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PROCEEDINGS

OF THE

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ONE HUNDRED AND TENTH REGULAR MEETING.

February 5th, 1894.

In the Society Rooms, High School Building.

The President in the Chair.

Twenty-six persons present.

Messrs. Wm. H. Smiley, A. F. Wuensch, Willard S. Morse, Chas. T. Carnahan, E. C. Engelhardt, and Hal. W. Hardinge, were elected members, and Mr. L. C. Jakway an associate member.

Mr. John B. Farrish presented the report of the Committee which had charge of the arrangements for the annual dinner of the Society, which was given in January.

The Librarian reported the donation of books to the Society by Mr. S. F. Emmons.

A vote of thanks to Mr. Emmons was passed.

COMMUNICATIONS.—Professor H. van F. Furman read a paper on "The Refining of Gold as Practiced in the U. S. Mint."

Mr. T. A. Rickard discussed "The Geology of the Metaliferous Mines at Pontgibaud, France."

ONE HUNDRED AND ELEVENTH REGULAR MEETING.

March 5th, 1894.

In the Society Rooms, High School Building.

The Second Vice-President in the Chair.

Twenty persons present.

Messrs. E. E. Olcott, John A. Church, Wm. A. Hover, and

George R. Hurlburt were elected members, and Mr. Jas. A. McClurg an associate member.

The Committee appointed to audit the accounts of the Treasurer presented its report.

COMMUNICATIONS.—Mr. A. A. Blow gave an interesting lecture on "The Gold Belt of Leadville." Mr. Blow's discourse was subdivided into the following headings:

1. The locus of the gold ore chutes. These are embraced within the area lying about two miles to the east of Leadville in a comparatively unexplored territory known as "Breece Hill."

2. The trend of the chutes. He believes this to be identical with that of a number of prominent ore chutes on "Iron Hill," and was furthermore of the opinion that the gold ore chutes might possibly be found to be continuations of the silver ore chutes.

3. The character of the ore. It is highly siliceous, and but little silver and lead are found associated with the gold.

4. The occurrence of the ore. This is not confined to any special zones. It occurs both in the limestone and the porphyries (white and gray), or in the contact planes between the two. In connection with the gold ore deposits there occur intrusive dikes of porphyries younger than both the white and gray porphyries which characterize the silver deposits of Leadville. These younger eruptives appear to be intimately associated with the gold deposits, and may have influenced the deposition.

ONE HUNDRED AND TWELFTH REGULAR MEETING.

April 2nd, 1894.

In the Society Rooms, High School Building.

Dr. Richard Pearce, Chairman Pro-Tem.

Twenty persons present.

tance in aiding the Society to obtain its new quarters at a very moderate monthly rental. The motion was unanimously carried.

Messrs. E. L. Newhouse, C. W. Goodale, and A. R. Nickels were elected members.

COMMUNICATIONS.—Professor Wm. C. Strong read a paper on "The Sanitary Features of the Artesian Waters of Denver."

ONE HUNDRED AND FOURTEENTH REGULAR MEETING.

June 4th, 1894.

In the Society Rooms, Boston Building.

The President in the Chair.

Forty-eight persons were present.

Messrs Wesley Brainerd, Edwin E. Chase, J. T. Eskridge, and H. W. McLaughlin were elected members, and Mr. Chas. R. Dudley an associate member.

The Curator exhibited some mineral specimens of gypsum presented to the Society by Mr. W. S. Ward, and also some fossils given the Society by Dr. Wm. P. Headden. He also brought up the matter of a fossil plant collection which he had undertaken to gather jointly with the late Professor Newberry of Columbia College, N. Y. This collection belonged in part to Mr. Hills personally, in part to the Society, and in part to Professor Newberry. A portion of the Society's share was in possession of Professor Newberry when he died. Mr. Hills had corresponded with the Trustees of Columbia College regarding this collection and had learned that Professor Newberry's entire collection had been left to the College and that it was impossible to select out and turn over to the Society that portion of the fossil plant collection which belonged to it. The Columbia College Trustees were, however, willing to take from the Society that portion of the collection already in their possession and pay for the same an adequate

monetary consideration. The Curator suggested that inasmuch as the partial collection was of little use to the Society the offer be accepted. He was empowered by the Executive Committee to take whatever action in the matter he might deem best.

Mr. W. S. Ward, on behalf of Professor Henry Ward of Rochester, N. Y., made a proposition to the Society to cut a piece from the large meteorite belonging to it. The piece taken off would weigh about five or eight pounds. He would agree to polish the face where cut and pay for the section cut off the sum of $200. The Executive Committee accepted the offer and empowered the Curator to attend to the transaction.

COMMUNICATIONS.—The Secretary read a paper written by Dr. Whitman Cross on "The Geology of the Cripple Creek District." It was discussed by Messrs. Guiterman, Argall, Palmer, van Diest, Moore, Hills, Freeland, Rickard, and Pearce.

The Secretary also read a paper written by Professor R. A. F. Penrose on "The Ore Deposits of Cripple Creek."

ONE HUNDRED AND FIFTEENTH REGULAR MEETING.

July 2nd, 1894.

In the Society Rooms, Boston Building.

The President in the Chair.

Nineteen persons present.

The Secretary presented to the Society in writing the following amendments to Sections 10 and 13 of the By-Laws of the Society; proposed by Messrs. F. Guiterman, Chas. S. Palmer and R. C. Hills.

Proposed amendments to Section 10.

The Executive Committee shall have the general control of all expenditures of the Society; shall appoint the necessary curators; *shall elect members and associate members;* etc., etc., the remaining portion of the section being left unaltered.

Proposed amendment to Section 13.

Members and associate members shall be elected by the Executive Committee, two negative votes being sufficient to prevent an election, etc., etc., the remaining portion of the section being left unaltered.

COMMUNICATIONS.—Professor Chas. S. Palmer read a paper on "The Differentiation of Silver," being an exposition of the methods being used in carrying out the researches of the author along these lines.

ONE HUNDRED AND SIXTEENTH REGULAR MEETING.

August 6th, 1894.

In the Society Rooms, Boston Building.

The First Vice-President in the Chair.

Twenty-five persons present.

The amendments to the By-Laws proposed at the last meeting were adopted.

COMMUNICATIONS.—Mr. R. C. Hills read a paper on "The Mercur Mine of Camp Floyd District, Utah."

Prof. Edmund B. Kirby then read a paper on the "Gold Ore Deposits of Mount Carribou, Idaho." In this the common change of mineral solutions from alkaline to neutral, was illustrated.

Mr. J. B. Farish gave a description of a copper-bearing bog in Bingham Canyon, Utah. This copper deposit was formed by cupriferous solutions from some of the neighboring mines flowing into the bog, the copper being precipitated as metallic copper by the organic material of the bog.

Mr. P. H. van Diest read a paper on "The Slate Resources of Colorado."

ONE HUNDRED AND SEVENTEENTH REGULAR MEETING.

September 3d, 1894.

In the Society Rooms, Boston Building.

The President in the Chair.

Twenty-five persons present.

Messrs. John K. McKinzie and R. M. Dickman were elected members. Mr. Franklin Ballou an associate member.

COMMUNICATIONS.—Professor Chas. S. Palmer gave an account of a visit to Long's Peak, Colorado.

Mr. L. D. Godshall made an informal communication on pyritic smelting as conducted by him at Rico. Discussed by Messrs. Pearce and Dwight.

Professor Palmer called attention to a notice in an English paper of a possibly new element—argon—closely associated with the nitrogen of the atmosphere. He commented on the physical properties ascribed to the supposed element and upon the atomic weight assigned to it, and stated that these were irreconcilable with the periodic law as formulated by Mendelejeff.

Professor Palmer also delivered a few remarks on the death of Dr. Williams, professor of geology at John Hopkins University. Although Dr. Williams was not a member of the Society, still he was known to many of its members, and had occupied such a prominent place in the scientific world as a geologist, that a tribute to his worth was tendered.

ONE HUNDRED AND EIGHTEENTH REGULAR MEETING.

October 1st, 1894.

In the Society Rooms, Boston Building.

The First Vice-President in the Chair.

Forty-seven persons present.

The Secretary stated that Mr. Chas. D. Walcott, director of the U. S. Geological Survey, had during the previous month paid a visit to Denver on his way west, and had expressed a desire to meet the representative mining men of the State, as well as those interested in the work of the Survey. The Society had tendered Mr. Walcott an informal reception to which a number of Denver's most prominent citizens had been invited. Owing to Mr. Walcott's short stay in Denver, the time for arranging this reception was so very brief that no formal announcement of the meeting could be made to the members through the regular channels and recourse was had to the newspapers. The meeting was well attended, over fifty persons being present.

Mr. Walcott took occasion to outline the nature of the work now being conducted by the Survey and to define the plans upon which it would be conducted in the future. He expressed himself as highly gratified at the interest shown by the Society in the Survey, and trusted that the latter would be so conducted as to merit the cordial support of the organization.

Messrs. W. F. Patrick, A. Chanute, Chas. J. Ling, D. G. Miller, and R. A. F. Penrose, Jr., were elected members; Messrs. Dennis Sheedy and Seymour Coleman associate members.

COMMUNICATIONS.—Mr. Francis T. Freeland read a communication on "Mining Litigation," in which he offered certain suggestions for the amelioration of the present U. S. mining laws, by the adoption of which the present complex features surrounding the location of claims, and affecting the validity of titles and the rights of veins, might be overcome.

The communication had been submitted to, and printed by an eastern journal, but the subject was of such great importance that Mr. Freeland thought the Society might with propriety, discuss it, and perhaps take action upon it.

Messrs. Farish, van Diest, Kirby, Schwartz, Guiterman, and Hallet participated in the discussion which followed.

The Secretary moved that the chair appoint a committee of five, of whom he should be one, to draw up a set of resolutions concerning such amendments to the present mining law as would, in their opinion, prove of benefit to the mining community. These resolutions should be subsequently presented to the Society for

approval, further amendment, or rejection. In case final resolutions were adopted by the Society they were to be presented to the representatives of the State of Colorado in Congress as a suggestion for the improvement of the mining law.

The motion was seconded and passed.

The chair announced the appointment of the following committee:

Messrs. Francis T. Freeland, Philip Argall, Wm. Byrd Page, P. H. van Diest, and John B. Farish.

Mr. F. C. Knight then read a paper on "A Suspected New Mineral at Cripple Creek."

ONE HUNDRED AND NINETEENTH REGULAR MEETING.

November 5th, 1894.

In the Society Rooms, Boston Building.

Mr. F. C. Knight, Chairman Pro-Tem.

Fourteen persons present.

Messrs. Frank C. Smith, Louis Pelatan and Fabrizio Clerici were elected to membership, and Messrs. Moses Hallett and Geo. W. Peirce to associate membership.

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

COMMUNICATIONS.—Mr. P. H. van Diest read a paper entitled "Notes on the Geology of the Western Slope of the Sangre de Cristo Range in Costilla County, Colo."

ONE HUNDRED AND TWENTIETH REGULAR MEETING.

December 3d, 1894.

In the Society Rooms, Boston Building.

Mr. O. J. Frost, Chairman Pro-Tem.

Thirty-two persons present.

Messrs. W. R. Ingalls, Thos. Withers, G. H. Rowe, Benj. L. Cress, and E. A. Schneider were elected to membership, and Mr. James V. Dexter to associate membership.

The Chair appointed Messrs. Jones and Charlton to act as tellers in the election for officers for the Society for 1895. The ballots were then cast and the tellers announced the election of the following gentlemen:

President,	A. S. Dwight.
First Vice-President,	Philip Argall.
Second Vice-President,	A. Raht.
Recording Secretary,	F. Guiterman.
Cor. Sec'y and Librarian,	P. H. van Diest.
Treasurer,	R. M. Hosea.

EXECUTIVE COMMITTEE.

Richard Pearce. P. H. van Diest.
Irving Hale. H. Van F. Furman.
R. C. Hills.

COMMUNICATIONS.—Mr. E. B. Kirby read a paper on "The Sampling and Measurement of Ore Bodies in Mine Examinations."

ANNUAL MEETING.

December 17th, 1894.

In the Society Rooms, Boston Building.

The President in the Chair.

Eighteen persons present.

The newly elected president for 1895 was duly installed.

The retiring president, Professor Chas. S. Palmer, read an address entitled "The Recent History and Present Status of Chemistry."

ABSTRACT OF MINUTES

FOR THE YEAR 1895.

ONE HUNDRED AND TWENTY-FIRST REGULAR MEETING.

January 7th, 1895.

In the Society Rooms, Boston Building.

The First Vice-President in the Chair.

Fourteen persons present.

The annual reports of the Secretary, Corresponding Secretary and Librarian, and Treasurer were read.

Messrs. D. W. Brunton, F. M. Taylor, W. E. Newberry, Karl Eilers, A. L. Dickerman, F. Cazin, L. E. Lemen, and James H. Baker were elected members, and Messrs. J. I. Higgins, Jno. L. McNeil, W. H. James, C. B. Kountze, J. H. Thatcher, and C. H. Toll to associate membership.

The Secretary read the following amendment and additions to the Constitution, and amendments to the By-Laws, which had been handed in in writing, endorsed by Messrs. Argall, Guiterman and van Diest:

AMENDMENT TO CONSTITUTION.

A. Article IV. Persons of recognized attainments in some branch of natural or applied science shall be eligible for admission as members of the Society.

ADDITIONS TO CONSTITUTION.

B. Proposed Article VIII. Honorary Members. Persons of great attainments in some branch of natural or applied science

offered an explanation why the zinc contents of cyanide solutions do not increase with the continued precipitation of gold from solutions which are used over and over again.

Dr. Richard Pearce called the attention of the Society to some investigations he had recently been making on the gold ores of South Dakota. He had been struck with the physical analogy between these ores and those of Cripple Creek. The South Dakota ores occurred in the Potsdam sandstones of the region. Microscopic examination demonstrated that the gold-bearing rock was eruptive. Dr. Pearce ventured the opinion that it was an altered phonolite. Dr. Whitman Cross, of the U. S. Geological Survey, had stated that outside of Cripple Creek, Colorado, South Dakota was the only locality known in the United States where phonolite occurred. The samples were of two kinds; the "blue ore" as it was called, and a reddish-brown ore. The "blue ore" consisted of a hard, jaspery material of bluish cast and color, sprinkled here and there with pyrite and containing also fluorite. The reddish-brown variety was essentially the same except that the pyrite and other metal minerals present had been oxidized. In neither of these ores could free gold be detected by the miners' test of panning. An examination with the lens showed in the reddish-brown ore small cavities lined with reddish-yellow tufts. It was the appearance of these tufts which had led him to suspect the presence of tellurium in an oxidized form. A chemical test on the ores verified his surmise.

Dr. Pearce also stated that he had been investigating the behavior of tellurium ores in roasting. Much to his surprise he had found that in ores free from pyrite there was but a very small amount of tellurium lost in roasting, while in the presence of pyrite the loss was somewhat greater. In neither case, however, was the volatilization anywhere near as great as he had been led to believe it would be from the current published statements. In roasting tellurium ores of gold and silver, associated with silica and pyrite, he had found that the tellurium remains behind in the oxidized form of TeO_2, either free, or combined with ferric oxide.

Dr. Pearce had come to the conclusion, in view of the preceding investigations, that the loss of gold in roasting tellurium ores was not a matter of such great importance as everyone had been

led to believe from all previous statements. He proposed to continue his investigations and trusted in due time to be able to lay before the Society the results of his researches.

ONE HUNDRED AND TWENTY-FIFTH REGULAR MEETING.

May 6th, 1895.

In the Society Rooms, Boston Building.

The President in the Chair.

Twelve persons present.

COMMUNICATIONS.—Professor van Diest exhibited a number of fossils found in a railway cut about ten miles west of Pueblo. They consisted principally of imprints of ostræ and other shells, associated with sharks' teeth in Niobrara limestone, which contained also nodules of marcasite.

Dr. Pearce gave the results of further investigations with telluride ores. He showed some crystals of pyrite covered with gold crystals, which had been obtained in the following manner. A crushed sample of Cripple Creek ore carrying 1,100 ounces gold per ton, had been digested in a very weak solution of chloride of sodium and sesqui-sulphate of iron in very much diluted sulphuric acid. This solution had been made to correspond as nearly as possible to the waters found in nature. The ore and solution were kept at a temperature of a little less than that of boiling water for about six weeks, when all the gold—except one ounce per ton—was found to have gone into solution. When this auriferous solution was brought into contact with carbonaceous shale, the gold was precipitated on the edges of the shale. A few small crystals of pyrites were placed in some more of the solution and the gold was precipitated upon them also. It was observed that the gold was precipitated upon the pyrites crystals which contained zinc, galena, or other extraneous matter. The pure pyrite crystals brought about little, or no gold precipitation.

ONE HUNDRED AND TWENTY-SIXTH REGULAR MEETING.

June 3d, 1895.

In the Society Rooms, Boston Building.

The President in the Chair.

Eighteen persons present.

The election of Mr. C. I. Andrews to membership was announced.

The librarian made his report and mentioned the donation to the library by Professor Palmer of a work on chemistry.

It was announced that the Executive Committee had decided to hold the next meeting in Cripple Creek, on Monday, July 1st.

COMMUNICATIONS.—Mr. C. I. Andrews read a paper on "The Eruptive Rocks of Alum Hill, Boulder County, Colorado."

Professor Palmer read an informal communication on the "Present Status of Argon," in which he briefly sketched the facts which led to the discovery and isolation of this new ingredient of the atmosphere, referring to the works of Rayleigh, Ramsay, Crookes, Olzewski, Berthelot, and others. The vapor density and the specific heat of this new substance would indicate a monatomic molecule having an atomic weight of about 40. But on the other hand there is no arrangement of the periodic law which provides for such a new element. Moreover the behavior of argon under liquifaction would indicate a simple nature. The spectrum of this element may indicate complexity of the molecule but this is uncertain.

The failure to obtain evidence of the chemical activity of argon seems to have been due to the disruptive nature of the electric spark, Berthelot having obtained, by means of the silent electric discharge, evidence of a union between it and benzine. The resulting compounds obtained by this process were alkaline and seemed to resemble aniline. Should these facts be substantiated, they would constitute a strong argument for the nitrogenous nature of the new substance. Indeed, Berthelot and Mendelejeff seem to incline to this view.

Attention was also drawn to an experiment of Crookes' in which it was possible that nitrogen may have been changed into argon.

In connection with this important discovery note was made of the identification of helium as a terrestrial element. It was found in the gas evolved from the uranium mineral broggerite, the analysis of which was first made by Dr. Hillebrand of the U. S. Geological Survey. Dr. Hillebrand overlooked, however, the nature of this gas, supposing it to have been nitrogen. The vapor density of helium is about 3·8, and the atomic weight about 7·6, in the supposition that the formula for the determination of the specific heat has been accurately interpreted.

It is interesting to note that there is no place in the periodic law for such an element, if its atomic weight is 7·6, but it readily finds its place as a member of the hydrogen series if its atomic weight is 3·8. Helium would appear to be distinctly acidiferous while argon is only very slightly so, being almost inert. Helium received its name because its spectrum was first observed in the solar spectrum; argon, because of its chemical inactivity.

The view was advanced that before the questions relating to helium and argon are settled, chemists will possibly be obliged to adopt new conceptions regarding the atom and the molecule, and their relations to each other.

ONE HUNDRED AND TWENTY-SEVENTH REGULAR MEETING.

July 1st, 1895.

In the Masonic Hall at Cripple Creek, Colo.

The First Vice-President in the Chair.

Thirty-four members, and about eighty of the local mine managers and leading citizens of Cripple Creek were present.

Messrs. John W. Nesmith and Nelson Franklin were elected to membership.

COMMUNICATIONS.—Mr. F. T. Freeland delivered an address, the subject being "The Bull Hill Mines." Mr. C. J. Moore followed with a dissertation on "The Characteristics of the District in General and of Battle Mountain in Particular."

Messrs. Palmer, Strong, Headden, van Diest, and others participated in the discussion which followed.

Mr. J. D. Hawkins read a paper on chlorination.

The next morning the members of the Society, being divided into two parties, proceeded to visit the mines and mills.

Among the points of interest were:

The Anaconda Tunnel—This double-tracked tunnel entered Gold Hill over 1,200 feet. The vein at a depth of 500 feet was 30 feet in width.

The Elkton Mine—On the 200-foot level this property was opened up by drifts for a total length of 400 feet. A cross-cut on the 100-foot level east, reached a dike of nepheline basalt running parallel to the vein.

The Catherine Mine—In this mine attention was called to a much altered phonolite dike crossing the Catherine vein at right angles on the 215-foot level.

The Home Run Mine—This claim is on the south slope of Squaw Mountain and was in the granite, and, so far as known, no dikes of phonolite, etc., occur in its vicinity.

The Portland Mine—The two parties met at this point at noon and partook of an excellent lunch provided by the management of the property. The Anna Lee claim, one of those operated by this company, was first visited. The shaft follows down a chimney of ore, or rather an old geyser, 90 feet long and 20 to 40 feet in width, beyond which the ground has no value. The ore is a pudding stone, the cementing substance being ore and lime.

The Independence Mine—Here the long stope at the 300-foot level attracted the most attention. At this point a few men were daily breaking down $5,000 worth of ore.

In addition to the above named mines, the Portland, Raven, Ruby, Lucky Guss, Zenobia, Pharmacist, Victor, Buena Vista, Londonderry, Climax, Deerhorn, and Summit were visited.

The Brodie and Hartzell Mills were also inspected.

In the evening the members attended an elaborate banquet

tendered them by the citizens of Cripple Creek. Several appropriate toasts were proposed and responded to, and, at the close, resolutions of the most appreciative character were passed, thanking the mine owners and citizens of the district for their courtesies and liberality, and for the opportunities which had been given the members for inspecting the mines.

During the morning of July 3d the members visited special mines, and in the afternoon the return trip to Denver was begun. A special train conveyed the members to Gillette, where the chlorination plant of the El Paso Reduction Works was visited, after which the special car of the party was attached to the regular train for Denver.

ONE HUNDRED AND TWENTY-EIGHTH REGULAR MEETING.

September 9th, 1895.

In the Society Rooms, Boston Building.

The President in the Chair.

Sixteen persons present.

The Secretary announced that the Executive Committee had elected Messrs. G. Lavagnino and V. G. Hills to membership and Mr. A. R. Wilfley to associate membership.

COMMUNICATIONS.—Dr. Richard Pearce described the occurrence of uraninite on the dump of the Wood Lode in Leavenworth Gulch near Central City in this State. Both nitrogen and helium have been found to be present in this ore.

Dr. Pearce also exhibited specimens of beautifully crystallized slag, containing 7·28 per cent. of free arsenous acid.

The analysis of the slag showed:

SiO_2	14·70	Fe_2O_3	20·42
Cu_2O	5·70	Al_2O_3	2·09
CuO	47·50	Bi_2O_3	1·65
As_2O_3	7·28	PbO	1·93
			101·27

Mr. A. Eilers called attention to an auriferous pyrrhotite found at Trail Creek in British Columbia.

Dr. Pearce stated that he knew of no other instance of gold being associated with pyrrhotite. He thought the gold might be due to the presence of a telluride.

Professor van Diest gave to the mineral cabinet two specimens of gold ore from the 100-foot level of the Strong Mine at Cripple Creek. These specimens showed the characteristic occurrence of gold in the said district. The crystalline telluride of gold, and, next to it, the finely divided gold (appearing as a yellowish bronze powder, which when rubbed exhibits the gold lustre and color) showed the results of the decomposition of the telluride.

ONE HUNDRED AND TWENTY-NINTH REGULAR MEETING.

October 7th, 1895.

In the Society Rooms, Boston Building.

The President in the Chair.

Twenty-eight persons present.

The election of Mr. W. Weston to membership was announced.

The President announced that the Executive Committee had accepted a cordial invitation to hold the next regular meeting of the Society in the State School of Mines at Golden.

COMMUNICATIONS.—Professor C. S. Palmer read a paper on "The Dike in the Columbia Vein at Ward," being one of a series of papers on the eruptive rocks of Boulder County, Colorado. A discussion followed in which Messrs. Chauvenet and Rickard participated.

Mr. T. A. Rickard then read a paper on "The Walls of Fissure Veins," which was illustrated with numerous diagrams from sketches taken underground in different mines.

Discussion by Messrs. Dwight, Porter, Schwartz, Hills, and van Diest.

ONE HUNDRED AND THIRTIETH REGULAR MEETING.

November 4th, 1895.

In the Auditorium of the State School of Mines, Golden, Colorado.

The First Vice-President in the Chair.

Forty members present.

The First Vice-President requested Professor Chauvenet to take the chair, and the latter opened the exercises with an address of welcome to the visiting members, which was responded to by the Secretary.

COMMUNICATIONS.—Professor H. B. Patton read a paper on "Concretions of Chalcedony and Opal in Obsidian and Rhyolite in Colorado." This was followed by a description of peculiar formations at the head waters of the Rio Grande, illustrated by stereopticon views.

Professor Geo. C. Tilden read some notes taken during the summer while on a mining trip.

After a vote of thanks to the local committee, the meeting adjourned.

ONE HUNDRED AND THIRTY-FIRST REGULAR MEETING.

December 2d, 1895.

In the Society Rooms, Boston Building.

The President in the Chair.

The following names were placed in nomination for officers of the Society for the year 1896. All nominations were duly seconded.

For President . . . . . Regis Chauvenet.
For First Vice-President . . . . . T. A. Rickard.
For Second Vice-President . . . . . F. T. Freeland.
For Recording Secretary . . . . . H. Van F. Furman.
For Corresponding Secretary and Librarian . P. H. van Diest.
For Treasurer . . . . . R. M. Hosea.

For the Executive Committee:

Richard Pearce,	P. H. van Diest,
Irving Hale,	Wm. H. Smiley,
R. C. Hills,	J. A. Porter,
J. B. Farish,	George C. Munson,
J. W. Nesmith,	H. A. Vezin.

The question of having an annual dinner was discussed, and on motion of Professor van Diest, the President appointed a committee of three, consisting of Messrs. Lawrence, Hale and van Diest, with authority to select the day and place for such dinner and to make the necessary arrangements.

COMMUNICATIONS.—Mr. A. S. Dwight exhibited pieces of a so-called meteorite, found at Marks, above Salida, in this State, and gave it as his opinion that it was not a meteorite at all, but a mixture of magnetic iron and zeolite, which has been found elsewhere in eruptive rocks.

He showed also some specimens of arsenious acid occurring in beautiful crystals on copper speiss drawn from a reverberatory furnace at Pueblo. The analysis corresponds to the one given by Dr. Pearce at the September meeting.

Professor van Diest gave an account of a peculiar vein formation observed in the Silent Friend Adit, at Dumont, Clear Creek County, Colorado.

ANNUAL MEETING.

December 16th, 1895.

In the Society Rooms, Boston Building.

The President in the Chair.

Sixteen persons present.

The president announced the election of the following officers:

President,	Regis Chauvenet.
First Vice-President,	T. A. Rickard.
Second Vice-President,	F. T. Freeland.
Recording Secretary,	H. Van F. Furman
Corresponding Secretary and Librarian,	P. H. van Diest.
Treasurer,	R. M. Hosea.

EXECUTIVE COMMITTEE.

Richard Pearce, P. H. van Diest,
J. A. Porter, R. C. Hills,
J. B. Farish.

After the installation of the new officers, Professor Chauvenet made a few well chosen remarks, which were followed by the address of the retiring President, Mr. A. S. Dwight.

After gracefully acknowledging the honor he considered the Society had conferred upon him by electing him President, in a few well chosen words he congratulated it upon having such a zealous and popular Secretary, whose unflagging interest had largely helped to make it the success it was. In addition to his wide scientific knowledge he possessed fine literary ability which had been of great value to the publication committee.

