silver Situation in the United States," p. 107), concedes that gold has appreciated, but holds that improvements in production have more than compensated debtors, saying:

" It is true that the creditor gets more commodities than he gave; but he gets the product of the same amount of labor as he devoted to the com-

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* In this connection it would be interesting to know to what extent the creditor states and nations are supported by the enhancement of their credits caused by the appreciation of gold.   It is not, however, in its nature a sectional question, but one of justice to debtors and producers everywhere.

modities originally lent ; and why should he not share with the rest of the community the benefit of a general increase in the productiveness of labor?"

Further on he says the fall in prices has

"been due chiefly to the general improvements in production; they have not been accompanied by a fall in money incomes, and they cannot be said to have caused an increase on the burden of debtors."

The right of the lender to interest on his proportion of the larger advance of capital, directly or indirectly involved in all improvements in the productiveness of labor, is conceded; but the question Professor Taussig propounds, as I apprehend it, hinges upon whether the creditor contributes to the increased productiveness of labor beyond what supply and demand grant as interest. Being utterly unable to conceive any arguments which can be advanced in support of the question, when thus directly stated, the few remarks here offered will be confined to the reasonableness of the negative view.

For the purposes of this paper capital may be considered as of two kinds, lender's capital and employer's capital.

Lenders, intent upon safety of principal and regularity of income, choose to avoid the risks of business and the worries of production.   In furtherance of these ends, they abstain from the use of their capital and permit others to use it, but for so doing receive a stipulated charge called interest.   Thus, as lenders, their part in production is purely negative, and their compensation is provided for.   Justice is done as far as concerns any given principal when repayment is measured by a standard that will buy the same number of commodities as the standard in use represented when the loan was made.   Any other view ignores accepted conceptions of the nature of value, and is untenable.   The borrower pays interest to the lender as compensation *in full* for the use of his capital.   There is no reason of expediency why the lender should receive more than interest, as, owing to the increasing effectiveness of labor capital is created with ever increasing rapidity, and from the nature of human society a suitable proportion is loaned.

Of the increase in the productiveness of labor, whatever share the creditor is to get should be determined not by any lurking or insidious advantage of appreciation in the standard, but in the

open market by supply and demand. With the present system
the most careful borrower cannot calculate what a loan will cost.
He knows the nominal rate of interest he pays, but he cannot
know the rate of appreciation in the standard. Mulhall (Dic-
tionary of Statistics, p. 76) gives the following table of bank
interest rates which are pertinent in this connection:

	1851-60	1861-70	1871-80	1881-85	Average 35 Years	1889
Great Britain	4·17	4·23	3·28	3·30	3·81	3·55
France..........................	4·30	3·55	3·94	3·34	3·84	3·18
Germany........................	4·05	4·56	4·30	4·20	4·28	3·70
Austria	5·26	4·77	4·79	4·71	4·91	4·12
Italy	5·35	5·69	4·85	4·74	5·22	
Holland.........................	3·60	3·98	3·40	3·56	3·64	2·50
Belgium	3·62	3·59	3·60	3·66	3·62	3·62
Europe..........................	4·27	4·30	3·71	3·93	4·12	3·44

This table shows that nominal interest rates were higher dur-
ing the first two decades than since, but in order to get at the
average cost of loans certain corrections are necessary. For ex-
ample, from 1851 to 1870 we must deduct from the nominal rate
about one per cent. as the average rate of depreciation of the
standard (rising commodity prices) during that period; and to
find the cost since we must add to the nominal rate at least one
per cent. on account of appreciation (declining commodity prices).
This being done, we find that the real cost of money in Europe
during the former period was about three and three-tenths per
cent., and that since it has been four and a half per cent or more.
Thus, from the conception of a stable standard, the cost of money
has been low, at the expense of lenders, or unjustly high to bor-
rowers, according as the gold supply exceeded or fell short of the
monetary demand.

Now, although the lender is only entitled to interest for his
abstinence, it does not follow that he is excluded from sharing
indirectly in "the benefits of a general increase in the productive-
ness of labor."

Every advance in the methods of production, firstly, creates
capital with greater rapidity than that which it superceded; and,
secondly, furnishes employment for a greater investment of capital

both by the more extensive use of machinery, which advances in production involve, and by building up other industries. Thus, while it has already appeared that through improvements in its productiveness labor is better paid per unit of time, it now appears that, without depending on any such implication as Professor Taussig's question involves, capitalists legitimately share in the benefits of the increasing productiveness of labor by receiving interest and profits on larger and larger accumulations of capital. In actual fact it is conceded that through this cause alone they rightfully get a larger and larger share of the total product.