In a general review of the past history of the Society he spoke of its birth under the auspices of the U. S. Geological Survey, and of the high standard set by the early papers presented. He also referred to the great loss to the Society when the members of the Survey removed from the State, and to the duty devolving upon the remaining members to take an active part in the work so well begun.

The advisability of the introduction of papers having a more technical bearing was then discussed, and he stated that an attempt to confine them to pure science and original work practically limited them to the sciences of geology and mineralogy, since original work by those actively engaged in other lines required more time than most of the members could afford to give.

He quoted from President Emmons' original address at the

organization of the Society, showing that its object was not only the publication of original papers, but scientific intercourse of a more general character. Finally he offered the following suggestions as a means of accomplishing the desired end:

First.—The Society should have a committee charged with the duty of securing papers, or speakers, to lead in the discussion of topics of present and general scientific interest. This committee should carry on an active canvass among the members, and solicit communications from them regarding special work of general interest which they may at that time have in hand, or be particularly familiar with. It should have the authority to use discretion in calling upon members to review certain scientific books, and present a general critique for discussion by the Society. In short, it should be charged with the duty of providing a topic for each evening, which, by a wise choice, will bring out the many specialities of the great work all are interested in. It is too much to expect of the Secretary that he should do all this, in addition to his regular duties.

Second.—The practice of holding field days and meetings in various interesting localities in the State should be encouraged, as well as the very delightful annual banquets at which the members meet on another footing, and in lighter vein.

Third.—There should be a standing committee on publication, charged with the duty of passing upon the value of all papers presented for publication in the transactions, and capable of carrying out the critical and routine work necessary for editing the transactions in a creditable manner. It would be well to publish too little rather than too much.

In conclusion, he added that the members should respond, one and all, to the efforts of their officers. True success can only come by each doing his best. As for himself, he carried away a deeper interest in the Society than he ever before possessed, a greater faith in its splendid possibilities, and a determination to prove himself a more worthy and efficient member than he was a President.

Upon motion of Mr. Argall, which was duly seconded and carried, the retiring President was tendered a vote of thanks for his address and services.

ABSTRACT OF MINUTES

FOR THE YEAR 1896.

ONE HUNDRED AND THIRTY-SECOND REGULAR MEETING.

January 6th, 1896.

In the Society Rooms, Boston Building.

The President in the Chair.

Fifteen persons present.

The Secretary announced the election of Messrs. G. K. Gilbert, W. H. Dailey and A. L. Collins to membership.

The annual report of the Treasurer was presented.

The President appointed Messrs. Rickard, Jones and Vezin a committee to audit the treasurer's accounts. He also announced the appointment of the following committee on publications:

H. Van F. Furman. P. H. van Diest.
R. M. Hosea. Irving Hale.
R. C. Hills.

As Curator, the President announced the appointment of Mr. R. C. Hills.

COMMUNICATIONS.—Dr. W. L. Austin read a paper on "The Nickel Deposits Near Riddle's, Oregon," and presented to the Society a number of specimens of ore and rock, illustrating the occurrence of this mineral body. The paper was discussed by Messrs. Argall, Rickard, Chauvenet and others.

ONE HUNDRED AND THIRTY-THIRD REGULAR MEETING.

February 3d, 1896.

In the Society Rooms, Boston Building.

First Vice-President in the Chair.

Ten persons present.

The Auditing Committee, appointed to audit the Treasurer's accounts, reported that they had found the report submitted by the Treasurer to be correct, and on motion the report was approved.

COMMUNICATIONS.—Mr. L. J. W. Jones read a paper on "The Reduction and Determination of Iron," which was generally discussed.

ONE HUNDRED AND THIRTY-FOURTH REGULAR MEETING.

March 2d, 1896.

In the Society Rooms, Boston Building.

Dr. W. L. Austin, Chairman Pro-Tem.

Twelve persons present.

COMMUNICATIONS.—Professor P. H. van Diest made some remarks upon the necessity of accurate surveys in connection with metalliferous mining. He illustrated the point in question by reference to the recent accident on the Americus and Sleepy Hollow mines in Gilpin County. He showed that if these mines had been accurately surveyed, and provided with proper maps, the accident would not in all probability have occurred.

ONE HUNDRED AND THIRTY-FIFTH REGULAR MEETING.

April 6th, 1896.

In the Society Rooms, Boston Building.

The President in the Chair.

Eleven persons present.

The Secretary announced the election by the Executive Committee of Dr. Whitman Cross and Dr. W. F. Hillebrand to honorary membership.

COMMUNICATIONS.—Mr. H. Van F. Furman read a paper on "Pearceite, a Sulpharsenite of Silver," and on "The Crystallization of Polybasite," by Professor S. L. Penfield of the Mineralogical and Petrographical Laboratory, Sheffield Scientific School, Yale College. A general discussion of the paper by Dr. Pearce and others, followed.

It was moved that, as Professor Penfield is not a member of the Society, the Corresponding Secretary be instructed to write him, expressing the thanks of the Society for his paper.

ONE HUNDRED AND THIRTY-SIXTH REGULAR MEETING.

May 4th, 1896.

In the Society Rooms, Boston Building.

The President in the Chair.

Ten persons present.

The election, by the Executive Committee, of Mr. F. P. Mills to membership, and of Mr. J. Harmon, to associate membership, was announced.

COMMUNICATIONS.—Dr. Pearce presented a communication on "The Association of Gold with Pyrrhotite and Chalcopyrite." He exhibited several specimens from Trail Creek, B. C., and also assays and analyses of the same. The conclusion reached from the assays was, that the gold is associated with the chalcopyrite, and the pyrrhotite is practically barren.

Messrs. Austin, Rickard and Chauvenet participated in the discussion which followed.

There was exhibited a specimen of ore from the Black Hills, South Dakota, showing free gold in Trenton limestone, presented to the Society by Professor Jenney.

President Chauvenet brought up the question of the advisability of arranging for exchanges of duplicate specimens belonging to the Society. Messrs. Patton and van Diest were appointed as a committee to arrange for such an exchange of specimens with the State School of Mines.

ONE HUNDRED AND THIRTY-SEVENTH REGULAR MEETING.

June 1st, 1896.

In the Society Rooms, Boston Building.

The President in the Chair.

Twelve persons present.

COMMUNICATIONS.—Professor H. B. Patton read a paper on "The Occurrence of Tourmaline with Gneiss and Schist, on Beacon Hill, Jefferson County, Colo." Discussion by Messrs. Hosea, Rickard and van Diest.

Professor P. H. van Diest presented a paper on "The Geology and Deposition of Gold in South Africa."

In view of the approaching Colorado meeting of the American Institute of Mining Engineers, it was decided to abandon the usual summer outing of the Society, and to extend to the aforesaid Institute the use of the Society's rooms during their meeting in Denver.

The Secretary was instructed to correspond with the Secretary of the said Institute relative to this subject.

The President appointed Messrs. Rickard, Munson and Nesmith to act, in conjunction with the Executive Committee of

the Society, as a committee of entertainments, etc., of the Institute.

ONE HUNDRED AND THIRTY-EIGHTH REGULAR MEETING.

September 7th, 1896.

In the Society Rooms, Boston Building.

Only five members present, the meeting adjourned without transacting any business.

ONE HUNDRED AND THIRTY-NINTH REGULAR MEETING.

October 5th, 1896.

In the Society Rooms, Boston Building.

The President in the Chair.

Twelve persons present.

COMMUNICATIONS.—Dr. Pearce made some remarks on a specimen of covellite, presented to the Society by Mr. C. W. Goodale of Butte, Montana. He also presented some notes on the occurrence of a rich silver and gold mineral containing tellurium, found in the Griffith Lode near Georgetown in this State.

The paper of Dr. Cross on "The San Miguel Igneous Rocks of the Telluride District," was discussed by Messrs. Pearce, Porter, Patton, and Chauvenet.

Some specimens, illustrating the occurrence of ore in the Camp Floyd District, Utah, were presented to the Society by Mr. V. C. Heikes.

The Secretary announced that the Executive Committee had

elected Messrs. F. S. Titsworth, W. C. Davis, E. C. Woodward and H. C. Lay to membership.

ONE HUNDRED AND FORTIETH REGULAR MEETING.

November 2d, 1896.

In the Society Rooms, Boston Building.

Dr. Richard Pearce, Chairman Pro-Tem.

Ten persons present.

COMMUNICATIONS.—Dr. Pearce presented a paper entitled "Notes on the Occurrence of Tellurium in an Oxidized Form in Montana."

A discussion followed in which Messrs. Austin, Kirby and Furman participated.

ONE HUNDRED AND FORTY-FIRST REGULAR MEETING.

December 7th, 1896.

In the Society Rooms, Boston Building.

The President in the Chair.

Seventeen persons present.

The following names were placed in nomination for officers for the ensuing year:

President, ...	W. L. Austin.
First Vice-President, ...	Irving Hale.
Second Vice President, ...	F. Guiterman.
Recording Secretary, ...	L. J. W. Jones.

Corresponding Secretary and Librarian, . . P. H. van Diest.
Treasurer, ... H. A. Vezin.

For members of the Executive Committee:

Richard Pearce,	T. A. Rickard,
P. H. van Diest,	T. B. Schwarz,
B. B. Lawrence,	E. Le Neve Foster,
H. Van F. Furman,	H. B. Patton,
H. E. Wood,	G. C. Munson.
J. A. Porter,	F. Cazin,

J. W. Nesmith.

Mr. R. C. Hills moved that the Secretary notify members that an annual banquet would be held. Motion seconded and carried.

Mr. E. Le Neve Foster read a paper on "An Automatic Recording Water Gauge."

Dr. W. L. Austin presented some "Notes on Boundary Creek and Trail Creek Mining Regions, B. C." A number of samples of ore and rock were exhibited, illustrating the paper, and were afterward presented to the Society.

These papers were discussed by a number of members.

Mr. R. C. Hills presented some notes (illustrated by specimens), on the association of cinnabar with pitchstone at Sulphur Creek, California. A peculiar feature of these deposits is the occurrence of petroleum with the cinnabar and pitchstone.

ANNUAL MEETING.

December 21st, 1896.

In the Society Rooms, Boston Building.

The Retiring President in the Chair.

Election of Officers.

The President appointed two tellers to count the votes re-

ceived by the Secretary in response to a circular sent out by him giving a list of names, put in nomination by the Executive Committee, to be voted on for officers for the ensuing year. Upon receipt of the report of the tellers, the President announced the election of the following officers:

President,	W. L. Austin.
First Vice-President,	Irving Hale.
Second Vice-President,	Franklin Guiterman.
Recording Secretary,	L. J. W. Jones.
Corresponding Secretary and Librarian,	P. H. van Diest.
Treasurer,	Henry A. Vezin.

EXECUTIVE COMMITTEE.

Richard Pearce, P. H. van Diest,
B. B. Lawrence, H. Van F. Furman,
Henry E. Wood.

The new officers being duly installed, and Dr. Austin having, in a few appropriate words, expressed his appreciation of the honor conferred upon him by the Society, Professor Chauvenet delivered his retiring address.

He remarked that precedent allowed him to choose from a wide field of topics, and that he would rather confine himself to the scope of the Society's work than attempt a review of the year in scientific discovery.

The tenor of his remarks was that the membership of the Society having become largely technical, it was thought by many that more attention could be given to papers of strictly practical tendency, without interfering with the purely scientific feature which would continue to be the distinguishing characteristic.

Some outline of scientific history was given, to elucidate the idea of how interdependent the physical sciences must be. Illustrations were also adduced of the frequent errors made by those who had more practical than scientific acquirements, and per contra, of how much the theory of certain lines had been improved through discoveries made in practical applications, some of these being of a nature such that the observations could hardly have been made except in actual practice.

The general deduction was made that the Society could lose

no scientific dignity by admitting and encouraging papers of a practical nature, thus adding to its other functions that of bringing together the sciences and some of their applicate arts.

The speaker closed by predicting that this policy would lead to a more active interest in the meetings and the work.

On motion of Mr. R. C. Hills, seconded by Dr. Pearce, and duly carried, a cordial vote of thanks was tendered the retiring President for his address, and for his able presidency of the Society during the year.

President Austin then appointed the following committees:

PUBLICATION COMMITTEE.

R. C. Hills. P. H. van Diest.
H. Van F. Furman. L. J. W. Jones.

AUDITING COMMITTEE.

T. B. Schwarz. H. B. Patton.

COMMITTEE ON ANNUAL DINNER.

P. H. van Diest. Irving Hale. Harold Pearce.

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ABSTRACT OF MINUTES

FOR THE YEAR 1894.

ONE HUNDRED AND NINTH REGULAR MEETING.

January 8th, 1894.

In the Society Rooms, High School Building.

The President in the Chair.

Thirty-eight persons were present.

Mr. G. H. Ad. Koch was elected to membership.

The President appointed Messrs. H. V. Pearce and F. Guiterman on committee to audit the accounts of the Treasurer.

COMMUNICATIONS.—Dr. Richard Pearce read a paper on the "Nature of the Gold in Cripple Creek Ores." Discussed by Professor Chas. S. Palmer and Professor H. van F. Furman.

Professor Palmer called attention to an extremely delicate test for tellurium, which consisted in treating an ore supposed to contain this element with copper foil and sulphuric acid, when the tellurium gives a deep carmine red color.

Professor Furman mentioned the peculiar characteristics of some gold bullion coming to the U. S. Mint at Denver from the stamp mills at Cripple Creek. Even after refining, this gold shows a peculiar crystalline structure and is of a brittle nature. This he attributed to small quantities of tellurium remaining with the gold.

Dr. Pearce thought Professor Furman's hypothesis not an unlikely one, and said that it might be a parallel case to the action of minute quantities of arsenic, which, when alloyed with gold, also causes it to become brittle.

REPORT OF LIBRARIAN FOR THE YEAR 1896.

During the year 1896 the number of complete volumes, standworks, and reference books was increased by 57. The total number indexed at the end of the year is 1,760. This does not include periodicals nor publications of societies and institutions which were acquired by exchange during the year. Our exchange list included at end of year 106 societies and institutions, an increase of two during the year. The number of periodicals subscribed for was reduced in 1896 from sixteen to fourteen, covering seven branches of science.

REPORT OF RECORDING SECRETARY FOR THE YEAR 1896.

MEMBERSHIP. At the beginning of 1896 the Society had 135 members and 18 associate members. At the close of 1896 the Society has 140 members and 17 associate members; a gain of 4 during the year. Eight members and one associate member were elected during the year. One member died, and four members and associates resigned.

MEETINGS. Eleven meetings, including the annual meeting, were held during the year. In consequence of the meeting of the American Institute of Mining Engineers in Colorado during September, no summer meetings were held. All the meetings were held at the rooms of the Society in Denver. The total number present at the meetings of the year was 133.

PAPERS PRESENTED. Fifteen papers were presented during the year, of which ten have been printed and distributed, the other five papers being informal communications were not printed.

H. VAN F. FURMAN,
Recording Secretary.

REPORT OF TREASURER.

DENVER, COLO., December 31, 1896.

TO THE COLORADO SCIENTIFIC SOCIETY,
L. J. W. JONES, Secretary.

DEAR SIR: With this I hand you my report as Treasurer of the Society for the year 1896.

DR.

Balance January 1, 1896	$ 528.01	
Received from dues of members	1,299.95	
Received from sales of Proceedings	29.70	
		$1,857.66

CR.

Rent of rooms 119-124	$ 600.00	
Services Miss Thornburgh, Librarian	183.00	
Subscriptions to Journals and other Library expenses	106.07	
Printing and publications	197.50	
Postage and incidentals	65.59	
Due from P. H. van Diest, Corres. Secretary	2.58	
Due from R. M. Hosea, Treasurer	.20	
Balance in Denver National Bank	702.72	
		$1,857.66

Yours truly,
R. M. HOSEA, Treasurer.

I have delivered balance to the Treasurer-elect, Mr. Henry A. Vezin, with all papers, books, etc., appertaining to the office.

January 1, 1896.

The undersigned have audited the above account and the books of the Treasurer, R. M. Hosea, and find the same correct.

T. E. SCHWARZ.
HORACE B. PATTEN.

THE MODE OF OCCURRENCE OF GOLD IN THE ORES OF THE CRIPPLE CREEK DISTRICT.

By Dr. Richard Pearce, Denver, Colo.

Meeting of January 8, 1894.

About two years ago, soon after the discovery of gold at Cripple Creek, some experiments were undertaken by the writer, with a view of following up some investigations on the association of gold with other metals in the west, the results of which were published in the "Transactions of the American Institute of Mining Engineers."*

The experiments on the Cripple Creek material were at first limited to ores as they were received at the works of the Boston & Colorado Smelting Company of Denver. At the time, the prevailing opinion was that the gold of this district was associated with tellurium, and the following plan, adopted also on a previous occasion, was employed to test the truth of this theory.

The ore was concentrated by vanning, all the gangue and waste matter rejected, and only the very small quantity of heavy mineral, which had resisted oxidation, reserved for examination, with the result that a careful test of the concentrated product demonstrated the entire absence of tellurium.

One particular experiment, however, was attended with very striking results. A lot of so-called concentrates, which were evidently derived from some sort of amalgamating process since the presence of quicksilver was subsequently detected in them, was vanned. The resulting concentrates were found to represent an extremely small percentage of the total quantity treated, probably not more than one-quarter of one per cent. This product consisted of what appeared to be iron pyrites, in which an examination under the microscope failed to show any free gold. On

* Presidential address, Washington meeting, February, 1890.

treating the concentrates with nitric acid, an abundance of gold was separated in a brown, spongy condition, resembling in every respect that obtained by parting an alloy of gold and silver. No evidence of tellurium, bismuth, or any metal which could occur in combination with the gold was found, and the writer was in consequence led to believe that the gold existed as a *sulphide*.

In the summer of 1892 the matter was referred to Prof. Clarke and Dr. Hillebrand of the U. S. Geological Survey at Washington, with the hope that they would be able to continue the research, but nothing was done. Since that time the Cripple Creek mines have been steadily developed, and, owing to the greater variety of ore produced, the hope was entertained that some positive conclusion as to the original combination of the gold could now be reached. With this idea in view the investigation was resumed within the last few months, and the result forms the subject of this communication.

No opportunity has been afforded the writer of studying the peculiar geological conditions which exist at Cripple Creek, but at some future date Dr. Whitman Cross has promised to present a paper to the Society on this very interesting subject.

The Cripple Creek Ore.

The Auriferous Portion.—The ore as shipped in bulk from Cripple Creek has all the appearance of rhyolite, and reminds one very forcibly of the peculiar features which characterized the silver deposits of Silver Cliff, Colorado. The ore from that locality was a rhyolite, having its joints and fracture planes filled with psilomelane, carrying cerargyrite in sufficient quantities to warrant its being worked on an extensive scale for the silver it contained.

The Cripple Creek ores have similar characteristics; small quantities of psilomelane line the joints of the rock, but are associated in this case with gold instead of silver.

The material on which the investigations were renewed, came from the "Garfield Grouse" mine, and was kindly furnished by Mr. Franklin Guiterman. It consisted of lumps of rhyolite, one or two of which were coated with quartz crystals, accompanied by clay and psilomelane, the latter occurring in small rounded or botryoidal concretions characteristic of this mineral. The rest of

the sample, forming about 25 per cent. of the whole, was a soft clayey material, enclosing lumps of softened rhyolite, which could easily be rubbed down by the hand to an unctuous, clayey mass.

To discover in which portion of the rock the gold existed, the sample was carefully washed, and the loose material separated with a soft brush. This loose material was then rubbed down by the hand, and vanned on the shovel. Several pieces of free gold were found, one or two of which exhibited a peculiar brownish color; they were extremely brittle, being easily broken by a very slight pressure with the point of a penknife. The gold also exhibited a decided crystalline character, or rather appeared in elongated plate-like forms which had slightly grooved surfaces, and bore altogether a striking analogy to the habits of sylvanite, from which the inference was drawn that they might be pseudomorphs after that mineral. On the basis of this supposition the conclusion was reached that in the soft clayey portion of the ore, tellurium would be found in an *oxidized* form. The clayey matter yielded readily to friction on the vanning shovel in contact with water, and in it some pieces of gold were found associated with quartz and psilomelane, with the same peculiar characteristics observed in the former case.

The fine clayey product separated in vanning was thrown on a filter, and after draining and drying, was digested with hydrochloric acid—which acts on oxidized tellurium compounds but not on tellurides—with the result that a well-defined quantity of the suspected element was shown to be present. This would seem to prove conclusively that the free gold which was present in considable quantity, was obtained from a former combination with tellurium by alteration, and it seems almost certain that the original tellurium compound was the mineral *sylvanite*.

An attempt was made to determine the amount of tellurium in the oxidized form in two samples of rich gold ore from the "Prince Albert" and "Independence" mines of Cripple Creek. These samples represented in each case lots of about 20 tons; the "Prince Albert" ore contained 7 ounces of gold per ton, and the "Independence," 9 ounces. In each case 50 grammes of the sample were taken and treated with hydrochloric acid and filtered. To the clear solution stannous chloride was added, and an abundant

precipitate of metallic tellurium was obtained. The "Prince Albert" ore was found to contain 0·14 per cent. of tellurium, and the "Independence," 0·17 per cent.

In support of the theory that the gold was derived from sylvanite a comparison is drawn between the ratio of gold to silver in their telluride minerals, and that which exists in the Cripple Creek ores:

In the crystalline sylvanite the ratio of gold to silver is.....27:11
In massive calaverite 40:3
And in krennerite 35:5

The results of sampling a great many tons of Cripple Creek ore show that the relation of the gold to the silver more nearly approaches the ratio which exists in sylvanite than in calaverite or krennerite.

The following figures, showing the relative proportions of gold and tellurium in three samples of the oxidized material, will, however, prove the existence of a large *excess* of tellurium over the amount required to have originally formed sylvanite:

The ratio of gold to tellurium in sylvanite is as .....1:2·454
In the "Prince Albert" ore, sample No. 1, the ratio of gold to tellurium was as.....1:5·833
In the "Independence" ore, sample No. 1, the ratio of gold to tellurium was as.....1:5·519
In the "Prince Albert" ore, sample No. 2, the ratio of gold to tellurium was as.....1:4·385

This excess of tellurium can only be accounted for, either by supposing that other tellurium minerals were present (probably native tellurium), or that a portion of the gold originally combined with it had been removed.

About the time the experiments which have been enumerated were being made, specimens coming from a greater depth were furnished by Mr. T. A. Rickard which exhibited all the stages of transition from the mineral sylvanite, to pure gold with tellurium in an oxidized state. This free gold appears in a remarkable condition. It is very much like gold which has been precipitated and allowed to dry, being quite soft, and yielding readily to pressure with a knife. Associated with the gold is a soft, yellow incrustation containing strong evidence of the presence of tellurium in an oxidized form. In several pieces the free gold again

showed distinctly the habit of sylvanite, of which mineral there were pseudomorphic impressions in a matrix of granular fluorite, the gangue being a metamorphosed rhyolite.

It may here be noted that pseudomorphs of gold after sylvanite were long ago observed by the writer in a specimen from one of the Boulder mines and mentioned in a paper read before the Society.*

Sylvanite itself appeared in the Cripple Creek ore in little silver-white specks, disseminated through a mass of greenish rhyolite, accompanied by amethystine fluorite. A similar occurrence of sylvanite associated with fluorite was encountered some years ago in the tellurium belt of the Boulder district, notably in the "John Jay" and "Melvina" mines, and this recurrence of the same peculiar association suggests some intimate connection between fluorine and gold.

The Gangue.—The rock gangue accompanying the ores of Cripple Creek which were subjected to examination, was apparently of two kinds, the white and the green. The former is exemplified in the "Garfield-Grouse" mine, and the latter in the deep workings of the "Anaconda."

The following analysis by Mr. F. C. Knight will show the most important constituents of the two rocks:

	White Rock.	*Green Rock.*
SiO_2	61·25	56·30
Al_2O_3	18·30	19·45
FeS_2		6·90
MgO	2·23	1·33
Alkalies	Undt	Undt.

The metamorphosed rhyolite coming from below the zone of oxidation in the "Anaconda" probably owes its peculiar greenish color to the presence of iron in a ferrous condition.

In the "Garfield-Grouse" mine the ore is mainly the white rock which in itself is quite barren, or nearly so, but the joints of which are filled with high-grade auriferous material. Some

* Proc. of the Colo. Sci. Soc., Jan. 7, 1885. "The occurrence of native gold in distinct pseudomorphs after sylvanite, in Boulder County, would indicate that native gold may in some cases have been derived from the alteration of auriferous tellurides, and I have reason to believe that some of the beautiful specimens of native gold which I have seen from the Cable mine, Montana, are the result of the alteration of nagyagite, for we find this mineral associated with the gold, and in many cases showing strong evidence of decomposition."

idea of the richness of the latter may be had when it is stated that the lot of ore in bulk which furnished the samples on which the foregoing experiments were made carried 75 ounces of gold per ton.

The greenish metamorphosed rock from the "Anaconda," in which the mineral sylvanite was observed, assayed 12 ounces of gold per ton. It is a significant fact that the green color of the metamorphosed rhyolite from below the zone of oxidation has its counterpart in the Boulder mines.

Solution and Reprecipitation. – Attention has already been drawn to the fact that the quantity of tellurium existing in an oxidized form in the ores of the "Prince Albert" and "Independence" mines, was in excess of that required to combine with the available gold to form sylvanite. Two explanations are suggested, one being the possible existence of native tellurium, and the other, the solution and removal of a portion of the gold, and its reprecipitation at some other point.

This latter theory seems not at all an unlikely one. The presence of bin-oxide of manganese together with solutions containing alkaline chlorides and sulphuric acid, derived from the decomposition of the pyrite, would effect the removal of finely divided and precipitated gold, by means of the chlorine generated.

Origin of the Deposits.—As to the origin of the Cripple Creek deposits, it may reasonably be inferred that they were caused by solutions brought up from below through the joints or lines of least resistance, the gold being, at the time, associated with silica and fluorine.

These circulating solutions effected a marked chemical change in the rocks through which they percolated. In some cases the alteration can hardly be traced beyond the surface, as in the white rock of the "Garfield-Grouse" mine. In others, as in the "Anaconda," the whole mass of rock became impregnated with pyrite and sylvanite, resulting in its partial metamorphism.

As the Cripple Creek mines are explored to greater depths, remote from the zone of oxidation, it is not unreasonable to expect that the economic treatment of the ores by methods other than smelting, will offer greater difficulties than at present exist, on account of the association of the gold with tellurium as telluride.

Specimen from the Moose Mine, Cripple Creek.

FURTHER NOTES ON CRIPPLE CREEK ORES.

By Dr. Richard Pearce, Denver, Colo.

Meeting of April 2, 1894.

Since the presentation, some two months ago, of a short paper on "The Mode of Occurrence of Gold in the Ores of the Cripple Creek District," further investigations have been made, and as the results of recent developments may prove of interest to the members of the Society, they form the subject of the present communication.

A number of experiments have been made at various times with a view to determining the existence of tellurium in oxidized Cripple Creek ores; the results have fully confirmed the theory advanced in the last paper on this subject, and tend to prove that the free gold has been mainly derived from the oxidation of tellurides, the tellurium being still present in the ore in an oxidized form.

The presence of gold in these oxidized ores may be indirectly determined by a very simple and reliable test for tellurium since it has been found that the two are invariably associated with each other; the quantity of the gold may also be roughly estimated by the amount of tellurium indicated by the test.

To make this determination 50 grammes of the fine pulp are treated with dilute hydrochloric acid, consisting of equal parts of acid and water. This mixture is heated to boiling, filtered, and to the filtrate is added a solution of stannous chloride. The tellurium, if present, will immediately be precipitated in a black flocculent form as metallic tellurium. If its quantity is small it is best to heat the solution, which aids the separation. It must, however, be remembered that this test is only applicable to ores which contain the tellurium in an oxidized form, and is of no value in other cases.