Who is entitled to the direct benefits of the increasing productiveness of labor? In the last resort, this question is clearly one of property rights. Unless property rights are denied, it must be conceded that the active agents of production are entitled to a stable standard. Laborers devise all modifications in production. Employers bear the expense of testing the modifications. Together they unquestionably make whatever improvements are made. Laborers and employers, therefore, have full property rights in the products due to improvements in production, and lenders, having no part in the proceeding, are not entitled in the repayment of principal to more commodities than they gave; so, in forcing adherence to an appreciating standard they violate property rights. Strangely enough, the very lending class which most strongly asserts property rights in other respects assumes the position of denial in this, thereby encouraging by force of example the communistic and other movements which are founded on the denial of property rights generally. Here an illustration will be useful.

THE EFFECT OF AN APPRECIATING STANDARD ON PRODUCTION AND DISTRIBUTION.

To show the effect of an appreciating standard on distribution under ordinary conditions, *i. e.*, where capital is partly borrowed, let the line AD represent the total product of any given productive enterprise. The principal division of this product, as above alluded to, is between laborers and capitalists. The proportions of the division will vary of course in ordinary times mainly with the nature of the enterprise.

Capitalists' Share.		Laborers' Share.
Lenders' Share.	Employer's Share.	
Interest.	Profits.	Wages.
A B	C	. D

The share of the product going to capital is subdivided into interest and profits. For the purposes of this illustration "interest" may include rent, both being at stipulated rates and preferred claims on the product. In the simple case of uniform productiveness, the effect of appreciation in the standard is to increase the proportion of the total product going to the lender, that is, to lengthen the division, AB, without any increase in the line, AD. This occurs primarily at the expense of the borrowing employer, because, having fixed charges to pay, he is in no position to enter upon a struggle with his workmen to lower wages, and the proportion of product devoted to wages has to correspond with the proportion in the case of production by the non-borrowing employer. Therefore the borrowing employer's profits are shortened to correspond with the lengthening of the line AB. Thus, in periods of slow appreciation, the borrowing employer is the principal loser of what the lender gains. But there is a further more general and absolute loss, because decreasing employers' profits have a discouraging effect on production, and lagging production means both lagging competition for labor and lagging demand for capital.

So much for a slow rate of appreciation when the effects are with difficulty traced by practical men. But in time of rapid appreciation, complicated with a collapse of credit, whatever the cause for the collapse may be, a period such as the country has recently been going through when money is the only commodity in great demand, the case is most serious and the effects most obvious. The employer is unexpectedly confronted with both interest and wages encroaching not only upon his profits, but upon his capital; or, in other words, his products, if salable at all, are so greatly reduced in price that they will not pay for his raw materials, even at their reduced prices, and for interest and wages in addition. The result is, first, inability to meet obligations;

second, *failure*, with the lender in charge and labor thrown out of employment. Thousands of recent failures are thus explained. The chances are that the lender does not understand the situation, or, if he does understand it, is not in a position to make the best of it, but is forced to dispose of the plant to outside parties at a sacrifice. The outcome, then is ruin to the employer, hunger and crime for improvident labor, loss to the lender and disorganization to industry.

Thus, it is to be understood that the existing money system does not operate to the unmixed gain of the lender. Besides having property thrown on his hands which he is unable to manage, as already indicated, the wheels of industry stop in time of panic and long remain partly idle; reducing the demand for lenders' capital and depressing interest rates for considerable periods after panics.

There is much reason to believe that the evils described are not necessary evils. As pointed out, the general trend of commodity prices for twenty years past has been downward, but as also shown, the fall in prices was interrupted during the latter years of the last decade. Beginning with 1887, there were several years of great industrial productiveness, business activity and speculation, resulting, in spite of the general tendency to appreciation in the standard, in an expansion of credit and slightly increased prices. But this rise in prices, shown in the foregoing table from Sauerbeck, was clearly less than it would have been under an expansion of credit and a supply of gold more nearly corresponding in the long run to the average level of values; and the Baring trouble of 1890 acted as a decided check to undue expansion, so that the panic of this year is to be ascribed to other causes than unduly expanded credit, although it is equally clear that much of the credit existing collapsed. No doubt there was much apprehension that the country was tending to a silver standard, but while gold has been appreciating for twenty years, it has been proven that silver has kept near the average level of values, and that therefore the seat of the trouble was not the instability of silver, so much as the instability of gold favorable to creditors. Under an excessive supply of gold, however, a crisis occurred in this country in 1857 and one in England in 1866. Both were pre-

ceded by activity, speculation and over-banking—tendencies which for a time are stimulated by a depreciating standard, and which naturally terminate in a collapse of credit.