Sometimes it happens that the tellurium is found existing in both the oxidized and unoxidized form in the same rock, and a most interesting example of this phenomenon is furnished by a specimen from the "Moose" mine at Cripple Creek, which forms the subject of the present remarks.

The accompanying plate is a reproduction of a drawing of this specimen which was kindly made by Mr. Stephen Rickard. The rock which, until its petrographical character is specifically determined may be called rhyolite, clearly shows the changes which have been brought about by the action of circulating oxidizing waters. A portion of the specimen (A) has retained its characteristic dove color, whilst the larger part (B) has been discolored and has assumed a brown tint, being permeated by a number of tiny little veinlets which are filled with peroxide of manganese.

Mr. F. C. Knight has furnished two analyses of this specimen, one taken from the oxidized, and the other from the unoxidized portion of the rock. There is a well defined jointed structure to the specimen, three joints being very clearly marked. The material selected for analysis was taken from a section drawn clear across the two different portions.

It may be well to state that the alkalies were determined by difference, as it was only thought necessary to investigate in a general way the composition of the rock with regard to certain changes produced by impregnation and subsequent alteration.

ANALYSES.

Unoxidized Portion.		*Oxidized Portion.*	
SiO_2	56·70	SiO_2	50·55
Al_2O_3	19·35 (1·55 sol in HCl.)	Al_2O_3	19·93 (3·18 sol in HCl.)
K_2O, Na_2O	13·967	K_2O, Na_2O	12·131
Fe	4·20	Fe_2O_3	10·57 = Fe 7·39
S	4·75	SO_3	2·55 = S 1·02
MgO	0·37	MgO	0·12
Te	0·10	Au	0·049 = 14·58 oz.
Au	0·041 = 12·24 oz. per ton.	TeO	0·79
Ag	0·022 = 6·7 oz. per ton.	MnO_2	0·27
H_2O	0·50	H_2O	3·05
	100·000		100·000

It was found that the portion soluble in acids constituted 11 per cent. of the total in the unoxidized, and 17·58 per cent. in the oxidized rock. The soluble Al_2O_3 in the first instance was 1·55 per cent, and in the second 3·18 per cent. If we deduct these from the insoluble Al_2O_3, we get the following percentages:

	Unoxidized.	*Oxidized.*
SiO_2	56·70	50·55
Al_2O_3	17·80	16·75
K_2O, Na_2O	13·77	12·18
	88.27	79·48

These figures calculated to a basis of 100, would give the relative composition of the normal rock:

	Unoxidized.	*Oxidized.*
SiO_2	64·23	63·72
Al_2O_3	20·17	21·07
K_2O, Na_2O	15·60	15·21
	100·00	100·00

The unoxidized rock may be said to consist of 88·27 of normal rock with 11·73 of FeS_2, together with sylvanite, or some other gold telluride, and the oxidized rock of 79·48 of normal rock, with 20·52 of a mixture of basic sulphate of sesquioxide of iron, alumina, peroxide of manganese and tellurous oxide.

If we suppose that the sesquioxide of iron exists as a hydrated basic sulphate, we find that the proportion found in the analysis compares very closely with that of the mineral "glockerite," whose formula is $2Fe_2O_3SO_3+6H_2O$. This requires:

Fe_2O_3 10·57, SO_3 2·63, H_2O 3·57, while we actually find Fe_2O_3 10·57, SO_3 2·55, H_2O 3·05.

Dana says, in his "System of Mineralogy," that this mineral is frequently found as a result of decomposition of pyrite and marcasite, hence we may reasonably infer that some compound similar to glockerite occurs in the oxidized portion of the Cripple Creek specimen, as a result of decomposition of the pyrite which it originally contained, and which we still find existing in the unoxidized part of the rock.

It may be noted that the percentage of iron in the oxidized

rock is larger than that found in the unoxidized part, but that the percentage of sulphur, existing in the former as SO_3, is very much smaller than that contained in the unoxidized ore. From this it seems probable that a portion of the sulphur, in the alteration of FeS_2 into basic sesquisulphate, has been removed in the form of SO_3, and this has perhaps played some part in changing the structure, and to some extent the general physical character of the rock.

The specimen shows no indication whatever, to the naked eye, of the existence of free gold, except in one or two of the small cracks or joints running at right angles to the main joints of the rock, and in this case the gold occurs in the form of a soft brownish deposit, similar to that observed in the "Anaconda" specimen described in a former paper. It affords a most interesting and instructive example of the impregnation of a rock with iron pyrites and tellurium gold minerals forming a mineralized band or zone of high-grade gold ore.

The following is the ratio between the gold, silver and tellurium in the two portions of the rock. The unoxidized part gave by careful assay 12·24 oz. Au., 6·7 oz. Ag., 0·10 per cent Te. The oxidized portion gave: 14·58 oz. Au., no Ag., 0·69 per cent. Te.

Calculated to a basis of 100 we get the following ratio:

	Unoxidized.	*Oxidized.*
Au	25·45	7·00
Ag	13·94	none.
Te	60·61	93·00
	100·00	100·00

or a ratio in the former of rather more than twice as much tellurium as gold, and about twice as much gold as silver, and in the latter about thirteen times as much tellurium as gold, showing a very large increase in tellurium, and the entire removal of the silver. The presence of sesquisulphate of iron may possibly account for the disappearance of the latter metal, and to a certain extent for the solution and redeposition of the gold, since it is a well known fact that both gold and silver are readily soluble in this salt.

The analysis of the unoxidized rock would indicate that the

telluride mineral is sylvanite, whose composition compares very closely with the results given above. Dr. Genth gives the analysis of sylvanite from the "Red Cloud" mine, Boulder, Colorado, as follows, showing a very close resemblance to the analysis of the unoxidized Cripple Creek ore.

	Red Cloud.	*Cripple Creek.*
Te	59·78	60·61
Au	26·36	25·45
Ag	13·86	13·94
	100·00	100·00

The sylvanite in the "Moose" mine ore is present in a very finely divided form in close association with pyrite, and no evidence of its existence can be discovered, even with the aid of a pocket lens.

A study of this particular gold bearing rock would lead one to the conclusion that it was first impregnated with pyrite and sylvanite by means of highly sulphuretted waters circulating through its natural joints; at a later period the effect of surface waters would be to promote the oxidation of the pyrite into basic sulphate of iron, and the tellurium into its oxide, whilst additional iron and manganese may also have been introduced in solution, probably in carbonated waters, thus giving rise to the phenomena we have been considering.

Although not bearing directly upon the subject of this paper as far as the actual locality is concerned, it may yet be of interest to note that tellurium in an oxidized form has recently been found in surface oxidized ores both from the "Frontinac" mine in Gilpin County, and the "Gem" mine in Clear Creek County; and while the existence of tellurium in small quantities in two or three of the mines of Gilpin County has been pointed out before by the writer, it was not supposed to exist so generally as now seems probable, for the previous investigations were limited to the heavier mineral or concentrates produced by vanning, the oxidized portion being rejected. It would appear, however, that in oxidized ores the tellurium should only be looked for in the oxidized portion, and not in the undecomposed unoxidized pyrite.

The oxidized Leadville deposits which contain gold, would

form a most valuable material for further investigation into this most interesting subject, since tellurium is found to be present in nearly all the sulphides of that district, and the general conclusion to which recent discoveries would seem to lead us, is that this metal is far more generally distributed in ores than has hitherto been supposed.

Specimen from the Moose Mine, Cripple Creek.

THE SANITARY CHEMICAL CHARACTER OF SOME OF THE ARTESIAN WATERS OF DENVER.

By Prof. Wm. C. Strong, Denver, Colo.

Meeting of May 7, 1894.

History.

The artesian waters of the Denver Basin were discovered in the spring of 1883. Their softness and purity at once excited wide-spread interest. On March 3, 1884, a committee of six was appointed by the Colorado Scientific Society to investigate the artesian wells of Denver and vicinity; and on June 2, of the same year, the report of the committee was presented in four sections, as follows:

I. "Geological Relations," by Prof. Whitman Cross.
II. "Data Concerning the Wells," by Frederick F. Chisholm.
III. "Chemistry of the Wells," by Prof. Regis Chauvenet.
IV. "General Information," by P. H. van Diest.

March 1, 1886, additional notes on the same subject were presented to the Society by Prof. Whitman Cross and Charles G. Slack. A number of facts gathered from these valuable reports are summarized by the writer, because of their bearing on the work he has undertaken.

Summary.

The Denver artesian wells are sunk through the Denver Tertiary beds into the Laramie formation, which is regarded as transitional between the Cretaceous and the Tertiary. The Tertiary beds under the city of Denver have been mostly removed by denudation, having a thickness in the vicinity of Larimer Street of about fifty feet; while the Laramie underlying has a total thickness of 1500 feet or more.

The depth of the artesian wells varies from 250 to 1,000 feet, the average depth being about 600 feet. The shallower wells cut fewer water-bearing strata, and afford a less abundant water supply. Water from the deeper flows appears to contain more mineral matter, and, on that account, is less useful for many purposes. The water flows are from beds of sand, which have a thickness of from one to six feet. Between these sand beds are sandstones and clays, exhibiting strong tendencies to cross lamination, so that there appears to be but little regularity of superposition in the strata pierced by the wells, even when these are near one another. All the wells manifest a connection underground with one another by their sympathetic variations of pressure, though this connection is less evident in wells some distance apart. Nearly all the wells within the city proper have ceased to be free flowing, while some upon much higher land a few miles away flow about as freely as ever. The artesian waters have their origin along the borders of the Denver Basin, being supplied by the rains and snows which fall upon the upturned edges of the Laramie strata, and by streams and ditch waters flowing over them. A large part must enter the rocks along the skirts of the foot hills, though some may find entrance on the south and east sides of the Basin. They have a natural outlet over the lowest part of the rim of the Basin northeast of the city of Denver, in the vicinity of Platteville.

The chemical examination, made ten years ago, of the waters from three of these wells, shows a striking similarity in the mineral constituents of the two shallower wells, and a striking difference from these two, in the 900-foot flow of the Court House well. In the former cases, sodium carbonate made up 80 per cent. of the residue on evaporation; while in the latter case, along with a larger amount of sodium carbonate, was a nearly equal amount of sodium chloride. No attempt was made to estimate the amount of organic matter or gaseous constituents, so that comparisons from a sanitary standpoint are impossible.

Sanitary Chemical Investigation.

About a year ago the writer formed a plan to make sanitary chemical examination of all the different kinds of water supplied to the city of Denver and suburbs. It is needless, perhaps, to say

that he has not yet gone very far in the execution of this plan. The artesian waters came in as a part of the field to be investigated, and the information gained from them forms the basis of the present paper. He hopes at a future date to present another paper on other parts of the subject.

The choice of wells for examination was made to cover a wide area and several depths. The most northerly ones are those at the Globe and Argo smelters; the most southerly ones, at Osner's and Diamond Joe ranches, a mile south of University Park. The shallowest one is that of the Denver Brewing Co., 350 feet; and the deepest, Caraco's at Colfax and Twelfth streets, 1,000 feet. Some regard has been had to the distribution of the wells, and also to the quality of the boring and casing.

Sanitary Analyses of Artesian Waters.

The following table gives the results of the analyses. The numbers express parts per 100,000, with the exception of hardness, which is on Clark's scale.

Source.	Residue on Evaporation.	Chlorine.	Free Ammonia.	Albumen-Ammonia.	Nitrates.	Hardness.	Depth of Wells, etc.
Globe Smelter.....	23·0	·54	·0234	·0058	·020	1·7	600 feet.
Argo Smelter.....	22·4	·45	·0306	·0052	·015	1·9	600 feet.
Zang Brewery	22·0	·85	·0120	·0026	·050	2·5	666 feet.
" "	24·2	·56	·0112	·0012	·025	2·3	500 feet.
Denver Brewing Co. .	19·5	·60	·0244	·0018	·100	2·3	350 feet.
Daniels & Fisher	17·0	·54	·0205	·0066	·050	2·3	575 feet.
Windsor Hotel	24·0	·10	·0242	·0046	·025	2·3	515 feet.*
Caraco's.....	(34·2)	(2·10)	·0148	·0082	·045	2·2	1000 feet.
Court House	(62·0)	(15·80)	(·0638)	·0056	·080	(4·5)	900 feet.
Diamond Joe Ranch .	21·0	·50	·0150	·0054	·055	2·2	700 feet.
Osner's Ranch.....	22·5	·45	·0212	·0046	·030	3·0	700 feet.
Means	21·7	·51	·0197	·0047	·045	2·3	
Goose Creek.....	6·4	·33	·0014	·0142	·030	2·5	So. Park.

Results in parentheses not included in means. *Two flows.

For the sake of comparison, the analysis of water from Goose Creek, South Park, is appended, as being an example of pure mountain water, strikingly similar to the best surface waters of New England. There are considerable errors in the analyses because the quantities determined are so small. The nitrates present peculiar difficulties, and even the accurate determination of the chlorine in the artesian waters is no simple matter.*

RESULTS.

The Court House and Caraco wells are much deeper than any of the others, and the peculiarity of their waters is very marked, especially in the amount of chlorine. The other waters display a striking similarity in their sanitary characters, differing in no great degree between depths of 350 and 700 feet. They are somewhat affected by the local character of the sources from which they are derived, or by the rocks through which they flow. Still, there is evidently considerable mixing in the earth and more or

*METHODS OF ANALYSIS.—The methods of analysis were substantially the same as those employed by the Mass. Board of Health at their laboratory in the Institute of Technology, and at their Lawrence Experiment Station. Details will be found in their "Report on Water Supplies," page 519; and in "Purification of Sewage and Water," page 710. It will perhaps be sufficient to note departures from the above-mentioned methods.

In the determination of residue on evaporation, it was frequently necessary to use duplicate apparatus; therefore, light porcelain evaporating dishes glazed all over and entirely new were employed instead of the very expensive platinum.

The chlorine was determined by direct titration with standard silver nitrate solution. This gives, in the artesian waters, the chlorine a little too high. Previous evaporation, if carefully made, would give more accurate results.

In distilling for the ammonias, four tubes of 50cc each were obtained for the free, and three for the albuminoid ammonia, for very obvious reasons. Fractional parts of the tubes containing the first of the free ammonia distillate were always taken to avoid the large errors which would arise from the direct nesslerization of tubes high in ammonia.

Laborious investigation was undertaken to determine the accuracy of the methods for nitrates, which investigation is not yet completed and may be the subject of a future communication. The method appears to work well on standard solutions; but on waters as low in nitrates as the artesian waters of Denver, it is inaccurate, (1) because it is impossible to nesslerize with precision; (2) because multiplication factors must be used in reducing results obtained to parts per 100,000 and also in converting ammonia to nitrates, by which factors all errors are multiplied. Greater accuracy, it seems to the writer, would be insured by using at least 250cc of the water, and then distilling the product after the manner of a free ammonia determination.

Clark's soap solution for the determination of hardness deteriorates with age. No attempt was made to make or keep it at a standard. Its true strength was frequently determined by comparison with a standard solution of calcium chloride, and final results were obtained by calculation.

Too much importance can hardly be attached to having distilled water and important chemicals pure, and apparatus clean. Correct ammonia determination cannot be made in a laboratory where ammonia is in use.

less communication between wells—a conclusion first established by their sympathetic pressure, and now confirmed by chemical analysis.

The residue on evaporation is large, as might be expected of ground waters, though much less than the average of the public supplies of Denver. The Court House well being excepted, which has much sodium chloride, the greater part of this residue is sodium carbonate. The amount of organic matter is quite small.

The chlorine content is insignificant in comparison with that of the public supplies of Denver from the Platte and Cherry Creek, which ranges from about 2·5 to 5·0 according to season, etc. The high chlorine of the Court House and Caraco wells seems to indicate saline beds at the depth of 900 to 1,000 feet. The very low chlorine (·10) of the Windsor Hotel well—lower than that of any other artesian water examined by the writer—is a curious paradox, for which no explanation can be offered. This determination of chlorine for the Windsor well agrees substantially with the one made by Prof. Chauvenet ten years ago. Nearly equally low chlorine was found by him, at that time, in the Anderson well, which is now abandoned. The water from the Windsor well does not exhibit any other marked peculiarity.

Organic Matter.—It is necessary to distinguish sharply between the organic matter of a potable water and the products of decay. The usual indicator of the organic matter is the albuminoid ammonia. The products of decay are water, carbon dioxide, marsh gas and ammonia salts; the last only is shown in sanitary analyses by the free ammonia. The ammonia salts, by further oxidation, give rise to the nitrites and nitrates. All these products of decay may be absorbed by plants and animals and thus return to the form of organic matter. The amount of organic matter in the artesian waters is quite small, though the products of its decay are abundant.

The albuminoid ammonia is very low, averaging less than half that of Goose Creek and perhaps a third of that obtained from the public water supplies of Denver. It varies widely in different wells, but is in all far below what may be considered a normal, and, therefore, furnishes no sanitary choice between waters of different wells. No microscopic investigation has been made, but

it is hardly reasonable to expect any organic matter in living forms.

The free or saline ammonia is surprisingly abundant in all the wells, ranging from ·0112 at the Zang Brewery to ·0638 at the Court House. It averages nearly fourteen times as abundant as in the water of Goose Creek, and one-fourth as abundant as in that of the Platte at Mississippi street, in times of worst pollution. Such an amount of free ammonia in a surface water, in connection with high chlorine, would be regarded as *prima facie* evidence of grossest sewage contamination. But the chlorine present is very low, and pollution from the surface of the earth is evidently impossible; the high free ammonia, must, therefore, be the result of peculiar conditions, which will be discussed further on.

The nitrites are, in the opinion of the writer, entirely absent, though some doubt has arisen on account of the appearance of nitrites in the water after exposure to the air. Water from the well of the Argo Smelter, exposed to the air and then left to stand for two weeks in a corked bottle in a warm place, developed the unprecedented amount of 400 parts of nitrites per billion. Such an excess of nitrites is rarely found in water or even in sewage. The source of the agent of nitrification is an open question.

The nitrates are present in large measure as compared with the water of Goose Creek or those of New England, though lower than the average of the public supplies of Denver. High nitrates are characteristic of most of the waters of this region. In the artesian wells, they are far less abundant than would be expected in view of the large amount of free ammonia present. Evidently the ammonia salts have reached the nitrate stage only to a very limited extent.

Oxygen appears to be entirely absent in all cases. This is inferred from the abundance of oxidizable material present, but has not been proved by direct experiment.

The hardness is slight, averaging 2·3, which is nearly the same as that of Goose Creek water. The hardness of the public supplies of Denver varies from about eight to twenty according to source and season. The softness of the artesian waters is not due to the absence of mineral matters which are abundant, but to the presence of sodium carbonate which precipitates the salts of lime and magnesia.

To sum up, high mineral matter, very high free ammonia, and high nitrates; low chlorine and low organic matter; the absence of nitrites and oxygen; and the softness of the Denver artesian waters are their chief sanitary characteristics.

Conditions.

The absence of oxygen, the high free ammonia, and the formation of nitrites on exposure of water to the air are correlated facts, which are explained by the conditions. The waters have doubtless entered the Laramie rocks along the borders of the Denver Basin, conveying organic matter in suspension; they have taken up more organic matter and decomposition products from the rocks along their course in the earth. The oxygen supply being limited to the original content of the waters, the process of nitrogenous decay has been arrested at the ammonia stage, and possibly, in addition, nitrites have been reduced to ammonia. In other words, these waters have been bottled up for a long time in the earth, and the natural purification by oxidation has been arrested or modified. Evidently they need aeration to remove the disagreeable flatness of taste sometimes complained of, and to fit them more perfectly for domestic and industrial use.

Purity.

In point of purity, the Denver artesian waters can not be considered as greatly superior to the best of the public supplies, though considerably better than the average. From the standpoint of sanitary chemical analysis, the claim of surpassing purity sometimes made for them is not sustained. From the standpoint of bacteriology, they are, in the opinion of the writer, unexceptionable; for it is difficult to believe that they can contain any living germs of disease, their long residence in the earth being doubtless fatal to all pathogenic organisms.

GEOLOGY OF THE CRIPPLE CREEK GOLD MINING DISTRICT, COLORADO.*

By Whitman Cross, Ph.D.

U. S. Geol. Sur., Washington, D. C.

Meeting of June 4, 1894.

Introduction.

The following sketch must be considered as preliminary in so far as references to the detailed geology of the Cripple Creek district are concerned. It is based upon field work of the summer of 1893, upon the Pike's Peak atlas sheet of the geological map of the United States. This sheet is on the scale of 1:125000, nearly two miles to the inch, and covers an area of 930 square miles, being bounded by the meridians 105° and 105° 30′, and the parallels of 38° 30′ and 39°. Pike's Peak is situated in the northeastern portion of the area, and the mining district proper lies some ten miles to the southwest of the peak, in the center of the eastern half of the map area.

It is intended, however, to undertake a detailed examination in the mining district during the coming summer. The basis for this work will be a topographic map on the scale of about two inches to the mile, with a 50-foot contour interval. The general geological investigation will be carried on by the writer, and the study of the ore-deposits and the phenomena of their formation will be in charge of Professor R. A. F. Penrose, Jr., of Chicago University.

The mining district embraces an area about six miles square. The peculiarities of local geology are very marked, and do not

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seem to be repeated in any portion of the larger area thus far investigated.

The geology of the mining district is that of ancient crystalline rocks, granite and gneiss, and of Tertiary volcanic rocks which have broken through and lie upon the ancient crystallines. The chief difficulty in interpreting the geology of the mineralized area arises from the extreme decomposition of the country rocks by aqueous and gaseous agencies, which preceded or accompanied the deposition of the gold ores. A familiarity with igneous rocks, and the processes of decomposition to which they have here been subject, is a prime requisite in arriving at a correct understanding of the geology. The general survey of the district, including the mining region, has thus been of great value in affording a knowledge through which the obscurity produced by decomposition can be in a measure cleared away.

General Geology of the Region.

The Hayden Geological Map.—Although the area of the Pike's Peak sheet is adjacent to some of the oldest settlements of Colorado but little geological work has been done within its borders. The Hayden survey of the district was made in 1873, Dr. Peale traversing the extreme northern part, and Dr. Endlich the southern portion, but a considerable part of the region does not seem to have been examined. The representation of the Hayden map is correct only in its general features, the volcanic area outlined by Endlich simply indicating the general distribution of volcanic formations, which were not studied in detail. The Cripple Creek district is represented as of volcanic rocks, but these are given much greater extent than they actually possess.

Position of the District.—The small group of hills containing the mines of Cripple Creek, is chiefly composed of volcanic rock resting upon the great granite plateau, with an average elevation of between 9,000 and 10,000 feet above sea level, which stretches to the north, west, and south, from the base of the steeper slopes of Pike's Peak, with an undulating surface largely due to recent erosion, or to the piling up of volcanic materials upon the plateau. Immediately to the westward of the Cripple Creek region this

plateau has been deeply cut into by the canyons carved by Oil Creek and its tributaries, and the plateau level extends but a few miles to the southeastward from the Cripple Creek region, as here the Front or Colorado Range ends *en échelon*, and the sedimentary rocks of the plains wrap around its southern end and reach northward into Garden Park bay, to a point six miles southwest of Cripple Creek.

The key by which the principal factors of the Cripple Creek geology may be read, is to be found in the great volcanic region lying to the southward of South Park. The high country between South Park and the canyon of the Arkansas River is elevated above the general level of the park chiefly through the presence of great accumulations of surface volcanic rocks, which build up mountains two and three thousand feet in height above the granite floor on which they rest. The eastern portion of this volcanic region is included in the area of the Pike's Peak sheet, and its character is there shown in very distinct exposures in the mountains and mesas on either side of West Four-Mile Creek. Some of these volcanics extend to within a mile of the Platte River at Howbert, and their southeastern limit is on the flat ridges (plateau remnants) which front upon the valley of Oil Creek, near Garden Park.

The Cripple Creek volcanic area is separated at present from the eastern limit of the larger volcanic region by an interval of only a few miles, but evidence will be given to show that it is not to be regarded as belonging directly to the larger area.

The Western Volcanic Series.—The Hayden map represents the area in question south of South Park as containing a large amount of "trachoreite" with considerable amounts of basalt resting upon it, and, in Black Mountain, a single cone of andesite. The examinations of the writer extended but a few miles west of the western boundary of the Pike's Peak sheet, but from a knowledge of the volcanic rocks in the southwestern corner of South Park, and in the hills to the eastward of Salida, he is inclined to believe that the greater part of the area represented as volcanic upon the Hayden map, partakes of the characteristics which will be described for its eastern portion.

At the head of West Four-Mile Creek are a number of

mountains almost entirely composed of a dark fragmental volcanic formation, which has a distinct, nearly horizontally bedded structure. This is plainly seen in the masses of Thirty-nine-Mile Mountain, Saddle Mountain, The Castle, McIntyre Mountain, and Wicher Mountain. This formation varies in texture from tufaceous beds of rather insignificant development to coarse breccia and agglomerate. The agglomerate is specially marked in the mountain masses, where certain banks consist of an irregular mixture of large and small fragments of somewhat different lavas, but generally of dark color, and with a matrix of the same material which is, as a rule, crumbling, giving rise to smooth slopes except where there has been some local hardening, or protection through lava caps of more recent age.

While the dark agglomerate formation is geologically very simple from bottom to top there is a change in the character of the rocks represented in its fragments. The base of the series is chiefly made up of basalt, but upward there appears more and more of dark andesites, at first closely allied to basalt, and then passing into hornblendic and even micaceous andesites. There is locally, also, toward the upper part of this agglomerate, a horizon in which quite a number of different rock types, including pyroxene- and hornblend-andesites and trachyte, are commingled. The rocks are generally fresh, with the exception of oxidation of iron-bearing minerals, so that the prevailing color-tones are either the dark-gray of the fresh rocks, or reddish-browns or purple in the somewhat altered portions.

The fragments are of all structures and textures; massive or vesicular and scoriaceous, porphyritic or dense aphanitic. In all respects the materials are typical of the ejectamenta from a great volcanic vent by explosive eruption.

In Thirty-nine-Mile Mountain and Saddle Mountain there are many small dikes of basalt of very irregular trend and many local intrusive sheets of basalt, sometimes connected directly with these dikes. This fragmental formation does not appear to have been arranged by water, and it is to be interpreted as the surface material ejected from a great volcanic vent lying to the westward of the area investigated. The lower fragmental materials fill in hollows in the granite plateau, as is distinctly shown in the valleys of

upper Oil Creek and tributaries of West Four-Mile Creek. Along the border of the breccia formation little islands of granite may be seen projecting through the lower layers.

To the south of West Four-Mile Creek there are various bodies of massive andesite of several types, which were poured out from local fissures, and are seen lying upon, or intercalated in, the upper part of the great fragmental series, as lava flows. Numerous dikes of the same rocks appear cutting the agglomerate. There were also eruptions of rhyolite and of trachyte in the later phases of volcanic activity in this district, but the masses of these latter rocks are insignificant, and have no bearing upon the problems specially under discussion.

The Area of Crystalline Rocks.—The mass of Pike's Peak, and the plateau to the north and west from that point for several miles, is made up of quite massive granite, principally of two types; first, a very coarse-grained reddish rock, often porphyritic through large feldspar crystals; and, second, a much finer grained reddish granite, which is distinctly later than the coarser grained type. About the peak itself and over the greater part of the plateau from Florissant eastward the granites are massive, but toward Cripple Creek and in the vicinity of the Platte River there is a development of schistose structure in the granite, which is visibly the result of dynamic movement, a shearing stress which produced banded gneisses out of the massive granites; and over the greater part of the area cut into by the canyons of Oil Creek, Current Creek, and other tributaries of the Arkansas, the massive and the gneissoid structures are mingled in a very intricate manner.