The tendency of trade, under any money system that has ever existed, to go through cycles of activity, speculation and collapse, was long ago noticed. The facts actually indicate the existence of a close relation between this periodicity, and the failure of the money supply to so vary inversely with the tendencies to activity, speculation and depression as to keep average prices in conformity with the average level of values.

If, then, panics are to be avoided, financial systems need to be changed: first, to offset the instability of the precious metals; and, second, to regulate credit. Obviously the volume of money should contract as prices tend to rise, to check speculation and over-borrowing, both of which characterize undue expansion of credit; and it should expand as prices tend to fall to encourage production and to keep average prices constant.

The machinist has devised the "governor" by which he regulates the speed of machinery. Nature offers man as a governor the never-failing average level of values by which he may, if he will, regulate the speed of the industrial and business world, eliminating cycles of activity, speculation and depression by the substitution of expansion at a constant rate.

THE NATURAL STANDARD OF VALUE.

As the standard should bear a constant relation to the average level of commodity values, some modification of the tabular standard of Jevons, capable of universal application, is obviously suited for the purpose.* The plan, if it is to be adopted within a reasonable time, must make use of the prejudice in favor of the precious

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*Jevons' method was to calculate "from quarterly prices the average prices of a series of important articles during the six years, 1845-50. He assumed each average price to be 100, and on this basis made a percentage comparison of the prices of the same articles on the 1st of January or 1st of July of each year following." The yearly changes in the level of prices are arrived at by some statisticians by adding up the index numbers (the figures indicating percentage comparison) of the selected articles, dividing the total by the number of articles and getting a percentage result. Jevons, however, took the geometric average.

The need of considering the relative importance of commodities is apparent and is provided for by some tables.

metals. Aside from the powerful interests that are favored by the present standard, which will furnish, under all sorts of pretexts, unavoidable opposition to reform in the standard, the difficulty of the problem ought not to be discouraging. Jevons' plan involved calculation and was therefore impracticable, a fact which he realized, and he advanced it as suitable for deferred payments only. A modification which would furnish money as convenient as the most convenient money now in use, and which would not involve displacing the precious metals, ought to be practicable.

For example, the periodical determination of the exchange value of the precious metals might be referred to a competent national or international commission with power to vary from time to time the number of grains in the unit of each metal to correspond with its modified exchange value. The acceptance of the new unit as the standard of settlement for obligations at the time existing could be enforced by law. A dollar would then be a unit of definite exchange value, defined by statute to correspond with the data, for the preceding credit cycle if practicable, of the average wholesale exchange value of the present dollar, in the, say 100, leading commodities which might be decided upon as the basis of the multiple standard, taken in proportion to their relative importance.

Gold and silver, then, could not be coined, but certificates would be issued, redeemable in bullion, when presented in sufficient amounts, in units of weight established by the last announcement of the authorized commission. To prevent the withdrawal from the treasury of appreciating bullion, and to meet obvious business ends, the reduction in the weight of the units would be gradual, based upon the findings and authority of the commission. No more computation would be necessary to money transactions than now. All classes would of course be interested in the careful work of the commission; but, beyond this general interest, only those engaged in selling or buying the metals in the course of their production or use, or in the settlement of international balances, would need to keep informed on the weight of the precious metal units. Such a plan would provide an expanding currency to meet the demands of expanding business; because the weight of the units would be reduced to correspond with the

appreciation of the precious metals, and additional certificates, thus warranted, would be issued upon the bullion in the treasury vaults. The volume of money would thus be increased as required to keep average prices constant, contracting to check speculation and excessive borrowing as prices might tend to rise, and expanding to prevent business crises and depression as prices might tend to fall. A question of detail may bother some people with regard to the process of issuing such new certificates. A few ways may be here suggested:

They might be issued in buying up government bonds if there were any outstanding; in the payment for construction of permanent and needful public works; in the construction or purchase of systems of telegraph, railway, etc. For the purposes of the issue and the withdrawal of such a currency, a postal savings-bank system would also promise great usefulness. In case of the depreciation of the precious metals due to an increase of supply — an improbable case it will be conceded with regard to gold—more bullion would have to be purchased with the current income of each government, or as otherwise deemed expedient; but so long as the business of the world continued to expand with greater relative rapidity than the production of the precious metals, the world as a whole would be the gainer, as it should be, instead of the money loaner in particular, as now, from the appreciation of gold. In case of lessened national demand for money caused by national decline of business, the excess of a nation's certificates would be redeemed in the automatic course of trade, and the bullion would be withdrawn for shipment elsewhere. Thus, to whatever degree the production of one or both of the precious metals might at any future time be curtailed, every nation having its fair proportion of the world's supply at that time would have enough for its currency basis, and the supply upon which to base the entire business of the world would always be sufficient.

To the objection that a perfect system has not yet been devised for arriving at the average price of commodities, making due allowance for the importance of each, the answer simply is, that enough progress has been made to that end to furnish a far more stable standard than that furnished by the precious metals, one or both; and the establishment of the multiple standard would fur-

nish all the conditions for rapidly perfecting the methods of gath-
ering and dealing with data for ascertaining average prices. The
further objection that the standard of value might somehow be-
come the puppet of politicians is worthy of consideration, but if
properly undertaken, danger from this source need not exist.
With a similar tenure of office to that of the judges of the supreme
court, and with the same high standard in the selection of the
commissioners as prevails in that of the judges of that court, there
is no reason to doubt that results would be equally satisfactory.

In view of the great present evil, steps ought to be taken at
once to provide for carefully gathering necessary data looking to
the establishment of such a standard on a practical basis, national,
if necessary to start with, but international if possible. We are
frequently told that this country can not afford to adopt a differ-
ent standard than that in use by the creditor nations. It is con-
ceded that a uniform standard is desirable, but this paper has
missed its purpose if it has not shown that a stable standard is the
only just one. The view that this country can afford to pursue a
course independent of the creditor nations until they adopt a just
uniform standard, can rest therefore on the principle that all
changes must be in the direction of the right, instead of in the
direction of a system involving such manifest injustice as to defeat
one of its most important ends, and entailing periodic disaster to
business enterprise. On the grounds of world-wide morality, it is
a duty devolving upon the government of a strong nation like this
to take active steps toward the establishment of a standard of value
that will be just to all.

Every investigator of a scientific turn of mind is impelled to
carry his investigations to their logical termination; also to ask
those to whom his results are submitted to suspend judgment until
the argument and conclusions are understood, and then to judge
them, without prejudice, on their own merits. The writer has
aimed at a logical and scientific treatment of the subject under con-
sideration. He began the investigations, which have led to this
paper, inclined to accept the rightfulness of gold mono-metallism,
and therefore disposed to believe that the depreciation of silver
proved the decline in its value. Considerations regarding the
nature of value, deductions therefrom, and existing facts, taken

together, have led to the opposite view. The same grounds lead
to the conclusion that a radical change in financial systems is
necessary to meet modern requirements, and, fortunately, they
also indicate the nature of the change required.

NECROLOGY

Dr. John F. Main.

In the death of Dr. John F. Main the Society has lost a distinguished member and an esteemed friend. He died on May 11, 1892, in the 39th year of his life, his fatal illness being directly superinduced by pulmonary troubles, relief from which he had sought in the Colorado climate.

Dr. Main was born at Green Castle, in the Island of Jamaica, on July 7, 1854. He received his elementary education in the grammar school of Portsmouth, England, after which he entered Trinity College, Cambridge, graduating at that University in 1875. In 1876 he took the degree of Bachelor of Science at the University of London, and in 1877 had conferred on him by the same institution the degree of Doctor of Science.

In the same year Dr. Main entered upon his educational career and received the appointment of professor of mathematics at University College, Bristol, England, where he taught in the engineering, mechanical and mathematical departments.

In 1882 he accepted a professorship in the Normal School of Science, South Kensington, London.

In 1886 his health began to fail and for its recovery he took a trip to Switzerland, where he remained during the fall and winter. The change of scene and climate seemed to benefit him, and during the winter he felt himself strong enough to conduct a most interesting series of experiments on the viscosity of ice, and on the extension of glacier bodies under tension.