Another feature of the crystalline area, which is of much abstract scientific interest, and which causes some of the confusion of the local geology of the Cripple Creek region, is the occurrence of many fragments of quartzite and various schistose rocks in the granites. These fragments, which vary from those a few inches in diameter up to some that are miles in extent, belong to the ancient rocks of the crust which the enormous eruptive masses of the granite have, at least locally, broken up to such an extent that they are now known in all the area examined only as detached masses.

The granite plateau has for the most part been a continental area since Silurian times. To the south of Cripple Creek there are a few remnants of the lowest Silurian limestones found on the plateau, and in the Cretaceous period there was a connection between the main ocean of the plains and the waters of South Park, but the remnants of these sedimentary formations are very small, and play no role in connection with the geology of the mining district.

During the Tertiary period there were several lakes in hollows on the granite plateau, in which deposits of local interest were accumulated. The most important of these is that about the town of Florissant. There was here a long lake extending from near the Platte River to a point some ten miles northwest of Cripple Creek. Accumulations in this lake are chiefly of volcanic material, and seem to belong to the earliest explosive eruptions of the region. Preserved in the Florissant beds is a very wonderful insect fauna, together with some remains of fishes, of birds, a number of fresh water shells, and a large fossil flora.

Geology of the Cripple Creek District.

Crystalline Rocks.—To the north, east and south of the Cripple Creek district the prevalent rock is coarse-grained granite of the Pike's Peak type. In this vicinity it contains none of the large crystals which are characteristic of other areas. There are many small masses of fine-grained granite cutting the coarser rock, and the fine-grained type decidedly predominates from Cripple Creek westward for several miles. Aside from these two types there are some local modifications of granite, which in some cases seem to represent distinct eruptions, and in others a local facies or variety within large masses of coarse-grained granite. One of these varieties is a dark rock, very rich in biotite, which is found in the streets of Cripple Creek, and has a considerable extension about the town.

Large inclusions of schistose rocks of the general character that has been mentioned, are contained in the granites immediately about the mining district. They are prominent for example in the mass of Carbonate Hill, and on either side of the head of Gassy Gulch, and in smaller masses to the southwest of the town of Cripple Creek.

Another feature of the general crystalline area is the occurrence of small diabase dikes here and there. They belong to a very old period of eruption, totally disconnected with that of the main eruptive series of the region. One of these dikes is shown in the streets of Cripple Creek, and has attracted the attention of some so-called experts who have named it "The Black Dike," and have ascribed to it an important role in the mineral deposition of the region.

The Cripple Creek Breccia.—The rock formation which contains nearly all of the productive gold veins, is distinctly of volcanic origin. The greater part is fragmental, and massive rock can in almost all cases be seen to represent dikes or intrusions of later age in the fragmental rock.

In the absence of a map the area occupied by the Cripple Creek breccia, as this fragmental rock may be called, can be indicated somewhat as follows: Beginning at the divide on the toll-road northeast of the town of Cripple Creek, the boundary of the breccia runs in an irregular manner through the summit of Tenderfoot Hill, and crosses to the south side of the head of Gassy Gulch, leaving, however, a small remnant on the ridge to the north of that gulch. After some irregularities at the north base of Bull Hill the line recrosses to the north side of Gassy Gulch opposite Bull Cliffs, but immediately returns to the south side, and runs toward Big Bull Mountain, a part of the northern shoulder of which is breccia. From this point the contact runs down to Wilson Creek which it follows to the south base of Battle Mountain, near the Independence mine. From here the contact runs in an irregular, wavy line, over the divide between Squaw Mountain and Battle Mountain, across Arequa Gulch, and through Little Baldy to Barry, and thence on the slopes east of Cripple Creek to the point of beginning.

The contact runs with such an irregular relation to topography as to show that the breccia is resting for the most part upon a granite surface, which is uneven, very much like the surface of today. The breccia is therefore locally found in hollows, while in other places the granite projects through the fragmental material. A marked instance of the latter occurrence is the mass of granite and schist which forms the western part of Bull Moun-

tain, extending from Ironclad Hill toward Barry. Another small patch is found in the divide between Globe and Gold Hills. Small masses of breccia, isolated by erosion, are found on Mineral Hill and Rhyolite Mountain.

The original mechanical texture of the fragmental rock varies very greatly. It does not seem to be bedded like the corresponding material of the western area, but is locally coarse-grained, in other places fine, and in some spots resembles volcanic mud enclosing fragments of various sizes. In some places it is a quite distinct breccia of angular fragments, and again the fragments are very much rounded.

Secondary mechanical characteristics of the formation, due to decomposition and other causes, should be distinguished from the primary characteristics. The decomposition of the breccia, to be referred to later on, has sometimes rendered fragmental material hard through the deposition of secondary silica, and in other cases a crumbling clay-like mass has resulted. It is generally bleached, but on the other hand is sometimes colored purplish by fluor-spar, or stained by oxidation and hydration of the iron bearing minerals.

The original petrographical character of the breccia is often difficult to determine. It is probable that several allied rock types enter into its constitution. From an examination of the least altered fragments it is clear that the principal rock of the breccia is an andesite, and the most abundant type was one rich in augite, with some hornblende and mica. No evidence has been found to show that basalt entered into the composition of the Cripple Creek breccia, but it is possible, on the other hand, that some of the upper horizons within the breccia, contained mica-andesites or even true trachyte. The extreme bleaching of the fragments renders it impossible, from the examinations thus far made, to make any definite assertions in this respect.

The greater part of the original breccia was of dark colors, gray, purple, and reddish-brown, much like the agglomerate and tuff of the western area. Very distinct indications of its primary constitution may be seen in many places all around the borders of the area, especially on Rhyolite Mountain, Tenderfoot Hill, and in various prospects on the slopes below the Victor mine, at the

head of Wilson Gulch, at the Anaconda mine, and in other isolated places.

Soon after the mining camp was discovered some fragments of very much decomposed rock were sent to the writer who provisionally identified them as rhyolite. He now considers it probable that no rhyolite actually exists in the mining district, and that the specimens provisionally so identified were simply thoroughly bleached andesite.

Massive Andesite.—Associated with the Cripple Creek breccia are certain small masses of andesite which apparently belong to the same general period of eruption as the fragmental material. They are usually seen as small projecting ledges of rock, like that below the Victor mine, or as a small ridge or shoulder like the one occurring on the eastern slope of Battle Mountain. In both these cases the massive rock is a dark, fine-grained, porphyritic augite-andesite. These masses are of very subordinate extent.

Phonolite.—A unique and very marked characteristic of the Cripple Creek area is the occurrence of the rare igneous rock phonolite. Phonolite is closely allied to trachyte both in chemical and mineralogical constitution. It contains silica in less relative abundance to alumina and the alkalies than does trachyte, and hence gives rise to the mineral nepheline, or to the allied minerals nosean or hauyn, when certain other elements are present in small amount. The abundance of alkali in the rock is also manifest in the pyroxene and hornblende minerals, which belong to varieties containing a large amount of soda. The differences which seem slight in chemical analysis thus produce a rock with very marked petrographical characteristics. Phonolite is elsewhere known in the United States only in the Black Hills.

Phonolite appears in the Cripple Creek area in a great many narrow dikes, a few feet in thickness, which cut the breccia and surrounding granite as well, running in all directions. There are also several larger dikes, and necks, or irregular intrusions, and a great many surface masses of small extent which, by their characteristic weathering, form a very marked feature of the local geology. Some of these surface remnants form the capping masses of Mount Pisgah, Rhyolite Mountain, Trachyte Mountain,

Cow Mountain, a number of masses on the plateau southwest of Lawrence, and in the more immediate mining district they appear on Beacon Hill, Bull Cliffs, and a hill opposite to the latter on the north side of Gassy Gulch. The fresh phonolite of most of these occurrences is a very fine-grained gray or dull-greenish rock with few porphyritic crystals, which characteristically weathers into small irregular shreds or flakes, and the outer crust becomes quickly bleached to an ash-gray color. It is the fresh phonolite of this type which has usually been termed trachyte in the mining district.

Another variety of phonolite essentially like the first in chemical composition, but differing somewhat in mineralogical development, is shown at Altman, and on the southern slopes of Bull Hill. This rock in fresh condition has large tablets of pinkish feldspar, with some small prisms of dark pyroxene and a dense, almost vitreous-looking, groundmass. Reference will be made below to a decomposed form of this rock.

Local Source of the Volcanic Rocks.—The constitution of the great breccia suggests at once to one familiar with the western volcanic area, that the former is merely an isolated remnant of the larger formation. A careful study of the freshest materials in the Cripple Creek breccia shows, however, that it was probably in no part basaltic, and the general facts of occurrence seem to indicate that the breccia is of local origin. A very important indication is the occurrence of phonolite, a rock entirely wanting in the western area, as far as that district has been examined, but occurring in great abundance in and for some miles in all directions about the area of the Cripple Creek breccia. Various surface masses of the phonolite are evidently clustered about that center. Further evidence in favor of the local origin of these volcanic rocks will be referred to briefly here. The most important is the solfataric action which has been very marked, and still further the thorough decomposition through circulating waters, and the ore deposition itself within such distinct bounds, all go to show that there was a local vent or source of volcanic character at this place.

Solfataric Action.—There is abundant evidence to be found in

the area of the productive mines, and for some distance about them, that in the closing stages of volcanic activity at this point there was solfataric action or emanation of gases, chiefly characterized, as far as now known, by fluorine. Fluor-spar is noted as an accompaniment of the ores in many of the mines, and the indications are that this agent was especially active in connection with or immediately following the phonolite eruptions. Detailed observations are necessary to establish beyond dispute the nature of the association between the phonolite eruption and the evolution of the gases containing fluorine, but it is a very marked fact that the contact zones of many of the phonolite dikes in granite show the action of fluorine. The general effect has been the removal of quartz and the decomposition of the dark constituents of the granite, rendering a more or less porous zone with frequent formation of purple fluor-spar crystals in cavities left by removal of the quartz. Such porous zones were naturally good channels for the circulation of the later decomposing and mineralizing solutions. Detailed studies are necessary to determine the full significance of this period of solfataric action.

Rock Decomposition.—Aside from the action of the volcanic gases the Cripple Creek breccia has been greatly decomposed by circulating waters. In a large part of the formation, the rock has been thoroughly bleached by extraction of iron-bearing minerals, or the feldspars have been decomposed and changed into kaolin or muscovite, and the original nature of the rock often entirely obliterated.

As already remarked there has sometimes been silicification, and locally great coloration of the decomposed breccia through deposition of fluor-spar, and by hydration of a small amount of oxide of iron.

The result of this decomposition of the original andesitic breccia has been the rock commonly called porphyry or rhyolite. Small phonolite dikes have often been completely decomposed and rendered soft and scarcely recognizable as dikes. The larger masses of phonolite, when decomposed, have also been termed porphyry, whereas a fresh portion of the same mass would be called trachyte. The type of phonolite referred to above as containing rather large tablets of feldspar, yields, on decomposition, a

rock very naturally termed porphyry. It is probable that much of the massive porphyry found on Bull Hill, in the vicinity of Altman, belongs to a thoroughly decomposed mass of this phonolite.

The decomposing agents have also acted upon granite and schists in the vicinity of the breccia in a manner which has often destroyed their characteristic structures, and rendered them quite difficult to distinguish from the finer grained portions of the breccia. Thus, in Carbonate and Tenderfoot Hills, north of Cripple Creek, the fine-grained granite and schist have been so thoroughly decomposed that it is difficult to distinguish them from the adjoining breccia, and a careful inspection of each outcrop is often necessary. In Gassy Gulch, at the north base of Bull Hill, there is another spot where schists and enclosing granite are extremely decomposed. There is little wonder that certain students of the region have been unable to distinguish between the decomposed rocks of originally very different character.

Relationships of Mineral Deposits to Rock Masses.

While the scope of the work undertaken in the season of 1893 prohibited any special investigation of the ore deposits of the Cripple Creek region, there are some general conclusions to be deduced from the geology, which may be provisionally stated. The detailed work of the coming summer will no doubt modify or greatly extend them.

In the first place all the ore deposits seem to be directly connected with the volcanic phenomena of the district. Most of the mines are in the principal eruptive mass, and those which are beyond its borders in the general granite area, are, as a rule, intimately related to some of the phonolite dikes.

Within the main breccia area the character of the ore deposits depends principally upon the kind of rock at a given point. The massive bodies of phonolite and andesite when traversed by ore-bearing veins, give the conditions for distinct walls, the ordinary characteristics of fissure veins. The same is true of parts of the breccia which have been hardened through the earlier decomposing action of circulating waters, but the breccia formation, as a

rule, has been more open to the circulation of ore-bearing currents, so that in certain places there has been an impregnation with quite irregular boundaries.

The small phonolite dikes penetrating the breccia have, in a measure, acted as barriers to the circulation of ore-bearing currents, hence served to concentrate the ore on their walls and in their immediate vicinity.

The nature of the gold ore has already been determined by the investigations of Dr. Pearce and others. Some telluride of gold was undoubtedly the original ore mineral, which in the surface zone, has been largely decomposed, leaving the gold in the native state.

In view of the detailed investigation to be undertaken by Professor Penrose as to the character and origin of the ore deposits, it seems inadvisable to say anything more at present concerning their special character. The principal fact of importance is the association of ore-bodies with the general phenomena of this volcanic vent.

Comparison with the Rosita Hills.

Viewing the Cripple Creek deposits as intimately connected with a small volcanic vent it is of some interest to compare the district with another small volcanic center, not far away, in which there has been considerable mineralization, namely, the Rosita Hills, in Custer County.* This district lies nearly fifty miles to the southward from Cripple Creek, and is situated in relation to the Wet Mountains very much as is the Cripple Creek region to the Colorado Range.

The Rosita Hills represent a small volcano from which a remarkable series of different lavas were poured out, including, in order of eruption, hornblende-andesite, augite-andesite with hornblende and mica, dacite, rhyolite, mica-augite-andesite, and trachyte. The earliest andesite eruption was explosive, and produced breccia and tuff, much like that of the Cripple Creek region. Solfataric action took place, with sulphurous gases in this

*A sketch of the "Geology of the Rosita Hills, Custer County, Colorado," was presented to this Society by the writer at the Georgetown meeting, of July, 1890, and published in the Proceedings, Vol. III, p. 269.

case, and that was succeeded by very extensive decomposition through circulating waters, and deposition of various ore minerals. The common ores are of silver, lead, zinc, copper, and iron, and no close parallel can be drawn between the deposits of the two districts except in regard to the celebrated Bassick mine. This is situated directly in the throat of a volcanic vent in granite. The ores are concentric zones about andesite and other boulders of the agglomerate filling the eruptive channel, and here contain considerable gold in addition to silver, zinc, lead, etc., and there is a very small amount of tellurium present in some places.

The two districts have an interesting resemblance, in that they are both the sites of volcanic eruption on a small scale, but of long continued and varied character. In both centers the ore deposition may be regarded as belonging to the period of solfataric and spring action, which seems to constitute the last phase of a complete cycle of events at a volcanic center.

Prospective Developments in the Region.

The general geological study of the Cripple Creek region makes it plain that future developments will be restricted to the area of the breccia and the immediately surrounding granite with its dikes of phonolite. It is a matter for demonstration by experience as to what extent the mineralization associated with phonolite dikes some distance away from the center of eruption, will prove to be of economic importance.

The western volcanic field is one which should be thoroughly examined for other centers of eruption. It is unknown whether there is one large vent or several of smaller size whose products are mingled in certain areas. It is in any case a question of searching for the regions in which the solfataric and aqueous agencies have been active rather than a location of the points of purely volcanic outbreak. There may be various centers of the latter activity where decomposition and ore deposition have never followed. But mineralization is certainly more likely to have taken place in connection with the loci of earlier volcanic outbreaks.

It is hardly to be expected that if another area of ore deposition is found it will be exactly like that at Cripple Creek. It

may have as markedly different characteristics as the Rosita district.

SUMMARY OF RESULTS.

1. The gold bearing veins occur near, or in the immediate vicinity of, the volcanic rock.

2. The mineralized area is very circumscribed, embracing scarcely more than six miles square.

3. The principal volcanic rock is an andesitic breccia, a product of explosive eruption from a local vent, beneath some portion of the mass now seen.

4. Massive rocks cut this breccia as dikes, the most important of these later rocks being phonolite.

5. The Cripple Creek eruption was in many respects similar to that from a much larger volcano lying some miles to the westward, but is peculiar, as far as now known, in the decomposition by gaseous and aqueous agents, and the connected ore deposition.

6. The Cripple Creek breccia has been almost entirely decomposed by gaseous and aqueous agencies, so that the original character of the material is greatly obscured.

7. It is probable that the ore deposition was the last phase of the period of permeation by circulating waters.

DISCUSSION.

Mr. Franklin Guiterman.—I feel that I but voice a sense of great satisfaction on the part of the Society at the receipt of the very valuable paper which has just been read. It is the first account of the somewhat complex geological structure of the Cripple Creek region which may be accepted with a degree of confidence in its correctness, and I may say that it has been awaited with an ever increasing interest since the announcement by Dr. Cross that he would submit the paper to the Society.

It is not my purpose to enter into the discussion of the paper proper, but I cannot forego the opportunity to dwell, as briefly as possible, on the great importance of such well conducted geological investigations to the mining community, and to express the hope, that the continuance of the work by Dr. Cross may be uninterruptedly carried on to its legitimate economic conclusion,

and that the results of his labors may be published by the Government with all expedition.

The slowness of issue of governmental geological publications is a matter of much regret. It may have been caused by a lack of sufficient appropriations, but it is a question whether the funds which have been at command have been altogether most judiciously applied in the furtherance of the work which is of such momentous importance.

Dr. Cross has kindly sent us a number of topographic sheets, covering the area which is the subject of his paper. An examination of the map demonstrates the elaborate detail of the topography, as well as the perfection of the mechanical execution. In the study of this map the thought has arisen that were such work simply confined to areas which are to be made the subject of geological inquiry, no exception could be taken; it is, however, but too true, that the detailed work of the topographic corps has been applied, in part, to the survey of regions far in advance of all possible geological needs, and also to areas which are entirely unrelated to the purpose for which the geological survey was established. By reason of this view the suggestion naturally presents itself that if the appropriations could be so apportioned by the Honorable Secretary of the Interior that the topographical division be allotted an amount necessary only to adequately perform the service demanded by the geological corps, and the efficiency of the latter augmented to a degree commensurate with its importance, the results of such a course could not help but be productive of the greatest possible benefit to mining interests.

If the Society holds to similar views, I think it wholly within its province that it communicate its sentiments in proper form to the Honorable Secretary of the Interior, our Senators and Representatives, and the Chief of the Survey, to the end that they may be made aware what high value is attached to the work of the Geological Survey, and with what pleasure any action by which its effectiveness may be increased, would be regarded by the mining community.

Mr. R. C. Hills.—My own examination of the Cripple Creek district was altogether too hurried to afford me a clear conception of the specific nature of the processes in operation there at the

time the gold was deposited; though, in a general way, my interpretation of the facts led me to substantially the same conclusions as those expressed by the author in his closing paragraphs. As he has stated, the district is situated on the border of a region characterized by former explosive eruptions, resulting in accumulations of tufaceous material developed more or less extensively as far north as the Middle Park basin. At the present time only the Cripple Creek area is known to contain ore bodies of economic value. The suggestion that the latter are in some way related to the phonolite eruption is, no doubt, worthy of consideration. It is certain, however, that ore rich in free gold and telluride of gold occurs in the fracture-planes of the massive andesite as well as in the breccia—as at the Gold King mine for instance—and if the ore bodies of the district are of contemporaneous origin, as their paragenesis would lead one to infer, it will be important to show, at the outset, that the phonolite eruption was subsequent to that of andesite; since, if the reverse was the case no direct relation between the former and ore deposition can be established. The association of the ore bodies with fluorite is one of the anomalous features of the district. This mineral occurs not only as veins traversing the breccia, but in the same granular form in veins traversing the underlying granite. In this connection I question if the author, in his reference to gaseous exhalations containing fluorine, means that this substance was evolved in its uncombined form.

In view of the early detailed investigation of the ore deposits of the district it seems premature to speculate on the probable source of the gold, or the process by which its translocation was effected. This much, however, may be said, that the presence of veins of fluorite cutting the granite as well as the breccia, and their evident connection with the process of mineralization, supports the view that the bulk of the gold was derived from a source more or less remote from the surface, through the medium of ascending solutions. It is also reasonable to infer that alteration of the material of the breccia might result from solfataric action, following a period of eruption and fissuring, but preceding the deposition of the gold from solution. Accordingly, what is currently known as the "ascension theory" seems to be of sound

application in discussing the origin of these ore bodies. At the same time it may be well to suggest that, possibly, a portion of the gold was derived from the breccia itself since material of that character is more likely than not to have contained gold when originally deposited. It is not generally known that the eruptive conglomerates and sandstones of post-Laramie age are often sufficiently auriferous that accumulations of placer gold result from their denudation. Yet such is the case with the Ruby beds on the North Fork of the Gunnison, with the same beds on Garfield Creek and with similar beds on the Animas—the situation in each case precluding the idea of the gold being derived from any other source. The material of these beds is andesitic, like most of the tuffs and breccias of the early Tertiary including the extensive accumulations of the San Juan Mountains, where the conditions of fissuring and ore deposition support the view that vein material may be secreted from the enclosing rock. But the conditions which produced the shrinkage fissures of San Juan did not exist elsewhere in the state, to my knowledge, and the production of fissures—an operation which must necessarily precede the formation of ore bodies in tufaceous material—could only result from a subsequent eruption and the accompanying dynamic movement. Hence, the pertinency of the author's suggestion bearing upon further explorations in the country west and north of Cripple Creek, that the most promising localities will be those that were once eruptive centers. As he says, such places will show evidence of former solfataric action.

Mr. Charles J. Moore.—I have read with much interest the able sketch of the geology of Cripple Creek, by Dr. Cross, and fully agree with his skilful diagnosis so far as my limited observation has extended, this having been confined principally to Battle Mountain and Beacon Hill, especially the former.

He is mistaken, however, in noting an absence of bedding in the Cripple Creek region; it was the first peculiarity of structure which I noticed on taking charge of the Portland mine over two months ago. The bedding is remarkably regular, four successive layers or strata measuring 1·8 foot, 2·0 foot, 1·0 foot and 2·0 foot in thickness respectively. The joint planes are also well marked and with the bedding gives a general appearance to the country of

stratified rock for a small area. This extends for a distance of 150 feet below the surface, so far, in fact, as our developments in that region have extended vertically. So well marked is this, that at a depth of 70 feet below the surface a mining engineer mistook one of the joints in the footwall of a vein for an intersecting or branch vein, and has based an affidavit upon this assumption for use in a mining law suit.

The dip of the bedding is parallel, approximately, to the present ground surface, indicating erosion of much superjacent material similarly bedded.

It would have added still more to the interest of this paper if Dr. Cross had given us more details as to the characteristics of individual rocks. My observation does not lead me to classify all so universally as a breccia. While this is the true structure of a large proportion of the rock in the Cripple Creek eruptives, there is also much andesite of homogenous structure, crypto-crystalline in fact.

Regarding the breccia, it is interesting to note the granite fragments included in certain of the rock flows. The footwall rock of the main Portland vein is characterized by these inclusions varying from fragments the size of a finger nail to those of a turkey's egg, and showing various stages of alteration in which, however, the mica ingredient of the granite is invariably more highly altered than the feldspars, and the quartz least of all.

The deeper one descends into the crust, however, the less the alteration of these granite inclusions. In the Black Diamond shaft, at the depth of 195 feet, I took out a fragment of coarse, red granite, angular and very slightly altered with flesh-colored feldspars (orthoclase?) two inches long, this being an included fragment some six inches long in the ordinary andesite country.

Through the courtesy of Mr. E. E. Olcott, of New York, I forwarded, three months ago, to Prof. Kemp, of Columbia College School of Mines, certain typical rock samples from Cripple Creek for microscopic determination, and what Dr. Cross has pronounced andesite, he has termed trachyte.

Reasoning from the close analogy Dr. Cross finds between the eruption at the Bassick mine, in Custer County, and that at Cripple Creek, one is led to expect somewhere within the limit of

six miles square, covering all the known mines in Cripple Creek, a chimney, funnel or volcanic vent similar to that of the celebrated Bassick mine, but so far nothing indicates such unless it be the extraordinary ramifications of the ore body in the Summit mine on Globe Hill, one mile east of the town of Cripple Creek.

I quite agree with Dr. Cross in noting but little true tufa in the district; there is some, it is true, but a small proportion only of the general rock-mass.

I have not observed so general a solfataric action as Dr. Cross notes, throughout the region; I should be inclined to confine it to the lines of the vein fissures, at least along these only have I seen the blebs and cavities formed by gaseous action, and the vesicles containing or lined with the quartz and fluorite crystals.

We shall certainly look forward with great interest to the results of Dr. Cross' and Prof. Penrose's final examinations of this region during the present summer.

Mr. Philip Argall.—I am sure that all of us who are in any way interested in Cripple Creek feel very much indebted to Dr. Cross for the exceedingly able and instructive paper, which we have just heard. Such papers are of very great value to all engaged in mining work, giving, as they do, a clear insight into the geology of mining districts, and often indicating with remarkable exactness the probable limits within which active explorations may reasonably be expected to give economic results.

It goes without saying that the earlier the publication the more valuable such work becomes, a statement, the importance of which we should try to impress on the Federal Government, in order that the benefits attendant on the geological survey of our principal mining districts may be reaped by the public.

It would be exceedingly difficult to estimate the great and increasing value of Emmons' work on the Leadville ore deposits. Never, perhaps, has the geologist rendered such service to the mining community as that which the publication of the Leadville monograph and atlas has resulted in. The thoroughness of the work, the grouping of the correlated facts, the summary and phenomenal accuracy of the conclusions, have seldom been equalled and never excelled. We want more of such work.

I notice Dr. Cross states that the granite of the Cripple Creek

mineral area is in part finer grained than that of the Pike's Peak type, and that this fine-grained granite is in turn cut by intrusions of still later granite. In view of the reported fact that some of the mines are said to have pay veins in the granite rocks at considerable distance from the phonolite and the andesitic eruptives in which the principal deposits are found, it would be interesting to know if the ore deposits in the granites and those in the larger eruptives are in every case of the same age?

I have not had an opportunity to see many of the Cripple Creek mines but would say that the Anaconda tunnel gives a good section of the breccias and tuffs which there gradate into each other, and in places display a sort of irregular bedded aspect. Fragments of the red granite of the district and of schist and quartzite are not uncommon occurrences in this breccia, the whole being unmistakable products of explosive volcanic eruption.

The andesitic breccias and tuffs of the Cripple Creek district bear a close resemblance to those of the Coromandel gold fields in New Zealand, though the ore deposits are somewhat different. In the latter tellurium ores are rare, as is also fluor-spar, while the gold is associated with arseno-pyrite and occasionally native arsenic, in very small, but exceedingly rich quartz veins. I am not aware that arseno-pyrite or native arsenic have been found at Cripple Creek; it is not unlikely, however, that they do occur in the unoxidized vein matter in the andesites.

Pyrite is common at Cripple Creek, and, though probably auriferous, is but slightly so when occurring in the ore deposits found in the breccia and tuffs. In the granites, however, pyrite will probably play a more important part in the distribution of the auriferous values in the veins, while tellurium is likely to be much less abundant. In other words, I expect that the auriferous values in the veins contained in the granite, will occur in different mineral association than those found in the breccias.

The relative abundance of fluor-spar, in connection with gold, is a distinguishing peculiarity of the Cripple Creek District, and is also, I believe, unique in the history of auriferous veins. It also appears that the fluor-spar is much more abundant in the breccia than in the granite deposits. While the area of mineralization at Cripple Creek is fairly extensive yet the breccias are of

no great thickness, and it may be inferred that their contained deposits end at the contact with the underlying granite. This, however, remains to be proven. The veins in the granite, particularly those associated with dikes, will, no doubt, extend to great depths, as will, in all probability, those veins in the younger eruptives now filling the fissures of outflow.

The phonolite and andesite eruptions, the solfataric action, the silicification and mineralization of the rocks adjoining the fractures and fissures by circulating thermal waters, point clearly to the importance of volcanic agencies; not only in bringing up mineralized rock from great depths, but also in furnishing the energy to leach them and concentrate their precious metals in mineral deposits and veins. The further studies and researches of Dr. Cross in this interesting mining region will be awaited with expectant interest.

P. H. van Diest.—I cordially agree with what has been said in commendation of Dr. Cross' paper. It is indeed highly gratifying that we are at last in possession of the geology of the Cripple Creek District, and that we have been furnished with a satisfactory knowledge concerning the names and character of the eruptives characterizing that field. The decomposed condition of the rock masses has heretofore given rise to many misconceptions, and what has been written on the petrography of this important mineral region, appears, in the light of Dr. Cross' investigations, to have been far from right.

Dr. Cross states that all the ore deposits seem to be directly connected with the volcanic phenomena of the district, either in the principal eruptive mass itself, or in the neighboring granite areas into which the phonolite dikes have intruded.

Undoubtedly this is true of the prominent paying mines which have as yet been opened, but there are many mineral veins which occur in the granite at a relatively great distance from the loci of the eruptives, for instance, in the area east of Lawrence.

In looking at several prospects in that region I was struck with the great analogy between the veins and country rock there and those of the Sunshine and Gold Hill districts near Boulder. In these latter the veins are also located at a relatively great distance from eruptive dikes. The peculiar blue stain of the vein

quartz, its marcasite, its flakes of tellurides, the absence of free gold, even near the surface, are in both cases strikingly alike.

In the Boulder County telluride belt I have observed free gold and tellurium oxides only in those mines which are in close proximity to eruptive dikes.

It is possible that the source of the gold found in the Cripple Creek region, may have been in the granite, the original ore mineral being a telluride which, by the action of volcanic gases and by circulating waters, may have become decomposed and leached out from its original matrix, to be concentrated and reprecipitated in an altered form in the fissures and cracks in the adjacent breccia zone and the rock masses in its vicinity.

T. A. Rickard.—The paper of Dr. Cross is particularly opportune. Only too often the geological reports of the United States Survey are published so late that, on account of the rapidity of western mine development, they partake very much of the nature of obituary notices. The determination of the different rock species found at Cripple Creek, will be of immediate utility; for in this, as in most mining regions, there exists much confusion owing to the loose application of half-understood petrographic terms. The most prevalent rock of the lode-bearing formation has been determined by Dr. Cross to be an andesite. In November, 1893, I submitted pieces of the country rock enclosing the Victor vein, to Prof. Judd, at the Royal School of Mines, London, and he also found them to be andesite.

It is of importance to the student of economic geology to recognize the frequent association of rocks of this kind with valuable deposits of ore. The Tertiary andesites and the porphyrites, which, according to Rosenbusch, are their pre-Tertiary equivalents, are rocks whose occurrence in the most productive metal-mining regions of the world has been repeatedly noted.

In this connection it may be interesting to recall the fact that while the Comstock lode was at one time supposed to occupy a fault-fissure at the contact of a diorite on the footwall* and a diabase and other rocks upon the hanging wall,† it has compar-

*Von Richtofen called it syenite, so did Clarence King, but Church and Becker called it diorite.

†Von Richtofen called it propylite and Becker, diabase.

atively recently been shown by the microscopical investigations of Hague and Iddings* that the famous lode does not follow the line of contact of dissimilar rocks, but traverses andesites of different ages, though of a structure which so gradates from one to the other as to prove them to be petrographically the same. The investigations made on the rocks of the Comstock and other studies made elsewhere, and more recently, have done much to destroy the supposed importance of geological time as a factor in the classification of crystalline rocks.

Coming near home I may mention that the dikes traversing the granitoid-gneiss of Gilpin County are also andesite, more particularly that variety of the rock which carries a notable amount of quartz, and which, on account of its prevalence in the ancient Roman province of Dacia, now Transylvania, has been termed "dacite." The dike of the California mine on Quartz Hill, is a good sample. It has a fairly uniform thickness of about seventeen feet. The lode meets it at 500 feet from surface, and then follows it, having the dike for hanging wall, until between the 1,500 and 1,600 foot levels. At this point the lode cuts through the andesite, so that the latter becomes the footwall down to the bottom of the mine, at 2,190 feet.

The ore breaks or lodes of Red Mountain, Ouray County, occur in large dikes of andesite of very varying thickness, which penetrate the older igneous rocks of the district. At Marshall Basin and Telluride in San Miguel County, the country rock of many of the silver-gold veins is an andesite breccia. Such is the rock in which occurs the well known Smuggler-Union-Sheridan-Mendota lode. The crests of the Mt. Sneffles and Ophir ranges are composed of variously weathered andesitic breccia, huge thicknesses of which characterize the geology of this, southwestern, part of Colorado.

The rock of the Marshall basin mines resembles in appearance that enclosing the gold veins of the Thames, New Zealand. The district was recently referred to in another contribution,† and it will be remembered that andesite breccia traversed by bands of

*Bulletin, U. S. Geological Survey, No. 17, 1885.

†"Dissimilar Occurrences of Goldbearing Quartz," by the writer. Pro. Colo. Sci. Soc., 1893.

decomposition, was stated to characterize the gold-bearing formation.

In Arizona also, I can cite an instance of a similar association. At the Mammoth mine, Pinal County, the lode (15 to 25 feet wide of low grade gold-bearing quartz) occurs occasionally along the contact of the basal granite (a hornblende granite) of the region, and of dikes of porphyrite traversing the former. Frequently, however, the line of the lode takes it across both these formations and also through overlying masses of breccia-agglomerate composed of fragments of andesite.

In Transylvania, at Nagyag more particularly, the prevailing country rock is a dacite or quartz-andesite overlying Eocene conglomerates, sandstones and marls. The rich gold veins of the region cease to be productive when they penetrate into the underlying sedimentary formation.*

In most of the instances noted above, the occurrence of andesitic rocks has coincided with the development of valuable deposits of ore. At Rico in Dolores County, the immediate vicinity of eruptives of this class does not appear to be favorable to the discovery of rich ore, but it is interesting to note that the "porphyry" which occurs in the northern part of Newman Hill, Rico, is a porphyrite.

Returning to Cripple Creek, we find that the author has emphasized the close relationship of the ore deposits to the volcanic phenomena of the district, and the masses of eruptive rock resulting therefrom. In this respect his work is in accord with the many valuable treatises of the U. S. Geological Survey.

The reference to the "distinct walls" which are "the ordinary characteristics of fissure veins" is open to objection. The idea that well defined and distinct boundaries necessarily characterize the form of ore deposit termed a "true fissure vein" has been a serious hindrance to successful mine development. I speak now as a mining engineer and not as a geologist. At Cripple Creek, it is true, there are some veins, such as the Victor and Buena Vista, which are remarkable for their definition, but on the other hand there are lodes, such as those in the Deerhorn

*Information which I owe to Mr. E. H. Liveing.

and Summit mines, which are as noteworthy for their want of any clearly defined boundaries. Only too frequently the miner when he finds a wall or parting in the country rock, follows it without penetrating through it. The fissuring which characterizes masses of crystalline rocks, such as those of Cripple Creek, is noteworthy for its multiplicity. There are 'walls within walls' and the miner should avoid the tendency to imagine that the boundaries of any particular vein are the only lines of fracture which in any part of his mine are apt to be ore bearing. At the Anaconda there is a complete series of fractures and cross fractures, best described under joint structure. Few lode formations so well illustrate modern theories of ore deposition in so far as regards the replacement of country rock along joint and other fractures which have been the lines of passage for mineral-bearing solutions. And while this is true of this and other particular mines in the district, it is, I believe, also applicable to the Cripple Creek region in general.

THE ORE DEPOSITS OF CRIPPLE CREEK, COLORADO.

By R. A. F. Penrose, Jr.,
Professor of Economic Geology, University of Chicago, Illinois

Meeting of June 4, 1894.

The general geology of the Cripple Creek District has already been described by Dr. Whitman Cross, so that there will be given here only a few lines concerning the nature of the ore deposits. The present article is intended as only a very brief summary of some of the more important facts concerning the district. The subject will be discussed more fully in a future publication.

The Nature of the Deposits.

The Cripple Creek District consists essentially of an area of volcanic breccia protruding through, and possibly partly overlying, the granite which comprises the surrounding country. After the formation of the breccia area, both the breccia and the granite were intersected by numerous dikes and pipes or necks of phonolite and other eruptive rocks. Many of these dikes can be traced along the surface from the granite into the breccia area, and probably in some cases, through the breccia area into the granite again beyond. Most of the ore deposits appear to be more or less connected with the presence of these later eruptive rocks, in a manner to be described later on. Suffice it so say here that most of the ore deposits are either at the contact of the breccia or granite with the later eruptives, or else they are near such positions. In fact, the ore deposits may be grouped, so far as yet known, into three general classes: (1) Those at the contact of the breccia and the later eruptives (phonolite, etc.). (2) Those at the contact of

the granite and the later eruptives (phonolite, etc.). (3) Those wholly in the breccia. The last class, though wholly in the breccia, are generally near the contact with the other eruptives, and their presence, in many cases, may possibly be traceable to the existence of these contacts.

Other classes of deposits, such as those wholly in the granite, or wholly in the later eruptives, may possibly yet be shown to exist.

Since its appearance the breccia has more or less hardened and cemented, and its weathered surface often looks, on superficial examination, much like the weathered surface of the phonolite. Hence, the position of an ore deposit at the contact of the breccia and phonolite is not always apparent without careful examination.

The ore deposits of the Cripple Creek District, with a few exceptions, do not represent well-defined quartz veins, as in many other gold districts, but they represent impregnations or replacements of the country rock along the contacts, or other lines already described. In a few cases well-defined quartz veins do occur, but in most the ore consists of country rock containing more or less secondary quartz, fluorite, iron compounds and other minerals. Some of the highest grade ore in the district has been found in such deposits.

In the breccia the ore deposits frequently consist of the country rock intersected by thin bands of quartz and other minerals, from mere films to an inch or more in thickness, running parallel in the direction of the ore deposit. In some instances these quartz seams are not parallel, but form a network of thin, intersecting seams throughout the deposit. From such occurrences as these, there are all gradations up to a few cases where more or less solid quartz veins occur. In deposits at the contacts of the breccia with phonolite and other eruptives, the ore is sometimes in the breccia, sometimes in the dike, but in either case at or near the contact. Occasionally it may be found that the whole dike is impregnated with gold.

In the deposits at the contacts of granite with the phonolite or other eruptives, the ore is generally in the granite at or near the dike, though not necessarily always actually at the contact line. Most of the dikes in such positions contain small quantities

of gold; they have, however, not yet proved sufficiently large to work.

The ore deposits of the district vary from a few inches to many feet in thickness, but most of them would probably come between the limits of five inches and four feet, though some are much thicker. They range in strike from northwest and southeast to northeast and southwest, often approaching very nearly a north and south direction, parallel to the general course of the dikes. Deposits approaching an east and west direction, also occur, and have proved in some cases profitable sources of ore. The various deposits dip at angles varying from 45° to 90°.

The Nature of the Ores.

The ores of the Cripple Creek District are almost exclusively gold ores. They average from less than one dollar to several thousand dollars per ton in gold, but the product of most of the mines would come between the limits of twenty and four hundred dollars per ton. Some few of the mines produce limited quantities of much richer ore than this, while on the other hand some contain ore of much lower grade.

The minerals composing the ore deposits are, besides the materials comprising the country rock proper, quartz, fluorite, iron pyrites, iron oxides, manganese oxides, and other minerals in smaller quantities. The gold occurs as free gold, as a telluride, and probably also as auriferous iron pyrites. The free gold is found sometimes in a very finely divided condition, and at other times as "sheet gold," in thin films. The free gold predominates in the upper parts of the deposits, but before a depth of one hundred feet has been reached, and in some cases at much less depths, the telluride of gold usually appears, and, though often associated with free gold, continues down to as great depths as have yet been attained. Though such is the general experience in the district, yet there are some striking exceptions, and a few mines have been sunk several hundred feet without reaching the telluride. In most cases, however, some of the free gold on the surface seems to have been the result of the oxidation of the telluride, while some of it has probably been derived by oxidation from the gold originally in the iron pyrites.

The exact formula of the telluride of gold found in the Cripple Creek District cannot yet be given, as the analyses being made are not complete, but sufficient has been done to show that some of it at least is a pure telluride of gold, with little or no silver. Silver, in fact, is rare in the district, occurring in only very small quantities and in only some of the mines. One marked exception to this is the Blue Bell mine in Squaw Gulch, which has produced a very rich silver and gold ore, quite different from any other ore in the district as it contains a considerable quantity of galena and blende.

As regards the distribution of the gold in the deposits, it occurs in some cases comparatively regularly disseminated throughout; but in most cases, just as in other districts, the gold is found in shoots separated by greater or less areas of barren or low grade material. Sufficient work has not yet been done in the district to determine whether these shoots follow any definite laws as to their distribution.

The Treatment of the Ores.

Most of the ores are at present smelted, though some of them are milled. Milling, however, saves but a limited percentage of the gold, even in the best milling ores in the district. The various other methods of gold extraction have been tried, but the result is that most of the mine owners are sending their ores to the smelters; and, so far, the products of most of the mines have proved to be essentially smelting ores. Even some of the ores carrying free gold do not mill satisfactorily, and this is attributable to the film of oxide of iron on some of it, and to other conditions to be discussed in a future publication.

ORE DEPOSITS OF CAMP FLOYD DISTRICT, TOOELE COUNTY, UTAH.

By R. C. Hills.

Meeting of August 6, 1894.

The following notes on the ore deposits of Camp Floyd Mining District, embody the writer's observations, made during February and March of the present year, while engaged, jointly with Mr. Ellsworth Daggett of Salt Lake City, in an extended examination of the Mercur Mine. Owing to the severity of the season, the study of the district was necessarily restricted to the immediate neighborhood of the productive mines; for which reason, little can be said regarding the geological features of the surrounding country, or the relation of the eruptive bodies to the ore deposits. But, as exceptional opportunities were afforded for underground investigation, many interesting things were noted that are deemed worthy of being placed on record, notwithstanding that, in many desirable respects, the information available is lamentably incomplete.

The district is situated near the southern extremity of the Oquirrh Range, and at one of the lowest portions of it, where the mountains, while precipitous and rocky, are rarely craggy or inaccessible. The principal mining camp, known as Mercur, is distant about seven and one-half miles in a westerly direction from Fairfield, the nearest station on the Tintic branch of the Union Pacific system. The camp lies in the bottom of a gulch draining westward, and the site was formerly occupied by the defunct town of Lewiston, which twenty years ago attracted some attention as a silver producer. But the silver mines of economic value were rapidly exhausted, and there was a period of several years, pend-

ing the discovery of the auriferous deposits for which the district is now noted, during which the camp was practically abandoned. It is remarkable that deposits as extensive and important as these are known to be, and outcropping so near to mines which at that time were productive, should have been passed by without notice by the miners and prospectors who thronged the district at the time of the first "excitement." This instance, like the finding of carbonate ores at Leadville and auriferous ores at Cripple Creek, goes to show that many other districts, now thought to be worthless, may be found, upon further and closer investigation, to contain extensive and important bonanzas.

Geological Features.

The Oquirrh Range is the most easterly of the great system of parallel, north and south mountain ridges lying between the Wasatch and the Sierra Nevada, and its structure, on the whole, is of the well-known Basin-Range type. Camp Floyd District, however, affords a noteworthy example of the local modification of this type, presumably by eruptive agencies.

The town of Mercur, around which the productive mines are located, is situated near the vertical axis of a quaquaversal uplift, from which the strata are inclined in all directions, as from a common center, with the greatest inclination in the direction of previous flexing of the range. This form of uplift usually results from the intrusion of an eruptive mass immediately beneath the strata. Such is the probable cause in this instance, for while the amount of erosion has not been sufficient to reveal the intrusive body itself, its existence may be inferred from the presence of dikes traversing the uplifted beds. As frequently happens in uplifts of this kind, the summit of the arch has been deeply and broadly eroded, so that the true structure is fully apparent, and the outcropping edges of the strata are exposed concentrically around the eroded area.

The inclination of the beds is variable, depending upon the distance of a particular portion of the irregular outcrop from the center of the upheaval, and may reach, in places, as much as twenty degrees; although, in the productive ground, the average is about twelve degrees.

The lowest beds exposed are probably of Lower Carboniferous age, though the few specimens of *Productus*, *Orthis*, *Retzia*, and Bryozoans observed, were too imperfect for the purpose of specific identification. The predominant rocks are limestones, especially towards the lower portion of the section exposed. Higher up, they alternate with shaly beds containing thin limestone strata, and, towards the summit of the section, the shaly beds predominate. Like other limestones of the same horizon in the Great Basin, those of this district contain considerable cherty material; either in the form of nodules, or as hornstone masses of such length and thickness that they are regarded as quartz beds by the prospectors.

Diagrammatic Section of the Mercur Quaquaversal.

(a) Village of Mercur; (b) Dikes; (c) Auriferous zone; (d) Argentiferous zone. The arrow indicates the point of maximum upheaval.

Outcropping in the immediate vicinity of Mercur are two ore-bearing zones, situated about 150 feet apart, substantially conformable with the strata, and, therefore, dipping away from the common center of upheaval. The lower zone is silver-bearing, and the ores are contained in the masses of hornstone just mentioned. These masses are often seamed with thin veinlets of white quartz, particularly the ore-bearing portions; resembling, in this respect, the productive hornstones of Queen Spring Hill, and Ruby Hill, in the Schell Creek Range of eastern Nevada. The ores are also of the same tractable kind, capable of being treated by the Washoe process, except in one claim on the western outcrop where the silver-bearing material is an argentiferous sulphide of antimony.

Superficially, this zone has been pretty thoroughly exploited.

but the poverty of the surface ores did not encourage attempts at deep exploration, and the district enjoyed only a brief existence as a silver producer. As the deposits do not differ in any important particular from other silver-bearing hornstones, and as their economic value is questionable, no further reference to them seems necessary.

The upper metalliferous horizon (it can not be regarded in any sense as a vein), is the one to which the district owes its present importance, and as its description is the principal object of this paper, it will be treated more in detail under appropriate heads.

The Auriferous Deposits.

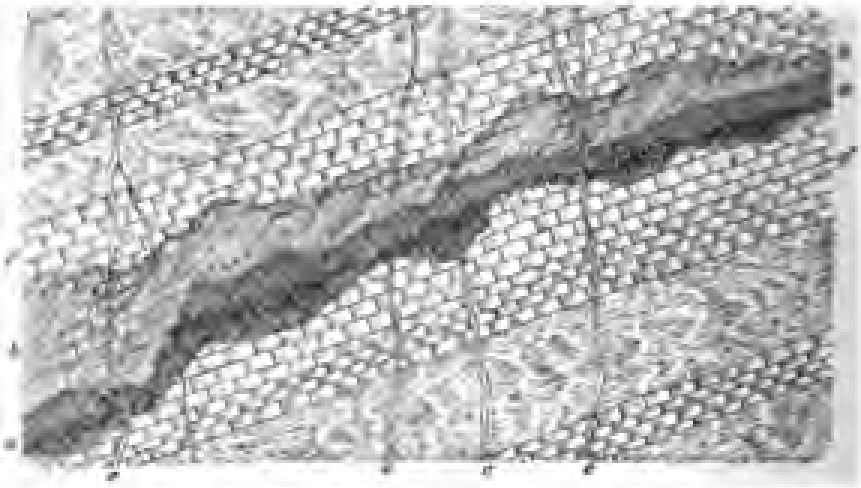
Mode of Occurrence.

The ore bodies exposed by the working of the Mercur, Marion, and Golden Gate companies, and which apparently continue into the adjoining territory to the westward, were deposited at a particular horizon, marked by an abundance of chert nodules, in a prominent band of limestone. By the erosion of Lewiston Gulch, which cuts through the uplift in an east and west direction, this limestone is exposed as a more or less continuous but irregular outcrop, somewhat elliptical in outline, and intersected by the bed of the gulch at the two most distant points in the contour, which are about one mile apart. Beginning at the Golden Gate shaft which is situated in the bottom of the gulch at the eastern intersection of this contour, the outcrop rises rapidly through the Mercur ground in a southwesterly direction, and through the Marion ground in a northwesterly direction, until the summit of the uplift is reached at an elevation of from 400 to 450 feet above the gulch level, when the outcrop inclines as steeply, in the opposite direction, towards the westerly intersection of the contour at a point lower down the gulch. As the latter does not traverse the central axis of the uplift, but passes a short distance to the south of it, the inclination of the beds southward is greater than to the northward.

While but little exploitation work has been done along the western half of the outcrop, the result so far has not been encouraging. Accordingly, the facts and conclusions here submitted per-

tain to the eastern half, which has been pretty thoroughly explored and shown to be of a productive character throughout the greater part of its extent.

The Mercur section affords several beds of limestone containing chert nodules and silicious material, but the one in which the principal ore bodies occur is the most prominent. The cherts are not distributed throughout the entire thickness of the limestone bed, but are arranged in aggregations of nodules, generally con-



Diagrammatic Section of a Portion of the Mercur Ore Body.

(a) Ore with chert nodules; (b) Shale and sandy material resulting from alteration of the drab limestone; (c) Hornfelsed extension; (d) Crystalline limestone floor; (f) Drab limestone roof.

nected with one another horizontally, or not very far apart, and spread out rudely parallel with the bedding, though at varying distances from a given plane of contact — that is, a layer will terminate and be superseded by another layer at a different level, which may be as much as ten feet away either above or below. The limestone enclosing the cherts is black and crystalline, but where the cherts are absent it graduates into a compact, drab-colored limestone (marly limestone) containing a considerable percentage of argillaceous impurities.

The most important ore bodies were formed in such a way as to include the chert nodules — the crystalline limestone around

them being partly or wholly replaced in the process of deposition. If partial replacement occurred, the ore was deposited mostly in the fracture-planes and seams of the rock, though to some extent in the rock itself. If the rock surrounding the cherts was wholly replaced, there resulted an ash-gray residue of sandy particles, or fine cherty material, associated in considerable quantities with the chert nodules. Much of the pay ore is of this character, but as the replacement was seldom complete throughout the full thickness of the ore body, the face of the standing ground often presents a distinctly brecciated appearance that at first sight suggests crushing and movement.

In the process of deposition the replacement seems to have taken place downward from the base of the marly limestone, with varying intensity depending upon the purity of the rock material. Accordingly, the floor is hummocky, and much less regular than the roof or hanging wall as regards the plane of separation between ore and country rock. It is noticeable, however, that while the floor is generally hard, solid limestone, the roof is often soft and shaly; and as this material graduates into marly limestone, it is probably a product of the latter by alteration, and removal of part of the lime during the period of ore deposition. Indeed, in places it has been sufficiently mineralized to pay for extraction, particularly where the alteration has been so intense as to reduce the rock to a tough, laminated clay. Elsewhere it contains little of value, and this is especially noticeable where the partly altered rock is soapy to the touch.

Since the ore bodies are usually associated with chert nodules, the continuity is interrupted at points where there are breaks in the continuity of the chert layer, or where the latter jumps from one level to another. As a consequence of this, the ore-sheet appears to have been, in places, badly faulted, though in fact, no faulting movement of any moment has occurred, the original conditions governing the secretion of the chert material having determined the position of the layer, and, indirectly, the position of the ore-sheet.

Seams of calcite in the joint-planes of the limestone are quite common, as they usually are in limestones of this age throughout the Great Basin. Their origin in this case seems to have been

anterior to the deposition of the ore. Small vertical veins of heavy-spar, cutting up through the limestone, are quite numerous, and apparently very intimately related to the formation of the ore bodies. These veins are seen both above and below the mineralized zone; but, unless the alteration or replacement has been only partial, they are not traceable through the ore itself.

The thickness of the ore-sheet varies from one to twenty feet. The mean of a large number of measurements showed an average of about seven feet.

Mineralogical Features.

Sulphide Ores.—The Grasshopper shaft on the Golden Gate property is situated in the bed of the gulch at the eastern intersection of the latter with the outcrop. The ore-sheet at this point is topographically lower than any other portion of it in the productive area, so that water-level lies but a few feet below the surface, and the ore developed in the shaft is entirely sulphuretted. Cherts are abundant in the gangue, associated with considerable blackish, or dark-colored shaly material. Owing to the extreme minuteness of the particles, the presence of pyrite is scarcely noticeable, although this mineral is really abundantly disseminated through the shaly portions of the gangue. The most striking feature is the abundance of realgar. This substance occurs as crystalline plates, or scales, in the planes of cleavage and lamination, around the chert nodules and in the fractures of the same. Orpiment is occasionally present, and less rarely cinnabar; though the amount of the latter substance present is nowhere sufficient to warrant its extraction as an ore of mercury. Rhodocrosite occurs in a number of places, but in small quantities, as also heavy-spar. Galena, stibnite, sphalerite, chalcopyrite, tetrahedrite, and other metallic sulphides usually occurring in deposits of the precious metals, are notably absent.

Oxidized Ores.—The bulk of the ore at present developed lies within the zone of oxidation, which is shown by the workings of the Mercur mine to extend to the face of the most advanced headings—one of which has penetrated a distance of 900 feet from the general line of outcrop. The Mercur workings are high above the gulch and well towards the summit of the uplift; a fact that nec-

roof of the ore-sheet immediately under the drab limestone where the latter has not undergone alteration.

Paragenesis.—The association of gold with arsenical compounds, such as mispickel and native arsenic, is sufficiently common to pass unnoticed. But the association of the same metal with realgar and cinnabar is, beyond question, phenomenal—much more so, indeed, than the occurrence of auriferous ore-bodies in limestone, since such are known to exist in the La Plata Mountains of Colorado, in Montana and elsewhere. That this association, in respect to the realgar, is not intimate, has been proven by assays of Mercur ore exceptionally rich in this substance, wherein little more than traces of gold were obtained; and Mr. Richard Pearce states that he carefully separated some of the realgar from a sample of Golden Gate ore, the former affording only a trace of gold, though a previous assay of the ore itself had demonstrated its fair average value.

In respect to the cinnabar the association appears to be more intimate. But assays of selected samples containing a high percentage of this substance gave only from $5 to $6 per ton in gold — indicating that only a small proportion of the metal in the ore was contained in that mineral. The association, therefore, of the gold with these two sulphides is compulsory rather than selective. The same is true of the cherty material, called black quartz by the miners, and thought by many to be the matrix of a bedded vein. A sample taken from a number of points in the Mercur mine, indicates that little more than traces of gold exist in the chert when carefully freed from other ore-bearing matter. The highest assays were obtained from samples of granular limestone in which oxide of iron mixed with clay was noticeably present in the planes of fracture—suggesting that iron is, as usual, the selective associate.

It is unfortunate, that thus far no investigation has been undertaken to determine beyond question wherein the values lie; to prove the presence or absence of tellurium compounds, or the association of the gold with its next most likely host, the finely disseminated pyrites.

Effects of Oxidation.

Undoubtedly, the most important change brought about by

essarily tended to promote the circulation of aerated water along the ore-sheet, the previous materials of which seem to have afforded an easy channel through which such circulation could be effected. Much of the circulation, however, probably took place through certain cavernous fissures, whose walls and druses are lined with gypsum crystals and calcite. Several of these fissures have been encountered in the Mercur mine, and as they are best defined and most characteristic where there has been the least alteration, the very correct impression has gained ground that they are a sure sign of the absence of anything but very lean ore in their immediate vicinity.