Returning again the following year to England he found, however, that the insidious disease which had grafted itself on his lungs had not been overcome, and his constitution had become so undermined that, in the year 1888, he bade adieu to the land with the educational institutions of which he had been so closely identified, to seek in Colorado's sunny clime the boon of health which had been denied him at home.

Dr. Main would greatly have preferred to have continued his educational career in Colorado, but lack of opportunity prevented his doing so. Being a man, however, of exceptional energy, and not willing to lead a life of repose, he decided to embark in a business career and to that end founded the Denver Investment and Banking Corporation, associating himself with Mr. Thomas J. Pulling as partner.

In the Colorado Scientific Society, which he joined soon after his arrival in Denver, Dr. Main found congenial associates. He evinced the deepest interest in the welfare of the organization, and only the demands of business engagements prevented his regular attendance at the monthly meetings.

At the meeting of April 1, 1889, he read a paper before the Society on "The Plasticity of Glacier Ice," an article which has been often quoted as offering an explanation of glacier action and of suggesting the indefinite extension and deformation which a holo-crystalline body may undergo when the necessary force is continuously applied.

Dr. Main remained to the last a hard student. He was a close observer, and in scientific speculation he found a recreation from business cares.

His personal characteristics brought him friends on all sides. He was of most pleasing address, always courteous, and entirely devoted to his sister, who followed him to Colorado, and to whom the Society extends that sympathy which is induced by a full and sorrowful knowledge of the keen loss that has befallen her.

HERMANN BEEGER.

Hermann Beeger, one of the Charter Members of the Society, died at his home near Denver, on December 7th, 1891, at the ripe age of 71 years.

He was born in Gadewitz, Saxony. In the year 1838 he was admitted as a student to the Royal School of Mines at Freiberg, Saxony, from which institution he graduated four years later as metallurgical engineer.

After graduation he went to Spain where he followed his profession until 1865 when he took a professional trip to New Zealand, Australasia. In 1867 he came to the United States and took charge of the smelting works of the Boston and Colorado Smelting Company, at Black Hawk, Gilpin County, Colo. These works, it may be said, were the first of their kind in the Territory, and the difficulties with which Mr. Beeger had to contend were enormous. Bringing all the resources of a fertile mind, and the practical experience of many years to bear on the project, he had the great satisfaction of making a complete success of the enterprise.

He remained with the company at Black Hawk until 1873, when he took charge of a branch establishment at Alma, Colo. From there he went to the company's refining works located at Boston, Mass., and superintended the refining operations of the gold-copper alloy produced at Black Hawk.

Advancing years soon compelled him, however, to lay down the burdens of technical life, and severing his connection with the Boston and Colorado Smelting Company, he returned to Denver to enjoy as a spectator the march of metallurgical progress in Colorado, to which he had given such an impulse by his own successful operations in Gilpin County. In recognition of his work and his contribution to the smelting art he was very fittingly termed by his confreres "the father of smelting in Colorado."

He was one of the original twelve who organized the Colorado Scientific Society, with whose welfare and progress he remained closely identified to the last. While he did not contribute directly to the Proceedings of the Society, his frequent discussions of papers submitted gave them at all times an enhanced value.

So kindly was his nature, and so beloved was he, that his loss was felt by every member as that of a personal friend.

J. H. ERNEST WATERS.

J. H. Ernest Waters was born in Parsonstown, Kings County, Ireland, on August 23rd, 1851.

His engineering education was obtained at the Royal School

of Mines of London and at the similar school at Freiberg, Saxony. In 1873 he won, in competitive examination, the appointment of mining engineer on the engineering staff of the Japanese government.

He remained in Japan until 1877 when he came to Colorado, locating at Silverton. Near that place at Gladstone he erected lixiviation works for the treatment of local ores. He practically remained in the San Juan until 1883, actively following his profession, when he left the United States for China under whose government he accepted the appointment of mining engineer. While in China, in the winter of 1883, he effected the sale of the Sheridan mine near Telluride, Colo., to a syndicate of English and Chinese capitalists. In the spring of 1884 he returned to Colorado and took the active management of the acquired property. Under his advice the adjoining mine, the Mendota, was also purchased by the same parties. The mines proved of great value and in the management of same Mr. Waters added greatly to his already extended reputation as a mining engineer. He remained identified with the properties until within a short time of his death, which occurred in Denver on May 9th, 1893.

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