The gangue differs in several respects from that associated with the sulphides. There has been more decomposition. Hence, there is more clay present and the material is less compact. There is also a pronounced change in color owing to the oxidation of pyrite, brownish-yellow and ochrey tints, mottled with black chert nodules, predominating, but varied occasionally with scales of bright-red realgar and spots of vermilion-colored cinnabar. Heavy-spar is noticeable, in many places, occupying small fissures where the process of ore deposition has not destroyed the rock structure, but distributed sparsely and irregularly where alteration and replacement have been most complete. Oxide of manganese, though present at a few points, is rarely met with. Rhodocrosite occurs somewhat frequently in the advanced workings which appear in places to be approaching the limit of the oxidized zone. At such points there is a noteworthy abundance of fibrous gypsum in the form of continuous thin seams along the bedding planes, and with the appearance of this material the rocks become darker colored owing to the presence of disseminated pyrites. But as alteration and replacement have taken place very imperfectly at such points, and the ore is invariably quite lean, it is not to be inferred that ore bodies affording greater facilities for circulation, and consequently oxidation, may not exist beyond. Indeed, it has been repeatedly demonstrated in the Mercur workings that where argillaceous matter formed an impermeable envelope, portions of the sulphuretted material escaped oxidation. Such residual portions, containing realgar and cinnabar, and protected by dark-colored argillaceous matter, are of common occurrence along the

oxidation, was that which effected the condition of the gold, and rendered it soluble in a potassium cyanide solution; whereas, in its previous condition, it was insoluble until the ore had been roasted. Whether or not the gold was originally in combination with tellurium, it would be difficult to determine. Indeed, its condition in the oxidized ore is not at all certain; although, from its behavior with cyanide solution it is thought to exist in the free state. The fact that "colors" cannot be found very readily by panning, indicates that if the gold is present in the metallic state, it is in an extremely finely divided condition, like the black flecks obtained upon parting an alloy of--say, six parts of silver to one of gold.

In the oxidation of the sulphides, that of iron was the first to succumb, realgar next, and cinnabar last; the latter being the only one of the three remaining in the ore that has been otherwise completely oxidized. The effect of the metallic sulphates formed — principally sulphate of iron — upon the material of the associated rock, is seen in the production of gypsum, the separation in places of slimy clay, and in the general softening and tendency to disaggregation. The last, or supplementary phase of the oxidation process developed itself in the zone near the outcrop, where the shaly layers have been bleached by removal of the iron oxide; presumably through reduction and solution in presence of organic matter.

Genesis of the Deposits.

So far as can be discerned, the auriferous deposits bear no relation to the silver deposits, either in time or mode of formation. The latter were deposits from solutions secreting silica; while the former were deposited from solutions capable of dissolving lime stone, and which in their passage upwards necessarily traversed the silver-bearing strata.

The cause, which in each case determined the horizon at which deposition took place, is to be sought for in the character of the rocks in the particular zone. The facts cited in connection with the auriferous ore bodies, emphasize two important points: (1) The persistent association of the ore-sheet with the chert layers in the limestone, and (2) the presence of numerous vertical veinlets of heavy-spar traversing the same rock.

At first sight it might appear that the cherts were the selective agents in determining the stratigraphical position of the ore-sheet. The evidence shows, however, that they were only remotely connected with the causes effecting deposition, and that the limestone was really the selective agent.

The secretion of silica in the production of chert nodules, is a process necessarily involving the purification of the associated calcareous material, as regards disseminated silica. If at a later period metamorphic action supervenes, the disseminated alumina, gathering around the nuclei of silicious particles and nodules, forms various crystalline lime-alumina silicates which, in limestones that have undergone but incipient metamorphism, are usually of microlithic dimensions. The residual carbonate of lime, relatively pure, crystallized during the operation, and the resulting rock is of such a character as to be readily attacked by mineralizing solutions of suitable composition, whether carbonated or sulphuretted. While the evidence of metamorphism in the district is scarcely noticeable, the distinctly crystalline structure of the cherty limestone indicates that some action has taken place, at least sufficient to induce crystallization in a rock previously purified by chert secretion.

The question will naturally suggest itself: If this crystalline and relatively pure limestone was the selective agent in the case of the main ore bodies, why were not the ores to a certain extent deposited in the impure limestones? In reality, such deposition has taken place. The diamond drill borings, in the sulphide zone, developed the fact, that realgar and pyrites were very generally disseminated through the rocks above the ore-sheet; though in small quantities as compared with the deposits in the cherty zone.

The heavy-spar veins traversing the formation are, as already noted, quite numerous — as much, in places, as the joint planes. The narrow fissures which the heavy-spar now occupies, were, apparently, the channels through which the mineralizing solutions reached the zone of deposition. This is indicated by the occurrence of the sulphides of arsenic and mercury in the veinlets themselves, and by well marked instances of the distribution of these substances along the bedding-planes and fractures adjacent; such

deposits thinning out and dissappearing a few feet away from the parent fissure.

The conclusion is, therefore, that the mineralizing solutions ascended through the fissure in question and deposited their burden, to some extent throughout the entire formation, but mostly at the horizon of the cherts where, owing to the freedom of the limestone from disseminated impurities, it was readily dissolved and replaced by sulphuretted compounds.

About the time the writer was leaving the district other deposits, similar in character and thought to be of importance, were discovered a few miles south of Mercur; but whether or not at precisely the same horizon is not known. In this connection it may be pertinent to observe, that the existence below the level of erosion, of other layers of cherty limestone capable of receiving auriferous deposits of economic value, is quite probable. A few deep bore-holes into the uplift would settle this question.

At present, the oxidized ores of the district are treated by the McArthur-Forrest process, and with marked success. But with the exhaustion of these ores some method of cheap roasting will have to be introduced — a fact well understood by all those interested.

A SUSPECTED NEW MINERAL FROM CRIPPLE CREEK.

By F. C. Knight,
Chemist, Boston & Colorado Sm. Co., Argo, Colorado.

Meeting of October 1, 1894.

The subject of the constitution of the Cripple Creek gold ores has been one that has on several occasions engaged the attention of the Society.

The character of the gold minerals has been more particularly considered by Dr. Richard Pearce, in two papers submitted during the last few months,* and by Prof. Penrose, in his summary of the results of his economic studies in the Cripple Creek field,† which was presented jointly with the recent paper by Dr. Cross on the geology of that section.‡

It was Dr. Pearce who first pointed out the occurrence of tellurium in an oxidized form as an associate with the unaltered telluride minerals in the Cripple Creek ores. Through this demonstration the impetus was given to look for some definite mineral compound in which the oxidized tellurium might be found, and it is with pleasure that I am able to state this evening that the search has been a successful one, and to submit the results of the analysis of what appears to be, from present investigations, an entirely new mineral.

The material which was subjected to analysis, was kindly furnished me by Mr. J. D. Hawkins whose great familiarity with Cripple Creek ores enabled him to discern that the specimen had characteristics which distinguished it from those ordinarily marking the Cripple Creek minerals.

* "The Mode of Occurrence of Gold in the Ores of Cripple Creek District." Meeting of Jan. 8th, 1894. "Further Notes on Cripple Creek Ores." Meeting of April 5th, 1894.

† "The Ore Deposits of Cripple Creek, Colorado." Meeting of June 4th, 1894.

‡ "Geology of the Cripple Creek Gold Mining District, Colorado." Meeting of June 4th, 1894.

The mineral was composed of a crystalline telluride mineral and a brown amorphous matrix. The association of the matrix with the telluride was so intimate that a separation of the former from the latter, in a pure state, was impossible. The analysis was, therefore, made on the mixture.

The physical characteristics of the matrix were as follows:

Color, light brown.
Luster, dull.
Brittle.
Fracture, uneven to slightly conchoidal.
Streak, bright yellow.
Hardness, not determined, but between 3 and 4.
Sp. Gr., not determined.

A portion of the mixed minerals was crushed, finely powdered, and two grams taken for the analysis. A qualitative investigation proved that gold, silver, tellurium, selenium, iron, and silica only were present.

The method of analysis was as follows:

The weighed portion was first dried at 100°C. for ten hours, until constant weight was obtained. The temperature was then raised to 160°C., and this heat maintained for eight hours, and the portion again weighed.

Having obtained the mechanically combined water and that of combination, the substance was dissolved in dilute hydrochloric acid ($1HCl:1H_2O$), and filtered through a Gooch crucible.

A. Treatment of the filtrate:

The solution was treated with sulphuretted hydrogen to precipitate the tellurium and selenium, and filtered; the filtrate was oxidized with nitric acid, and ammonia added to precipitate iron. The tellurium and selenium precipitate was placed, along with the filter paper, in a beaker, and treated with fuming nitric acid, more acid being added from time to time, until all organic matter was destroyed; the solution was then evaporated to dryness on a water bath, taken up with dilute nitric acid, a small quantity of hydrochloric acid added, and the AgCl filtered off and weighed.*

*The silver here was due to the solubility of chloride of silver in tetrachloride of tellurium, an interesting fact of which no note has been previously made, as far as the author has been able to ascertain.

The filtrate was again evaporated to dryness on a water bath with addition of more hydrochloric acid, the mass taken up with dilute hydrochloric acid, and the tellurium and selenium precipitated by protochloride of tin. The precipitate was filtered on a Gooch crucible and weighed.

The combined metals were then introduced into a fused bath of potassium cyanide, and the fused mass treated with water, effecting a solution of all the selenium with a small portion of the tellurium. Air was passed through the solution for an hour, and the precipitated tellurium filtered off. The selenium was precipitated from the filtrate by the addition of hydrochloric acid, filtered on a Gooch crucible, dried and weighed.

B. Treatment of insoluble residue:

The residue was treated at a gentle temperature for some hours with nitric acid by which the decomposition of the telluride mineral was effected. The solution was diluted and filtered, tellurium, selenium and silver passing into solution, silica and gold remaining behind. In the nitric acid solution the tellurium, selenium and silver were determined by the methods previously described. The residue from the nitric acid solution was treated with aqua regia, filtered off and weighed as silica. The gold was determined in the filtrate by oxalic acid precipitation.

The result of the analysis gave the following figures:

	H_2O	0·45	
Fe 5·68	Fe_2O_3	8·12	Sol. in HCl.
Te 14·24	TeO_2	17·81	Sol. in HCl.
Se 0·32	SeO_2	0·45	Sol. in HCl.
	Ag	0·22	Insol. in HCl.
	SiO_2	38·25	Insol. in HCl.
	Au	18·41	Insol. in HCl.
	Ag	1·20	Insol. in HCl.
	Te	14·72	Insol. in HCl.
	Se	0·32	Insol. in HCl.
		99·95	

In the foregoing analysis the iron has been figured as oxide; the tellurium and selenium soluble in hydrochloric acid as tellurous and selenious oxides, for the following reason: On treatment of the material with hydrochloric acid no chlorine could be

detected, and although free gold was known to exist to a considerable extent in the mixture, not a trace of it was found in the hydrochloric acid solution, which, it is evident, would have been the case had the tellurium existed as telluric oxide.

Calculated to 100, the soluble portion (eliminating the silver) gives:

Fe_2O_3	30·27
TeO_2+SeO_2.....	68·05
H_2O	1·68
	100·00

Replacing the selenium by an equivalent amount of tellurium, the molecular ratios are as follows:

$$Fe_2O_3\ 1{\cdot}87 : TeO_2\ 4{\cdot}14 : H_2O\ 0{\cdot}92$$
$$\text{or nearly } 2 : 4 : 1$$

which corresponds to the formula:

$$2(Fe_2O_3,\ 2\ TeO_2)+H_2O$$

This requires:

Fe_2O_3.....	32·72
TeO_2	65·45
H_2O	1·83
	100·00

From another small piece of ore, furnished also by Mr. Hawkins, which presented the same physical characteristics as the specimen on which the foregoing analysis was made, the portion soluble in hydrochloric acid gave the following results:

Fe_2O_3	35·44
TeO_2+SeO_2.....	62·79
H_2O	1·77
	100·00

In this case the molecular ratios are:

$$Fe_2O_3\ 2{\cdot}19 : TeO_2\ 3{\cdot}95 : H_2O\ 0{\cdot}97$$

While these two analyses of the portion soluble in hydrochloric acid present a not inconsiderable variation in the tellurium determinations, nevertheless, we may reasonably conclude, as has

already been suggested by Dr. Pearce, that a well definec of iron mineral does exist in association with the tellu erals of Cripple Creek, and that a close examination of t that section will bring to light purer material than ha my command.

It will have been noticed that the analysis of th insoluble in hydrochloric acid shows an amount of go excess of that demanded by any known telluride of gold That this excess is due to the presence of free gold wa strated by the analysis of a small quantity (0·6 gram) of fully selected crystalline telluride in the mixed material, following results:

Au	40·14
Te	56·22
Ag	3·63
	99·99

This mineral is identical with calaverite, the const which is as follows:

Au	39·40
Te	57·50
Ag	3·00
	99·90

The author greatly regrets that the material furni for the preceding investigations was far from pure. I have hesitated, perhaps, to publish the foregoing result plete and unsatisfactory as they are, were it not for the the identification of the tellurite of iron mineral is one of interest; and that, in view of the indications at hand, a will be furnished to those engaged in mining at Cripple who are brought in contact with the ores of that section, the discovery of purer material on which further inv may be conducted.

DISCUSSION.

Dr. Richard Pearce.—The investigations of Mr. Kni indicate, beyond a doubt, that an alteration product havi nite chemical composition is formed by the oxidation of in the Cripple Creek ores. I have for a long time susp

existence of a tellurite or tellurate of iron, but the difficulty has been to find material sufficient for examination.

It may be suggested that the physical characters of the mineral referred to in Mr. Knight's paper are not so well marked as they should be to fill the requirements of a new mineral, but I can see no reason why it should not be entitled to the same consideration as many other recognized minerals which are essentially alteration products, and are not marked by any very well defined characters, among which is crystalline form. Examples of such minerals are found in pitticite and chenevixite (hydrated arseniates of copper and iron), which are essentially amorphous minerals, and whose characters generally are perhaps no better defined than the mineral referred to by Mr. Knight.

I think we have to recognize the existence of calaverite as one of the tellurides of Cripple Creek, judging from Mr. Knight's analysis, although the bronze color so characteristic of the mineral is not so well marked as in some specimens found at the Melvina mine, Boulder County, some twenty years ago. Calaverite is a member of the sylvanite group of tellurides, and its presence at Cripple Creek might naturally be expected; but the specimen examined by Mr. Knight is the first I have been able to recognize as having the characters peculiar to that mineral.

THE GOLD ORE DEPOSITS OF MOU CARRIBOU, IDAHO.

ILLUSTRATING THE COMMON CHANGE OF MINERAL FROM ALKALINE TO NEUTRAL.

By Edwin B. Kirby.

Meeting of August 5, 1894.

A few years ago I had occasion to examine son deposits in the Mount Pisgah Mining District, Bingh Idaho. It was found that they were on a very extensiv showed clearly a very interesting genesis.

No account of these deposits has ever been publi brief description will be of interest.

Mount Carribou, alias Mount Pisgah, alias Mount is a lone mountain which stands several thousand fee general level of the surrounding country, and attains a of 9,800 feet above the sea. The main features of it structure were described by Orestes St. John in 1877.*

A series of sedimentary beds have been raised a an inclination of 40° from the horizontal. The ma been carved by erosion out of this tilted mass which l west dip. The gulches upon the northeast slope of th have, therefore, been scored down across the bassett e strata.

The series includes slaty shales, sandstones, qua conglomerates; with a few strata of limestone and num calated sheets of eruptive rock.

*See Hayden, Geological Survey, 1877. Report on the Teton District.

On the northwest side and in the lower edge of a glacial amphitheatre at the very top of the mountain, is the mine and mill of "The Nellie Gold Mining Co." In the immediate vicinity are a great number of undeveloped prospects. At the foot of the mountain, mainly in Iowa and Bilk gulches, there are extensive placer deposits which were discovered in 1870, and have been worked intermittently ever since. A trip over both slopes of the mountain, together with a detailed study of the "Nellie" mine and the prospect workings in its immediate vicinity, established the following facts:

The eruptive activity of the district seems to have been specially concentrated near the summit. The interjected layers are here more numerous, and irregular masses of trachyte and other light colored eruptives were seen at various points. The interjected sheets are very regular in thickness and have not preceptibly shattered or faulted the strata. They seem to be composed of the same material: a dark, coarsely crystalline mass of hornblende with a little plagioclase feldspar. It is apparently a true diorite. The trachyte and other acidic lavas seemed from casual inspection to be present as dikes and surface flows, and evidently belonged to a distinct and more recent period of eruption than the diorite.

A great number of quartzite strata near the top of the mountain have been prospected by surface pits, and are found to be gold bearing. The surface-soil and gravel down the entire slope of the mountain on this side is said to pan well in gold. These strata range from three feet to sixty feet in thickness and a single crosscut tunnel at the mine, 246 feet long, cuts as many as six of the gold-bearing quartzites. The only mining development ever done is that upon the "Nellie" quartzite at the point mentioned. This bed is twenty-five feet thick with a southwest dip of 36°, and has been mined over an area 264 feet deep and 275 feet along its strike. The entire thickness has been stoped and milled.

The history of ore deposition indicated by this bed of quartzite is probably also that of all the others in the vicinity, and is as follows:

The quartzite has at some period been subject to tl and dissolving action of alkaline waters in which th soluble. This has honey-combed the mass with vugs of every shape. Some layers were entirely disso others, more dense, resisted the solvent action in p fragile skeleton, thus remaining, was crushed by the s bent strata as they settled down upon it, and the b reduced in thickness. This corroded and shattered m a very open channel for the circulation of subterra At some later period these had so changed their ch instead of dissolving silica, they now deposited carbon in the interstices of the bed, cementing its fragm together. Gold-bearing pyrite was also deposited wit and this deposition of pyrite seems to have begun after and fractures had been partially filled with pure calci the depth reached by the mine workings the pyrit almost entirely oxidized by the circulation of surface ing air. The liberated gold is therefore free, and coarse grains. The ore, as exposed, therefore show quartzite stained in every shade of yellow, red an oxide of iron. Cavities and crevices formerly filled pyrite, are now open, and but partly occupied by a d mass of calcite, clay and iron oxide in powder or cr pockets are particularly rich in gold. In addition to t described, small black crystals of specular hematit sprinkled through the ore. The deep gulches which these numerous gold-bearing quartzites, were erode deposition of the gold, and the material thus remov doubtedly supplied the extensive placer deposits at th mountain.

These gold-bearing quartzites illustrate in a very way the effect of neighboring eruptive masses upon th of ore. It is probable that the hot subterranean water culated in the neighborhood after the second period were the agencies which first dissolved the silica, and deposited the calcite, pyrite and gold. The entire re abounds in eruptive rocks of various kinds, and is note surface lava flows which cover great areas. The last s

eruptive activity still appears in the hot springs which are found here and there over this part of Idaho.

This corrosion of quartzite beds by hot alkaline waters, followed by a deposition of ore within the open spaces thus formed, is not a novelty in the Rocky Mountains. The quartzite gold deposits of Battle Mountain, Eagle County, and also those of Ouray, Colorado, indicate this genesis with unusual clearness and certainty. In both cases there are eruptive masses close at hand showing that all the conditions for intense hydrothermal activity have been present in the past.

From these and the many similar cases which have come under the observation of the writer, he believes that there is quite a general rule which prevails in the history of underground circulation in the neighborhood of any eruptive mass. The evidence indicates that waters circulating in the neighborhood of cooling masses are alkaline and corrosive in their early history, but gradually change their character so as to become nearly or quite neutral. This further indicates that water under heavy pressure, acting upon intensely heated lavas, so decomposes the feldspars as to extract the alkaline salts. Such alkaline waters are, of course, powerful solvents for silica, gold, etc. After the lavas cool, the process of feldspar decomposition is so altered in its character that these alkaline salts are produced only slowly or not at all.

NOTES ON THE GEOLOGY OF THE WESTER OF THE SANGRE DE CRISTO RANGE COSTILLO COUNTY, COLORADO.

By E. C. and P. H. van Diest.

Meeting of November 5, 1894.

With the approach of the prospecting season eac custom of many mineral seekers to consult topog geologic maps has become more and more prevalent, being to select localities which offer the best chance ore deposits, and to avoid regions where geologic cor unfavorable to mineral deposition.

Many a miner in Colorado, in referring to the H knows, from the colors on the various charts, what he ı ably expect to find in prospecting any particular field. shows Silurian or Lower Carboniferous limestone, cut overlaid by an eruptive rock (porphyry or rhyolite) once that if mineral abounds in the section, it is apt t tiferous; should the colors indicate a region of m granite penetrated by eruptive dikes, he concludes t not unlikely to be found. Areas where the Upper Ca and Cretaceous are shown to prevail, with the absence c he avoids, because experience has shown that in such the chances of finding remunerative ore-bodies are v

Not infrequently have these simple means been Surveyor General's office at Denver to give informati pectors concerning unexplored fields, and in not a fe has the search after mineral guided by the knowledge ε proven most successful.

It must be admitted, however, that the Hayden ı too small a scale, and the survey was often too hastily ε

forming the foothills, are reached. Here the stream easterly direction, winding its way for about three miles wide and shallow canyon which has been eroded from beds. At this point, according to Hayden, the lake beds against the Upper Carboniferous. No dark-red sandst as were observed in coming over Vista Pass, could be where, but we found instead, on the north side of the distance of a quarter of a mile, some quartzite beds form cliffs, while, further along, the stream flowed over ligh limestones and finally over granite.

Geologic Features.

Directly north of the creek a thin bed of con appears. It is composed of light-bluish and greenis pebbles cemented by oxides of iron and manganese. F this bed follow layers of quartzites whose total thickne mated at 100 feet. These quartzites are saccharoidal i ance, of pure white color when freshly broken, but sta film of iron oxide where they have been exposed to the of the weather. The quartzites are succeeded by a th argillaceous shale, and the whole section is topped by light-gray siliceous limestones for about 200 feet, where parting separates them from others of somewhat dark The limestones end abruptly against the granite along fault, as is shown in the accompanying sketch. This fa strike of N. 35° E. and a dip to N. W. of 52½° as has be by a shaft sunk on it, and an adit driven along it lower hill. The fault can be traced by the eye for quite a dist the mountain south of the creek. Although no fossils h found as yet in the described beds, it is clear, from a stra point of view, that the limestones are of Silurian, and t ates of Cambrian age. An igneous dike, about thirt width, runs through the limestone beds in a northerly a erly direction. It is of a dark purplish-brown color, very and fine grained. In appearance it resembles more t basalt occurring between the lake beds, and is distinctive cut from the younger basaltic overflow which caps the b and west of the Rito Seco. The dike has had no distu

admit of great accuracy in detail, the errors coming more and more to light as the later work of the U. S. Geological Survey has progressed in and about the most prominent mining districts. During a short trip last August along the west flank of the Sangre de Cristo Range we had particular occasion to notice that the Hayden map is sometimes misleading, and it is hoped that the resumed field work of the U. S. Geological Survey may be designed to cover all sections which have not been subject to geologic inquiry later than that undertaken under the direction of Hayden.

From a glance at the Hayden map, it would appear that south of Veta Pass to the south boundary of Colorado on the west slope of the Sangre de Cristo Range, no other sedimentary rock occurs than the Upper Carboniferous sandstone; that the older eruptives are lacking, from which the inference could be deduced that, in all probability, the region is barren of ore deposits. F. M. Endlich states in his report to Hayden:

"Taking into consideration the extensive area surveyed, the numerous exposures of strata and masses in canyons and on the slopes of hills, it is surprising that in 1874 and 1875 not more of the Palæozoic formation (than the Upper Carboniferous), has been found. The only conclusion possible to arrive at, is that they do not exist in the regions examined: whether the material that composed them has been metamorphosed, or whether they never were deposited there, are questions that will require a long time to solve."

We found, however, that the lower series of the Palæozoic were not entirely wanting in that region, and that the Sangre de Cristo range had not been an extensive land mass up to late Palæozoic time, but that a portion, at least, had been submerged in early Palæozoic period, leaving only small islands in the Silurian sea.

LOCATION OF THE AREA OBSERVED.

The district examined is on the Rito Seco. This little stream unites with the Rio de la Culebra near San Luis, the county seat of Costilla County, a region nearly in the center of the lower neck of the Pliocene lakes, named by Endlich the "Coronados Lakes."

Leaving San Luis the Rito flows for about six miles in a northerly direction through scattered debris; when the lake beds

fluence whatever on the limestone beds, as is shown by the cuts run into the limestone on either side of the dike.

Northerly, and higher up on the mountain, a light-colored porphyry was observed, but, owing to lack of time, there was no opportunity afforded to determine what the extent of this eruptive mass might be, and what connection, if any, it might have with the dike, nor could we determine if, in an easterly direction, other quartzites and limestones rest on the granite.

MINERALOGIC FEATURES.

Silver Ores.—Some years ago "mineral" was found on the surface near the fault. Probably, under the impression that the ore came from a fissure vein, a shaft was sunk on the fault, and lower down an adit was driven. In these workings some mineral was encountered which occasionally contained fair value, but the general results not being such as to invite continued development, the workings were abandoned. Later on renewed prospecting disclosed an ore deposit in or above a quartz parting in the limestone beds, which body has been followed by an incline and further developed by several open cuts. At the time of our visit the deposit had been struck in a shaft which had been sunk at a depth at which it should have been encountered according to the measured dip of the limestone beds and the distance from the outcrop. The thickness of the ore-body had not yet been determined at the point where the shaft had cut it, but from appearances in the short incline, it was reasonably expected to reach several feet.

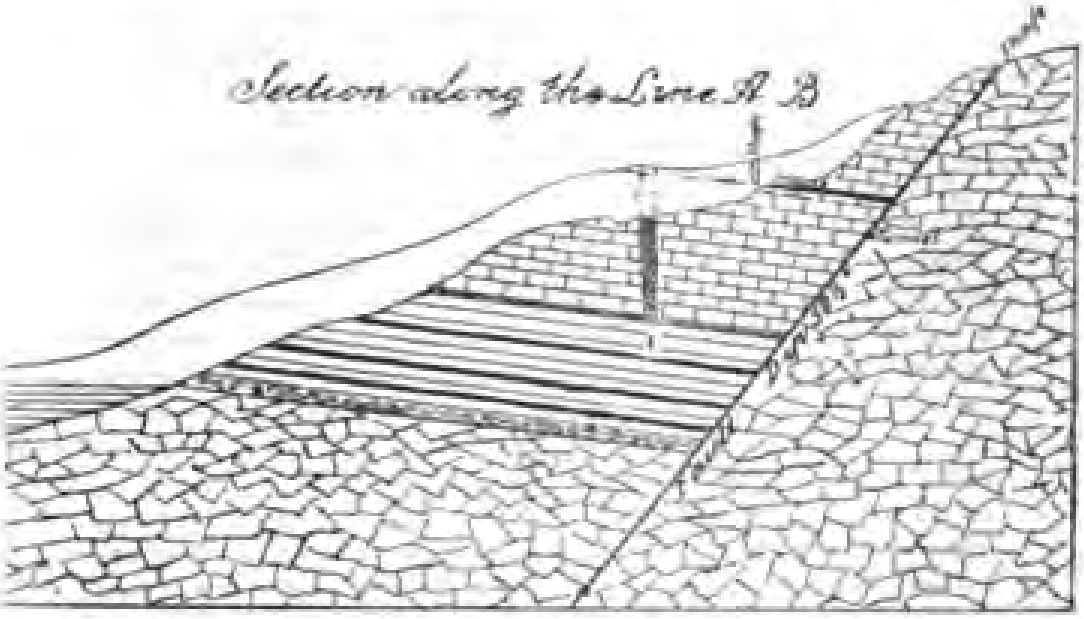
The ore consists of a mixture of galenite, anglesite, and cerussite associated with some sulphides of silver, copper and iron. Assays of the material showed it to carry from 40 to 80 ounces of silver per ton, with a little gold.

Gold Ores.—Close inspection of the rusty faces of the quartzite cliff has lately revealed that three distinct layers of auriferous iron pyrites occur between the quartzite beds, the lower one measuring about 12 feet in thickness, the next about 14 feet and the upper one 8 feet. At the time of our visit a drift had been run in the middle seam for a distance of 40 feet. The breast and sides of this drift stood in almost solid iron pyrites. This pyritic

ore, as broken down, contains from $5.00 to $15.00 p
gold.

So far no copper, zinc or other sulphides have bee
with the deposit. The field, although but little explore
be of promise, and it is to be hoped that development w
uninterruptedly prosecuted.

Map of a portion of the Western Slope of the Sierra de Cristo Mountains
Costilla Co. Colo



Conglomerate, Quartzite, Shale (Cambrian); Schist, Limestone (Silurian); Granite (Archean); Porphyry; Igneous Dyke; Lakebeds; Orebodies

THE SAMPLING AND MEASUREMENT OF ORE BODIES IN MINE EXAMINATIONS.

By Edmund B. Kirby.

Meeting of December 3, 1894.

CONTENTS.

Investors who contemplate the purchase of mining property, or who have to decide some question of business policy concerning property they already own, are frequently unable to judge of such enterprises or lack the time to investigate for themselves. It is then customary to call in the aid of some experienced mining engineer, in whose judgment and integrity absolute reliance is placed. Such men, who make a specialty of mine examinations, now constitute a large class of the engineering profession, and are commonly known as "mining experts."

The work is peculiar in that the engineer is generally called upon, not merely for his opinion on technical points, but as the judge of the investment. This makes the responsibility unusually heavy, since his decision is generally accepted as final, and the amounts involved are large.

The Scope of Examinations.

The examination of a mining property necessitates into everything that bears upon its value as an investme the principal facts to be determined are: The net v already discovered; the chances indicated for further e the best metallurgical treatment, and the past record o erty. Estimates are required of operating expense development, equipment, etc., together with the p expected. The price and terms of payment, the work needed, and the time required for its recovery; the title, the risks from litigation, flooding and other acc enter the problem.

After these and all other pertinent facts have bee determined, and arranged clearly before the mind, the tion at issue of investment or policy, is decided by th judgment which comes only from experience, and k rules or formulæ.

Estimates of Discovered Ore and Their Relative Importance.

It is the object of this paper to discuss only one work thus outlined: the valuation of discovered ore b and measurement. This has little or no importance in either because no ore has yet been found, or its quanti or other matters are sufficient to decide the question ment. In other mines the amount of discovered ore is chief considerations, and requires an accurate estimate difficult and laborious undertaking, often calling resource of technical skill. But little has been publ the subject in professional literature, and every en selected or evolved his own methods, generally with li edge of, or reference to those of others. It is, therefor to describe the methods which the writer has found e ive, in the hope that others engaged in the same fie contribute to this important subject.

TERMS DEFINED.

It is desirable to first define the exact sense in which the following terms will be used in this article.

Ore-shoots are those portions of an ore deposit where the ore bodies are so frequent, or so grouped, that partial boundaries of some definite shape and direction may be drawn around them, and such specially productive portions thus distinguished from the rest. The term is also applied to a single ore body which has considerable extension in one direction.

An *ore-body* is, in general, a solid and fairly continuous mass of ore, which may include low-grade and waste as well as pay ore, but is individualized by form or character from adjoining parts of the deposit.

Pay ore includes those parts of the ore body which are both rich enough and large enough to stope with profit.

In order that the facts may be clearly presented to the mind, the discovered ore is separated into two classes: *ore in sight* and *probable ore*.

"*Ore in sight*" is that contained in blocked portions of the deposit, each of which is so clearly exposed (by sections on several sides) that the limits, continuity and value of its contents may be determined and relied upon with reasonable certainty. Such ore is thus a proven resource, ready for extraction, and is expressed in terms of net profit.

"*Probable ore*" is a more elastic term, and includes any blocked ore not certain enough to be "in sight," and all ore which is exposed for sampling, but whose limits and continuity have not been proved by blocking. It may also include any undiscovered ore which, from the evidence, is too strongly probable to be classed under the heading "chances indicated." Probable ore may be estimated in several distinct divisions, and the relative degree of probability assigned to each.

In practice the ore-shoots and bodies of a deposit, themselves irregular in form, are found penetrated by every conceivable arrangement of mine workings, from orderly shafts and levels to the "corkscrew rat-holes" of the prospector or lessee. Thus every mine presents its own special problems.

The work of sampling and measuring both cla carried on at the same time and by the same me intended to estimate only the pay ore; and since limits are those which will afterwards be defined l stopes, it becomes necessary to ascertain what th extent of these excavations will be, and measure within their limits.

In order to secure working room, the dimensions will often be greater than those of the pay ore, and include barren rock and non-profitable ore. No atte to these worthless portions if they can be kept separ ing. If, however, ore streaks and waste are so inter it will be necessary to break them down together, and richer portions afterwards, the measurements and then made on the entire average mass as it stands.

Sampling Ore "In Place."

The Four General Systems in Use.

First. A large number of small samples for a which is quickly and roughly taken, are cut from line at small intervals over the area of each plane section.

Second. A limited number of large samples fo carefully and laboriously taken, are cut from lines c wider intervals.

Third. Mill-runs. In this system each sample to a mill where its actual yield is ascertained, or it some sampling or smelting works where an assayer's pared from it by accurate sample reduction with mac samples are very few in number on account of the time required. In the first case each one must be large s be milled by itself, and furnish enough product to c order that a sample may be representative, it is genera of ore from several points.

Fourth. Panning in a miner's gold pan, or hor is applied to a large number of very small samples, e has been roughly taken, and pulverized for the purpo or bucking-board, or in a mortar.

CONSIDERATIONS IN SELECTING A SYSTEM.

The first system is adopted to save time and expense whenever the second or third is unnecessary. There are many samples to assay, but the work of taking each one is small. It gives correct results only when applied to soft ore bodies where the sample may be cut out easily and uniformly by pick, gad or moil. The method is permissible only when the richest portions of the ore are not too much scattered in spots, streaks, or special layers, and are not too high in grade. In other cases it is applicable to very thin sheets of ore. It is frequently used on sections of probable ore, and for daily working samples in the operation of a mine, or in other cases where a quick, rough approximation is desired. Each sample may be small, requiring reduction to only half or one-fourth its bulk for the final package; again it is often sufficient to break so little from each point that it may be sent entire to the assay office. There may be a large error in any single sample, but this is balanced in averaging by the great number taken.

The second system is necessary for all hard ore (requiring blasting), and for bodies in which the variations of value are great, or where the richest portions are irregularly distributed. It is always expensive and laborious, but generally the most accurate method, and is therefore most frequently employed. The sample broken is always large enough, from 25 pounds to 50 tons, to correctly represent the variations along the line of its cut, and is reduced to a small package for transportation to the assay office. Each sample is accurate, the error involved in the system being that due to the wide intervals between samples and the small number to be averaged.

The third system, "mill-runs," is rarely adopted unless a mill happens to be close at hand, and the ore body is of such size, with values so variable or scattered, that samples by the second system would be very large (10 to 50 tons), and the work of hand reduction therefore very great. If mill runs are sent to a sampling or smelting works, the expense and delay is generally greater, and the results are no more serviceable than those of careful hand reduction at the mine. Mill runs are more useful for metallurgical tests than to determine the value of ore in place. For the latter purpose their results are frequently deceptive, and they are there-

fore dangerous in unskilled hands. This is because o is so tedious and expensive that few are made, and th scattered points of the ore deposit are tested. If en composed of ore from various points, it is practicall to have the right proportion from each one, and the subject to the serious errors of mixed samples (page 9 the mill is often metallurgically unsuited to the ore, a difficult to guard against fraud. When it is necessar system, extra money and time should be provided, and made numerous enough for safety.

The fourth system, panning, is restricted to fr and while it is not intended to furnish exact figures o very useful as an auxiliary method to determine the re bution of gold and the limits of pay ore. In the regul of a mine it is often used to guide the work, and if quently by assays or mill results, mine foremen so come remarkably expert in judging the exact value fro This cannot be done with unfamiliar ores, but even generally possible to distinguish roughly between o below pay.

SAMPLING OPERATIONS.

Distribution of Sample Lines. Each sample is cut making a trench or groove of the same dimensions and so placed as to cross any principal lines of vari grade or character of the ore. The lines of sample cut tially distributed over the area of the plane sections positions as nearly equi-distant as possible. The bound pay ore and low grade or waste, is provisionally fixed b If in doubt about a low-grade streak, a separate sampl it. The width sampled is always the width measured.

Taking Samples.—In the first system the samp shallow, uniform grooves—say, three to six inches deep ally within two or three feet in length.

In the second system the quantity broken is fixe the length of the line, and partly by the distributio along it. The usual range is from 50 to 400 pounds. secure reliable averages across a large and spotted

writer has found it necessary to break 25 and even 80 tons for single samples. These extreme quantities, however, were tested by mill-runs. The trench or groove is blasted out and afterwards trimmed to uniform dimensions. Large samples, exceeding, say, 300 or 500 pounds, may be received upon the bare floor of a level, but when the bulk is less it is handled on canvas. This is protected from injury by covering with loose plank before blasting.

It greatly facilitates the subsequent reduction of the mass broken down to work upon a smooth surface. Thus, where many samples are to be taken along levels, it is best to lay temporary platforms, made of loose plank, beneath the sample points. A platform may be moved and re-laid in ten minutes, and, for a heavy piece of work, three will do for a working force of one assistant and ten or twelve miners. In taking samples down a shaft or winze, a temporary platform is placed at each point. Work done in stopes also requires the use of movable platforms erected in any convenient way.

Samples from Loose Material.—In mine examinations it is frequently necessary to take samples from loose ore, dumps, mill tailings, etc. To obtain a sample of ore which is being extracted, one or more shovelfuls are taken out of each bucket, or car, and thrown into a pile to make the sample. In the case of sacked ore, a few pounds are taken from the top of each sack, or when greater accuracy is necessary every second or fourth sack is emptied on the pile. A pile of ore on the dump may be roughly sampled by taking one or more shovelfuls from each one of many points, distributed at equi-distant intervals over its surface. The only safe method, however, is to drive several open trenches or tunnels through the mass, taking, say, every tenth shovelful for the sample. For a dump of mill tailings, a boring tool is used, made of a sixteen-inch piece of two-inch pipe. This is easily carried to the mine and attached to a handle of convenient length. The dump is pierced by bore holes at equi-distant intervals, and the borings from each hole are reduced and assayed separately.

Reduction of Samples.

The reduction of a sample from its original bulk to that of the assayer's package, does not differ in principle from the process

followed at sampling and smelting works, but
accuracy. Moreover, instead of using machinery
methods, the reduction must be made on the spot i
samples varying greatly in grade and quantity, and
disadvantage of underground conditions, from sho
to the cramped quarters at the bottom of some
Therefore no two samples are reduced in the same
fixed rules are impossible, so that it becomes necess
with some detail the fundamental principles of t
applied to underground work. It is not, however, w
pose of this paper to enter into the many practi
manipulation, although accuracy in hand reduct
largely upon skill in these small points.

The process of reduction requires the continual
two consecutive operations. First, crushing to a cert
size; second, the impartial selection of a fractional p
mass. The latter operation comprises the two conse
mixing and cutting, these being performed once or
until the definite fraction desired is obtained.

Whatever final limit of error is permitted for a
it is a rule that at each repetition of this series of op
must be performed with more care than before. In
of this a very large sample requiring many repetition
finally reaches a stage where so much care and accur
sary that handwork is too laborious. At this poin
whatever its bulk, should be made up into the final
sent to the assay office where crushers, grinders, the b
and fine sieves are available for the final operation
bulk of the final package is fixed by deciding wheth
to incur the expense and delay of pushing reduction
further at the mine, or, on the other hand, to bea
transporting a greater weight to the assay office. I
packages generally range between four and ten po
quently reach twenty-five and fifty pounds, especia
assay office is near.

Crushing.—The ore is broken so that no lump sh
maximum size decided upon. Very rich lumps are b
in order to distribute their value. During the fi

reduction a pair of sieves with $\frac{3}{4}$ inch and $\frac{1}{2}$ inch meshes are useful to separate out those lumps which require breaking.

Relation of Maximum Size to Bulk.—The instinctive judgment derived from long experience in sample reduction, is necessary to promptly decide the maximum size, and the fraction to be selected at each series of operations. These must be so taken as to keep the work within the limit of error allowable, and at the same time have it move rapidly. Since this relationship of maximum size to bulk depends on several variable conditions, and is never the same for any two samples, it is impossible to illustrate it in a very satisfactory way. The first column of the following table will, however, give an idea of the maximum sizes selected by general judgment for two typical cases of reduction.

Reed's formula* is the result of an effort to find a rule which will express mathematically the effect of the aforesaid conditions for any case. It does this in a very satisfactory manner for the accurate work of sampling and smelting works where the limit of error is one per cent., and it is of interest here to compare the above figures taken from practice with its theoretical results. The other two columns, therefore, show the sizes calculated from the formula for limits of error of five and ten per cent.

The differences between these and the practical sizes are mainly due to the fact that for hand reduction several of the constants used in Reed's formula change with each repetition of the series of operations. There are also more repetitions than with machine reduction.

MIXING.

The three following methods of mixing are used in mine work:

Pouring from One Pan into Another. — This imperfect method is used only in the final stages of reduction, and when it is to be followed by riffle cutting.

Rolling in Canvas.—This is the best method known, and is used whenever the sample is small enough to handle, say, under 200 pounds.

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*Columbia School of Mines Quarterly, 1885. Vol. VI, p. 351.

Table Illustrating the Relationship of Maximum Size to Bulk in Two Typical Cases of Hand Reduction.

An average ore is taken, containing $10 to $50 per ton, and it is assumed that the richest lumps of full size do not contain more than five times the above value.

First Example. Reduction of an 1,800 pound sample to 7 pounds by taking one fourth after each crushing.	Sizes Adopted in Practice.	Theoretical Sizes as Calculated by Reed's Formula. Maximum Size of Lumps (Diameter in Inches.) Allowing a Limit of Error of	
		5 per cent.	10 per cent.
1,800 Pounds prepared for reduction by crushing to	4 in.	3 in.	38 in.
The 450 pounds prepared by crushing to	2	19	24
The 112 pounds prepared by crushing to	1	12	15
The 28 pounds prepared by crushing to ..... And then reduced to 7 pounds	92	075	09
Second Example. Reduction of a 300 pound sample to 5 pounds by taking one-fourth after each crushing.			
300 Pounds prepared for reduction by crushing to	25 in.	17 in.	21 in.
The 75 pounds prepared by crushing to	19	10	13
The 19 pounds prepared by crushing to ..... And then reduced to 5 pounds.	05	06	08

Coning.—The sample is shoveled into a conical pile so as to secure a uniform radial distribution.

The care used in mixing depends on the method of cutting which is to follow. Quartering requires very accurate mixing. It is not necessary for shovel or riffle cutting, but even here the work is improved with little trouble by roughly mixing before each cut.

CUTTING.

Three methods of cutting are used in the reduction of mine samples.

Shovel-Cutting.—The pile is shoveled over, one shovelful out of a certain number being taken to make the sample. The ratio depends on the bulk and the accuracy required, but may be, say, one in ten for a bulk of over five tons, one in three for 1,000 to 2,000 pounds, and one in two for smaller quantities. The latter is the ratio used in most cases even for larger amounts.

Quartering.—The pile of ore, thoroughly mixed, symmetrical in shape, and with the coarse and fine symmetrically distributed, is flattened, and divided into quarters, two of which, diametrically opposite to each other, are taken.

Riffle-Cutting.—("Splitting on a hand-riffle.") The size preferred for most underground work has several parallel troughs 1¼ inches wide, and the same distance apart, so that it may be used whenever the sample has been crushed small enough to pass this space. Riffle-cutting is the most accurate and generally the most rapid method in use.

Choice of Cutting Methods.—Shovel-cutting is specially adapted to a large bulk, but when this becomes small, say, 150 pounds, it requires too much labor and skill to insure accuracy, and either of the other methods is used. In the absence of a riffle, the work is finished by quartering, but otherwise the riffle is taken as soon as the lumps are small enough. Quartering is therefore used in the intermediate stage when the bulk is too small for rapid shovel work, but not yet ready for the riffle.

Assay Office Work.—The assayer is always instructed as to the crushing size, and further reduction of the sample package to the final assay pulp. From his results the assay value of each sample

is so calculated as to conform to the plan of cost estimate adopted. (See page 104.)

Samples for Special Purposes.

Sorting Tests.—In mines where the ore broken and hoisted must have its richer portions sorted out to make a marketable product, it is necessary to determine the percentages of total value and of tonnage, which are thus available. Sorting tests are made upon the mine samples, using those coarsely broken portions which were rejected during the first operations of reduction. These are mixed proportionately to form a few group samples, and experienced ore sorters from the neighborhood are put to work upon them. All the resulting products from sorting each sample are then weighed or measured to determine their relative weights, and each product reduced to the assay-office package. When underground sorting is done, the results of this are also determined.

Mixtures for Analysis.—Since the market value of smelting ore depends largely upon its chemical composition, proportional mixtures for analysis are prepared from the final pulp samples of all such ore.

Metallurgical Tests.—When metallurgical tests are required, such as those for concentration, free-milling, pan amalgamation, wet processes, etc., proportional mixtures are made for the purpose, often out of the rejected portions of the mine samples. In securing mixtures for tests on a large scale the difficulties incident to mill-runs are kept in view.

Rejection of Excessively High Assays.

Ore bodies frequently contain occasional streaks or pockets of high-grade silver minerals or metallic gold, and a sample here and there may chance to include one of these, thus giving an assay far above the general average. Since all the samples taken are at best few in proportion to the mass represented, the error introduced by averaging in such assays may be very great. It is therefore necessary after plotting the assay results to reject such values, and some arbitrary figure corresponding to a mean of the next adjoining samples, is substituted for use in averaging.

Danger of Mixed Samples.

It is here necessary to call attention to the danger incurred in the practice of uniting a number of samples and assaying the mixture. It is practically impossible to mix in correct proportions, and this plan also fails to furnish the necessary information about the distribution of values, and the limits of pay ore. The results are also liable to serious error from excessively rich samples as explained above.

The Measurement and Assay Value of Sectional Areas.

The Determination of Areas in Sight.

All the plane sections which have been selected to serve as the basis of measurement are plotted to scale. The drawing of each section includes all workings, measurements and ore limits shown, together with the sample lines and the figures of their length and assay value. Upon the section is then sketched that portion of the ore-body which, according to judgment, is safely proven by the mine workings within the plane of section, and may therefore be considered "in sight." In this operation a variety of problems is presented, those commonly occurring, being illustrated by the typical cases shown in Figs. 1 to 7.

In each figure the outer heavy black line shows the actual ore body. The heavy dotted line is the limit decided upon for the portion in sight. Within the thin black lines are the portions supposed to be pay ore at the time of measurement, and, therefore, sampled. The shaded areas show the actual pay ore as finally fixed by the sample results.

Fig. 1 is the section of an ordinary vein presented in a level where the entire thickness of the ore body is visible.

In Fig. 3 the actual bounding surface of the body appears at *A*, *B*, *C*, and thus indicates the most probable direction to be given to the curved line limit for ore in sight.

In Fig. 2, where no boundaries are disclosed and the ore has no definite structure to guide the judgment, the curved line *A*, *B*, *C*, is taken.

In Fig. 4, the ore-body is an irregular mass whose contents

are arranged in streaks or layers definite enough to justify the limit *a, b, c, d.*

Fig. 5 shows a thick sheet composed of regular layers in which the limit *a b c d* may be taken if the entire mass is pay ore, but if it is limited to a few streaks like the two shown, their continuance is less certain and *a b f d* is taken.

In Fig. 6 a thick sheet of ore in layers is shown by the single crosscut *K* in the long level *e f.* In drawing the limit *a b c d e f g h*, it is a matter of experienced judgment how much of the sheet is really proven by this crosscut, and how great a length may be given to *a b.*

Fig. 7 is a similar sheet in which the layerlike structure of the ore-body warrants the limit *a b c d.* When including areas not actually visible, care must be taken that no one is of such excessive value that its possible variations will introduce a serious error into the final total estimate.

Fixing the Boundaries of Pay Areas.

The actual pay areas as included within the intended stopes, are determined from the assay values of the samples. Whether these are above or below "pay" is generally evident from inspection of the values as they appear upon the section drawing, but in many cases it is necessary to make an approximate estimate of cost for each point. As this calculation is sometimes laborious, the most convenient methods are illustrated by the following three special cases.

In all the sections the figures show the sample numbers, and lines indicate the sample cuts. The length of each sample cut in feet or inches, and its assay value in dollars per ton are also given for each sample.

Approximate Yield and Cost of Stoping Per Ton of Ore Broken.

Taking the ordinary vein shown in Fig. 1, it has been found that the ore in place measures 13 cubic feet per ton, and the cost of stoping is $16.00 per fathom of 36 square feet. The sorting tests have shown that one ton of average ore broken yields 0·50 ton of shipping ore, and that this contains 75 per cent. of the total

value which was in the original ton broken down.* It has also been estimated that the approximate cost of hoisting, sorting, shipping, and smelting will be $12,00 per ton, figured upon the tonnage of ore broken. The following table is then calculated:

Thickness of the Pay Streak at the point considered.	*Tons per Square Fathom of Ore Sheet.*	*Cost of Stoping per Ton.*
A streak 4 inches thick yields.....	0·92	$17.33
" " 6 " " "	1·38	11.55
" " 8 " " "	1·85	8.67
" " 10 " " "	2·31	6.93
" " 12 " " "	2·77	5.78
" " 14 " " "	3·23	4.95

Applying these figures to any doubtful sample-point such as No. 20, the following estimate is made:

Cost of stoping an eight-inch streak per ton	$8.67	
Cost of hoisting, sorting, shipping, and smelting per ton of ore broken	12.00	
Total expense,		$20.67
Value saved is 75 per cent of the assay value of $19.00		$14.25

Thus demonstrating that the ore at this point will not pay to extract.

All pay points having been determined and marked, the pay areas which are to be included within the stopes, are sketched. (See shaded portions of the figure). These areas are then measured by scale, or calculated, and the length and average width of each one is also determined.†

*While the results of sorting vary according to the grade of the ore, and are not the same for any two points in the pay streak, it is nevertheless accurate enough for this purpose to use the average figures.

†Of the well known methods for measuring such areas the following will generally be found most convenient and rapid for this purpose:

A small piece of thin transparent paper is ruled with parallel lines, two, five or ten feet apart by scale, as the case may require, and this is placed over the area to be measured. The lengths of the strips thus formed are then measured by a scale.

In Fig. 5 the plane of an irregular drift and cross-cut presents a fair cross-section of a wide vein whose structure is in parallel layers. Four of the ore streaks shown have been sampled, but only two of these have proven to be above the pay limit. They are so far apart as to require stoping separately, and are therefore treated as though each one was a distinct vein. The pay areas are fixed as in the previous case, and extended to the limit adopted for ore in sight.

Fig. 2 illustrates the application of this method to the section of an irregular body of milling ore. It is in this case a more simple matter to compare the assay value of each sample with the total cost of mining and milling, plus the tailings loss, this sum being here taken as $5.00 per ton.

The pay areas outlined are carried only to the limit previously fixed for ore in sight.

Methods of Averaging the Samples.

In each section the value of its pay areas, either singly or jointly, is determined by averaging all the samples within these areas. In doing this each sample is given a weight proportional to that part of the area which it represents.

When uniformly spaced, as in some parts of Fig. 1, each sample value is multiplied by the length of its line and the sum of the products divided by the sum of these lengths.

When irregularly distributed, it is necessary to sketch by judgment that portion of the pay area which may be allotted to each sample. In doing this due regard is paid to the structure of the ore, whether homogeneous, in layers or otherwise. In every such portion the number of square feet is then measured, and multiplied by the value of its sample. The sum of these products divided by the total area gives its average value.

In Fig. 2 the pay area *e f j m n l* has been exposed for sampling only at two places, *A* and *C*. The average value of each part thus exposed, such as *e f d i*, is first determined by letting each sample represent the ore half way to that next adjoining. Sample No. 1, therefore, represents the portion *e f d;* No. 2 represents *e d g h;* and No. 3 represents *h g i*. The average value of part *m n l k* is determined in the same way. The number of square

feet in each of these two exposed parts is then multiplied by its average value thus determined, and the sum of both products divided by the sum of both areas. The result is taken as the average value of the unseen part *e i k l*. The part *d j f* is assumed to have the same average value as *e f d i*.

In Fig. 5 a variation is made from the plan just described because of the layer-like structure and the distance between the exposed places. In the upper pay streak the average value determined as before at each of the two exposed places *h m l g* and *n q u r*, is assumed to extend half way through the unseen portion to the line *e z*.

Fig. 8 illustrates the use of this method for averaging samples in the section of probable ore exhibited by a vein outcrop. The samples were taken wherever the ore was uncovered, from scattered outcrops and shallow prospect pits. The structure of the vein was very regular, being in uniform layers, so that each sample was assumed to represent the layers cut by it for a distance half way to the next adjoining samples. For instance, the sample line *a d*, represents the area *a k l b* + *b i j d* + *c g h d* + *a c f e*.

It will be noticed that these fractional areas are not all represented with the same degree of probability, and sample *o p*, for instance, is more certain to correctly represent the area *p q t u* than area *o r s q*. This is because the samples could not be uniformly distributed. If it happens for this reason that any areas are not well enough represented for the object in view, they should be excluded. In this case it was sufficient for the purpose to include all parts of the area within *w x v r*.

The same method is used for all special problems of this kind such as where samples are taken irregularly over a large open quarry of ore, or where a mass is pierced by scattered bore holes, or exposed by test pits. A case of the latter is shown in Fig. 13 where the thickness and value of the ore-sheet cut by each pit is given by figures. The outer line is the adopted limit within which the ore-body is considered probable, and the dotted lines show the area allotted to each sample point. Each area is multiplied by the ore thickness to give the volume, and this is multiplied by its sample value. The sum of the products is then divided by the sum of the volumes.

The Measurement and Assay Value of Volumes.

The object of measurement is always to determine the *most probable* volume and value indicated by the sections for the unseen interior of a block. How closely these figures agree with the facts depends on the regularity of structure in the ore deposit, and also on the proportion between the volume of ore in the block and the area of ore exposed in its sections. Blocks are frequently thrown into "ore probable" because the distance between the two opposite faces is too great for the small amount of ore exposed in them.

The judgment acquired by long experience in the structure of ore deposits is necessary to decide these questions so that the results will have the certainty required for "ore in sight." It is also necessary to judge how much these most probable figures may vary from the truth, and apply the safeguards and the factor of safety hereafter mentioned (page 105).

Ore Sheets of Ordinary Thickness.

The cases most frequently presented in practice, are illustrated by Fig. 9, which is a section on the plane of an ordinary vein whose thickness does not exceed the width of the mine workings. The pay areas determined in the various sections are indicated by heavy black lines.

Blocks with Two Parallel Sections.—This case is illustrated by block *C*. It is treated as a prismoid whose end areas are constituted by the sums of the pay areas in each section. Unless one end area is very much smaller than the other the use of the prismoidal formula is an unnecessary refinement. It is generally sufficient to average end areas and multiply by the perpendicular distance.

The average assay value per ton is obtained by multiplying the average value in each section by its total pay area, and dividing the sum of these products by the sum of the areas.

Blocks with Three Sections.—Block *B* is of this class, having the sections *n k*, *i j*, *g h*. Two of these sections are often found to be more representative than the third. Its results are, therefore, sometimes omitted in whole or in part, and sometimes merely

given less weight. When all the sections are used the block is measured by the *method of equivalent figures.*

Taking block *B* as an illustration, the sections *g h* and *i j* each have one pay area while section *n k* which cuts two ore bodies chances to expose three pay areas. The number of square feet, average value, actual length and average width, have been determined for each of the five areas. The purpose is to sketch within the block an average figure assumed of a certain uniform thickness, and of such shape that it will be the most probable equivalent of the pay ore included in the actual stopes.

The uniform thickness adopted for this purpose is the average thickness of the pay ore, which is found by adding the five pay areas and dividing by the sum of the five lengths. Each pay area is now divided by this uniform thickness, giving the length of an equivalent area, and these *assumed lengths* are plotted to scale in their average positions. (See lines *a b*, *w r*, *q s*, *t u*, *v x*.)

The equivalent figure shown by the shaded portions of the block, is now sketched from these lines. In doing this due regard is given to the indicated structure, the object being to place the figure in the position probably occupied by the assemblage of pay portions. Assuming that in this block the main shoot evidently passes from *a b* to *x q*, the figure is drawn symmetrically between them, allowing each area to represent conditions half way through the block. The area *w r* thus appears to be a side projection, and the figure *w r z y* is drawn from it to meet the main figure at the nearest point. The area of the entire figure is then measured by scale, and multiplied by the uniform thickness. Block *G* illustrates a similar case.

Fig. 10 shows block *B* when the structure indicates that one or more bodies extend between sections *i j* and *k l*. This gives two equivalent figures *a b v x* and *w r q s e t u*, or it may be treated as a combination of the simple cases under 1 and 3.

In the method of equivalent figures, the average value is determined by multiplying the value of each pay area by that portion of the total volume which it represents. The sum of the products is then divided by the total volume.

Blocks with Two Perpendicular Sections.—In the simple case illustrated by Fig. 12 the pay area in each section is converted to

an equivalent trapezoid like *a b c d*, whose shape conforms, as closely as possible, to the average actual shape of the pay streak by having the same length and by being wider at one end than the other, if necessary. The ends *a b* and *c d* are parallel. The two trapezoids are sides of an irregular wedge to which the prismoidal formula is applied.

Fig. 11 shows in perspective the case of block *F*, Fig. 9. Here the areas are also converted to equivalent trapezoids and the figure cut into wedges by the intersecting plane *c d f e*. Blocks *A* and *H*, Fig. 9, also illustrate this case, the method of equivalent figures being used for block *A*.

In wedge measurements the average value is calculated by multiplying the total pay area of each section by its value, and dividing the sum of the products by the sum of the areas.

Ore Deposits of Other Forms.

In irregular bodies, blocks are usually found with two parallel sections, but at times peculiar and more difficult problems are presented. The section planes are occasionally at an acute angle to each other, and while the method of the third case will generally apply, no rule can be given when each section shows several irregular pay areas. For such problems special expedients may always be devised. Masses cut by test pits or bore holes have their volume measured as explained by Fig. 13.

In practice blocks are often found with their contents partly stoped out, offering problems more complicated than the typical cases described. Additional planes of section are usually afforded by such stopes, and it is generally necessary to divide the block contents into several parts, each of which is measured separately. In such cases there is no difficulty in applying the principles already illustrated.

Rapid Approximate Methods, Dumps, Etc.

Rapid approximate methods are frequently used for preliminary estimates, or to check the results of detailed measurement and sampling, or to determine probable ore, or in estimating the chances for further discoveries, etc., etc.

Sometimes the contents of an ore-shoot or body are estimated

from the average yield per unit of area or of length of other portions already worked.

Again, a continuous sheet of ore is sometimes so intersected by mine workings as to expose and prove the sheet within the area bounded by a line circumscribed about these workings. It may then be unnecessary for the purpose in view to estimate each block separately. The entire area which is considered proven, is measured as a whole, and the number of square feet of vein area excavated by the workings, is also measured and deducted. From the total yield of the area already worked, that of the remaining portion may be calculated.

When this quick method is applied, with judgment, to the proper conditions, and the actual figures of production are known with *certainty*, its results agree very closely with those of detailed measurement and sampling, and are often used to check them.

Dumps are measured by ordinary cross-sections, but since they are generally on an inclined hillside, it is not always convenient to measure from the horizontal base plane of an instrument.

A string or line of sight between two poles is often preferred, and is accurate enough for the purpose. Irregular sections are always plotted.

The Reduction of Volume to Tonnage.

This is done by using the factor of cubic feet per ton for the ore in question. This factor is derived in two ways:

By Calculation from the Specific Gravities of the Minerals.

This method is applicable only to ore composed of simple minerals or simple rocks or their combinations in known proportions. A safe margin is always added to the theoretical result because the standard specific gravities given, are the figures for pure, dense, crystallized specimens, while in ore deposits the minerals are often more or less altered and somewhat amorphous and porous.

The following table gives the calculated figures for these minerals and rocks of which ores of the precious metals are mainly composed. The first column is the theoretical result, calculated

from the average specific gravity, and the second gives a general figure for practical use.

Figures thus assumed from calculation are always applied with much caution and judgment, because when rocks are so impregnated as to become ores they are generally full of small fractures and may be spongy or porous. The figures for practical use are calculated from the minimum specific gravities given by the authorities with an addition of about five per cent. for variations, crevices, cavities, etc.

Number of Cubic Feet Per Ton.

Material.	*Number of Cubic Feet of Solid Material in Place, Per Ton of 2,000 pounds.*	
	Theoretical Figure Calculated from the Average Specific Gravity. (For Pure Unaltered Specimens.)	*Figures for Practical Use.*
Galena	4·3 cu. ft.	4·7 cu. ft.
Pyrite	6·4 "	7·0 "
Blende	8·0 "	8·5 "
Hematite	6·6 "	7·5 "
Limonite	8·4 "	9·4 "
Dolomite	11·4 "	12·5 "
Limestone, Andesite, Syenite	11·9 "	13·0 "
Vein Quartz, Granite and Granitic Rocks	11·9 "	13·5 "
Clay, Quartz, Porphyry, Trachytes, Rhyolites, etc.	12·3 "	14·5 "
Vein Quartz with 15% Galena	10·7 "	12·2 "
Vein Quartz with 15% Pyrites	11·1 "	12·5 "
Vein Quartz with 10% Hematite	11·4 "	12·9 "

By Practical Tests.

Oxidized ores are generally amorphous, loose and porous, and

cannot be calculated. Their volume is, therefore, determined by practical test by any of the following methods.

In a thin sheet the ore may be stripped and several tons broken down and weighed; after carefully measuring the thickness and area broken to determine its volume.

In a mass of ore the writer has used the figure obtained by carefully stoping the right rectangular prism to be filled by one "square set" of timbers.

The determination is made on a small scale by filling a bucket, tub, or box, of measured volume with weighed, coarsely broken ore, and then pouring in water level with the top of the ore. The total volume occupied is then measured, the water is poured off and its volume measured; the difference being the volume of the solid ore. Occasional determinations of this kind on various ores soon make it possible to select a safe factor in most cases by judgment, since the principal object is not scientific accuracy but safety.

Loose ore piled on dumps in pieces from head to gravel size will have from 35 to 50 per cent. of interstitial spaces, the percentage being greatest if the lumps are somewhat equal sized. Thus a dump with 40 per cent. of spaces, and composed of ore averaging 12·7 cubic feet per ton in place, will measure 21·2 cubic feet per ton.

Estimate of the Total Net Value.

The net profit, or *net value* of the ore measured and sampled, is generally figured by the ton, either by a separate calculation for each individual block, ore-body, or shoot, or by one calculation for the entire mine. Conditions are generally uniform enough for the latter plan. The tonnage of ore measured is only what will be actually broken down. The sample assays represent this measured ore as it will be when broken, and before it is sorted, either under or above ground.

The methods of calculating the net value of this ore from these data, vary with every case; their details are not of interest here. It is, however, necessary to call attention to the four principal factors which usually enter the problem, and the variations in calculating each factor.

The Four Principal Factors Commonly Used in Making Estimates of Total Net Value.

I. *Gross or Assay Value* per ton. This is always calculated on the "ore broken," and from the assays and analyses. It is either: NOTE:—The assay value of various products from the ore broken is often required, such as: (This is determined by calculation or by special tests.)	1. *Full Value*, according to N. Y. quotations for the valuable metals contained. 2. *Partial Value*, with various losses, expenses and deductions subtracted here. 1. *Ore Milled*, (after some sorting.) 2. *Sorted ore shipped.* 3. *Concentrates.*
II. *Losses* (to be deducted from the assay value) are either expressed per ton, or as a percentage of the "assay value." They comprise either:	1. *All the losses.* 2. *Part of the losses*, the remainder being placed in I or IV.
III. *Tonnage* used is either:	1. *Ore measured*=ore broken. 2. *Ore hoisted*=the ore broken; often after it has been reduced somewhat by underground sorting. 3. *Ore shipped*=the ore hoisted, generally after it has been further reduced by sorting on the surface. 4. *Ore milled*=either the ore hoisted, or this reduced by further sorting.
IV. *Cost* per ton may be figured on either of the above tonnages or on that of the products, such as concentrates, etc. It includes both	1. *Cost of Mining:* Including general expenses and "development" only so far as they are required for extraction of the blocked ore "in sight." 2. *Transportation and treatment.* Some of the losses and smelter deductions from assay value are often included here.

It is to be noted that each one of these four terms is meaningless unless accompanied by a full explanation of how the calculation is made.

In estimating losses on milling ores it is not often safe to deduct a given percentage, but the loss should be expressed by a definite number of dollars per ton. The reason for this is that the loss in such ores is generally quite constant, and bears little or no relation to their original contents.

Safeguards and Factors of Safety.

Throughout the work the following principles are kept in view:

The accuracy with which a sample is made to represent its line should be somewhat proportioned to that with which this line represents its area, and the area its volume. At the same time since the limit of error in the sample is controllable, it is kept much less than the possible errors of area and volume, which are fixed by the conditions of the mine.

The possible error in the estimate of a block must be provided for in one of two ways. If there are a number of blocks not differing greatly in value, their errors will balance according to the probability of averages. If there are but few blocks, or the value of some one is so great that its possible error will be a large percentage of the final total estimate, a safety deduction is made to cover this possible error. The necessity for this deduction and its amount are matters for experienced judgment. Probably every one engaged in this work has had occasion to notice the danger in an estimate of ore in sight, based upon a single block, the variations of which are not balanced, and in this case a liberal deduction is often necessary for safety.

Fraud in some form, generally from salting samples, is a danger often possible, and every engineer devises his own private system of safeguards, but no system can do away with the necessity for constant care and vigilance.

THE RECENT HISTORY AND PRESENT STATUS OF CHEMISTRY.

ADDRESS OF THE RETIRING PRESIDENT, PROF. CHARLES S. PALMER.

Annual Meeting of December 17, 1894.

It is the custom of the Society to call attention, in the last meeting of the year, to some of the more notable scientific achievements of our day; accordingly I venture to consider

THE RECENT HISTORY AND PRESENT STATUS OF CHEMISTRY.

In summing up important results it is well to take a broader view than that bounded by any one year. History indeed makes use of years, decades and centuries, but there chronological counters alone do not make history. Historical progress moves not only in quietly regular advances, but also in great tidal waves which overlap our conventional time marks.

Moreover their movements—perhaps the greatest of all—are not always visible to the student of contemporaneous events, be he never so clear-minded and impartial.

And again it is difficult to estimate recent discoveries impartially, even when they are clearly preceived. It requires a certain maturity of view, and frequently also, the consensus of many wise men in order to group discoveries in correct historical perspective.

And thus the historical writer needs the divine gift of genius to grapple with his problem. I would make no pretension to such qualification, however indispensable it would appear. But realizing my deficiency I would make candid apology therefor, and would urge the optimistic view of the growth of knowledge so beautifully worded by Edmund Spencer. (F. Queene. Book II, Introduction, verse iii.)

"Yet all there were, when no man did them know,
Yet have from wisest ages hidden beene:
And later times thinges more unknowne shall show
Why then should witlesse man so much misweene
That nothing is but that which he hath seene."

Looking squarely at the year 1894, now drawing rapidly to a close, we cannot candidly say that anything of a revolutionary or of an epoch-making character has occurred in the chemical field.* Of course an enormous amount of research has been prosecuted in the various lines of work, and all this has been repaid by good clear results; but most of the results are so closely bound up with what has preceded that it would be unwise to consider them alone by themselves; rather should these results be taken in connection with the great movements of inductive thought and scientific experiment, of which they constitute a part.

We see, moreover, that it is probably impossible to estimate recent discoveries impartially. It is necessary to place them in their true historical perspective and relation.

Thus we are led to ask: what are the great individual movements characteristic of modern chemistry? If we see these clearly, we can best appreciate recent discoveries, by adjusting them to their proper historical setting. You will therefore allow me to refer to some cardinal points in modern chemical history. Doubtless most of us are familiar with these phases of progress, but a reference to them will greatly facilitate our grasp of the present situation.

The last half of the eighteenth century witnessed the introduction of sound methods of chemical analysis. We commonly date the commencement of the era of true modern chemistry from the time of Lavoisier, "of immortal memory." In this sense, the last period of chemistry introduced about 1775, covers the time in which we live, and there will never be any other period; it is the period of

QUANTITATIVE CHEMISTRY.

Quantitative analysis is at the foundation of all scientific chemistry. One can never dispense with its methods; one can

*At the date of this address the "argon" question had not become very importan yet it is a wonderful discovery and dates from 1894.

never transend nor ignore its results. We are sometimes inclined to sneer at the "mere analytical chemist;" but let us remember that the analyst is always conservative, orthodox and safe; his work is the bed-rock of all chemical foundation, and without this safe foundation there can be no safe superstructure.

It was the analytical work of such men as Bergman, Klaproth, Vauquelin, Wenzel, Richter and Proust, which prepared the chemical world for the atomic theory of Dalton. It was the analytical work of Gay-Lussac and Humboldt, on the volume-combination of gases, which laid the basis for the hypothesis of Avogadro and Ampere, that equal volumes of all gases, temperature and pressure being equal, contain the same number of molecules. It was the work of Berzelius in collating his own analytical results and that of others, which made him an authority on matters of chemical law and theory. In detail, it was the analysis of the mineral "polluxite" from Elba, in 1846, which makes Plattner the real discoverer of cæsium: his figures footed up a total of only 92·75%, yet he would not "cook" his figures although at the time they seemed inexplicable; we now know that he counted his cæsium, (which was not identified at that time,) as sodium.

Many other illustrations might be given, but we will not pause longer than to say that all modern chemistry is essentially quantitative; and hence, in a sense, all the various branches of organic, physiological, inorganic, and physical chemistry—all of these are only so many convenient subdivisions or wings of the one chemical structure which rests on the foundation of quantitative determination.

The main branches represented in the recent work of 1894 and the preceding years, are:

(1.) Organic Chemistry.
(2.) General Inorganic Chemistry.
(3.) Physical Chemistry.
(4.) Comparative Chemistry.

Organic Chemistry.

This includes by far the greater part of the work of the last half century in pure chemistry. Coming clearly to the front in the classic work of Liebig and Wöhler on the *benzoyl compounds,*

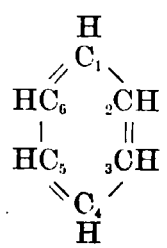
in 1832, organic chemistry has witnessed a regular succession of achievements; for instance, the "type theory" of Laurent and Gerhardt in 1837; the "substitution theory" of Dumas in 1839; Liebig's "Agricultural and Physiological Chemistry" in 1840, with its successive editions; the work of Wurtz and Hofmann on the "compound ammonias" in 1849; Frankland's theory of "atomicity" (or better, "valence" as now termed) in 1852; and the development of this idea in the fifties and sixties, culminating with the views implied in Kekulé's graphic formula for benzene in 1865 and 1866.

At first, especially in the case of the younger and less cautious chemists, the valence theory ran riot, and instances of its illegitimate applications were only too numerous. But with growing maturity of view, a more sober spirit regained control and, now, on the whole, we see chemists animated by the one legitimate aim of studying and interpreting reactions.

Let us consider in detail some of the more prominent problems.

The Benzene Theory.

The structure of benzene as illustrated by the formula:



has been the center of attack. There has been a general uniformity of view regarding the probability of—

(a) The quadrivalence of carbon.

(b) Some kind of a "closed chain" structure.

(c) The symmetry of benzene. Indeed it is more symmetrical in the identity of such ortho-compounds as C_4H_4 (CBr=CBr) and C_4H_4 (CBr−CBr), than required or allowed by the formula.

The main points at issue may be said to be:

(a) The possible existence of something like the "ethylene union."

(b) The possibility of a rearrangement and readjustment of these ethylene unions.

These problems have been subjected to a careful examination by Baeyer and others; and as a result it appears that a condition resembling a latent ethylene unsaturation does probably exist in benzene: and further that it may be displaced about the ring, and may be located, as is illustrated by Baeyer's so-called deltoid notation. In prosecuting the researches involved in this proof, two great ideas have been developed. These are:

(a) The tetrahedron theory of carbon and its deductions.

(b) The relation of the unsaturated benzene compounds to di-hydro-benzene, to tetra-hydro-benzene, and to hexa-hydro-benzene or hexa-methylene.

The development and application of these conceptions has served both to broaden and clarify our views of the constitution of benzene. At present it may be said, that on the whole, the old Kekulé formula with some modifications (the centric formula), holds the field; but various derivatives of benzene appear to vary in the arrangement of the valence unions.

The Tetrahedron Theory of Carbon.

This was proposed by LeBel and van't Hoff about the year 1874. Ten years later van't Hoff re-advanced the theory. In this he was supported by Wislicenus, Victor Meyer, and many others. At present it may be said that probably nine-tenths of the organic chemists accept it as a working hypothesis, and find it provisionally satisfactory. The chief arguments in its favor are the explanations it gives of:

(a) The fact that only one variety of any one of the mono-derivatives of methane is known although prepared in many ways.

(b) The varieties of the lactic, malic and tartaric acids.

(c) The relation of fumaric and maleic acids.

(d) The relation of the members of the sugar group.

(e) The relation of the stereo-varieties of the benzene compounds; e. g., the hydro-terephthalic acids.

(f) The extension of the stereo-chemistry of nitrogen: e. g., syn-aldoxime and ant-aldoxime.

The Sugar Group.

No group of compounds better illustrates the marvelous growth of organic work and theory than this. It was mainly the work of Emil Fischer, (a pupil of Baeyer's and now at Berlin), which enabled chemists to attack the structure of the sugars successfully.

Fifteen years ago the C_6 nucleus of the mono-saccharides was known; they were correctly supposed to be aldehyde or ketone-alcohols between the *mannite and dulcite* group of alcohols on the one hand, and certain acids on the other; they were also known to form pent-acetyl compounds.

But now we distinguish clearly between the *aldose* and the *ketose* group. The ketose radical has been located. Many of the inactive varieties have been split into the active modifications. The relation of the aldoses to the corresponding —"onic" and —"ic" acids has been largely cleared up. All this is largely due to the discovery of the *hydrazones*, the *osazones*, and *osones*, a remarkable series of soluble and insoluble compounds. The word "osazone" is identified for all time with the great name of Fischer.

As an instance of the numerous compounds to be distinguished here, it may be mentioned that corresponding to the aldose formula, $CH_2.OH$, CH.OH, CH.OH, CH.OH, CH.OH, CHO. There are sixteen active modifications possible, to which must be added eight inactive racemoid modifications. Rather more than half of these are known.

Time and space fail to enumerate the details of the great advances. A friend who is quite a student of physiological chemistry remarked recently to me: "It seems as though chemistry left only those compounds for physiological chemistry which are not well understood. As soon as the compounds are mastered they are at once claimed for organic chemistry." Of course the remark is not to be interpreted as ignoring the natural and legitimate field of physiological chemistry; but it is a naive confession of the enormous strides of organic chemistry.

Inorganic Chemistry.

The great basis in this line may be said to have been put into

shape by the masterly work of Mendeléeff and Lothar Meyer in 1869 in formulating the "periodic" arrangement of the elements.

The writer of this address has so often discussed this great work before the Society that it would perhaps be unnecessary to rehearse this periodic idea and all that it involves. It should be noticed that in 1891 a special "*Zeitschrift für anorganische Chemie*," was added to the large list of periodicals. Moreover, we notice that there is a tendency on the part of the larger and more progressive institutions to recognize the necessity for a special professor of inorganic chemistry in addition to the time-honored organic professorship.

It is true that many of the methods of organic chemistry are imitated as far as possible in this field. Again, many compounds are intermediate between organic and inorganic chemistry; and again, the utilization of many physical methods is a marked feature.

But in all these ways there is accumulating a vast array of classified information regarding inorganic elements. The publication of such text books as Remsen's (advanced course) "Chemistry;" Ramsay's "System of *Inorganic Chemistry;*" Mendeléeff's "*Principles of Chemistry*," and best of all the monumental edition of Dammer's "*anorganische Chemie*," a work justly called by some "the inorganic Beilstein;"—all of this clearly illustrates the brilliant development of the science. Among the more recent brilliant achievements may be mentioned incidentally:

(a) The isolation of fluorine and the demonstration of its remarkably corrosive properties.

(b) The artificial production of genuine diamond. (Both of these by Moissan).

(c) The clearing up of the oxides of nitrogen. (Ramsay and Lunge).

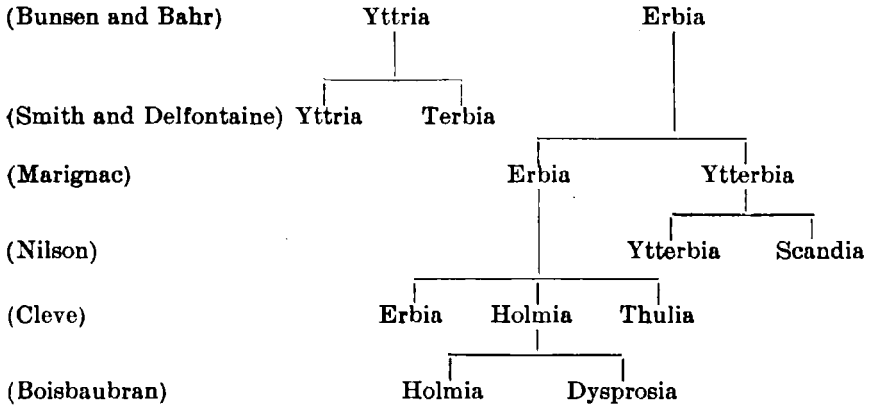
(d) The basic compounds of iodine. (V. Meyer).

(e) The carbon monoxide compounds of nickel. (Monde).

(f) The discovery of scandium (eka-boron); of gallium, (eka-aluminium), and of germanium, (eka-silicon).

(g) The fractionation of the old didimium, and of the "yttrium" earths, as explained in the following table, although

the entire explanation is not yet forthcoming; (Boisbaudran, Crookes, Nilson and others.)



[From Carnegie's "Law and Theory in Chemistry;" p. 62.]

The general inference to be drawn from this table is, I judge, not that any genuine elements have been separated into "sub-elements," but merely that the analytical separation of the rare earths is, at present, in a low state of development.

Physical Chemistry.

It would require a large allotment of time to describe how this branch arose. But in brief, perhaps the simplest description might be found in the application of the principles of thermo-dynamics to gases and liquids on the basis of the rule of Avogadro; and the brilliant experimental advance is due to the bold attack on the liquid and solid states from the analogy of gases.

In 1824 the second law of thermo-dynamics was developed, and, strange to say, before the first law, by the brilliant but short-lived French student, Sadi Carnot in his treatise "*Reflexions sur la puissance motrice du feu*, etc." (See Ostwald's Klassiker, No. 37).

The first law of thermo-dynamics appeared as a formulated statement by Seguin in 1839, and by J. R. Mayer in 1842; it was first carefully worked out experimentally by Joule in 1843-1849. It first received its full appreciation and extensive application in the paper of the great Helmholtz, recently deceased, "*Ueber die*

Erhaltung der Kraft," which appeared in 1847. (Ostwald *Klassicker*, No. 1.) It should be noticed that at present we distinguish sharply between "force" (*Kraft*) and *energy*.

It is not the purpose here to trace the further development of the remarkable generalizations involved in the first and second laws of thermo-dynamics in their broadest relations; but merely to note in a cursory way their connection with modern physical chemistry.

The objective point of attack of the new physical chemistry may be said to be, in a word, the behavior of *dilute solutions*.

The theoretical and practical both agree in giving a new interpretation to the structure of solutions. Thus it was formally supposed that in a dilute solution of common salt there were mainly molecules of NaCl as such. We are driven to the conclusion that such is not the case, but that in dilute solutions, the molecule, NaCl, is dissociated into "free ions" of atomic sodium and atomic chlorine. These ions of Na and Cl are free in the sense that they exist in the solution uncombined with each other or with anything else; but they are supposed to be held in equilibrium by reason of their enormous electro-chemical positive and negative charges. Of the real nature of this limited freedom but little can be predicted at present; we do not yet know enough of that paradoxical reality which we commonly call electricity. But for chemical purposes, it is enough to know, that in dilute solutions, we have many of the hypothetical radicals existing in a state of limited freedom entirely different from what is commonly recognized.

Moreover, regarding the *rôle* of the solvent, but little seems to be clearly known at present: the solvent seems to give the dissolved substance a theatre of action. Much more light is to be looked for along this line. Water seems to be unique as a solvent in its remarkable power of dissociating acids, bases, and salts into their respective ions.

Let us consider the following points:

The Osmotic Pressure.

It was found by the Abbé Nollet in the last half of the eighteenth century that if a glass vessel were filled with alcohol

and covered with a bladder tied over the mouth, and then if the vessel were immersed in water, the alcohol would absorb water, distend the bladder and burst it.

This line of investigation was followed up by the students of vegetable physiology, notably by Parrot (1815) Traube, Pfeffer, de Vries and others.

It was found that osmotic pressures vary directly with the concentration, or inversely as the volume (Pfeffer.) But this is only the analogue of the Boyle-Mariotte law of gases; $PV =$ a constant.

It was also found that the osmotic pressure varies directly as the absolute temperature; but this is only the analogue of the Charles-Gay-Lussac law of gases,

$$PV = T \times \text{ a constant.}$$

Further, Raoult in 1883 and 1887 ascertained that equimolecular solutions of various substances in the same solvent occasioned the same depression of the freezing point, and the same elevation of the boiling point; but such solutions have the same vapor tension and therefore exert the same osmotic pressure. This is only the analogue of the Avogadro rule of gases applied to liquids.

It was van't Hoff who summed all the statements up in the proposition that

"Is-osmotic solutions contain the same number of molecules of the dissolved substances at the same temperature: and their number is the same that would be contained in the same volume of an ideal gas at the same temperature and pressure."

It is difficult to realize the full significance of this statement; it means for instance, that although we cannot obtain gaseous "dextrose," yet a solution of dextrose exerts the same molecular pressure that it would, were the solvent imagined to be removed and the molecules left filling the same space, at the same temperature and pressure.

Moreover, the proposition enables us to measure the molecular weight of a dissolved substance from a measurement of the osmotic pressure, by the depression of the freezing point, or by the elevation of the boiling point.

At some later time I hope to illustrate these methods by the remarkably delicate and yet simple apparatus usually employed.

But every rule has exceptions, and they were not wanting here. It soon appeared that dilute water solutions of acids and bases and salts gave much greater osmotic pressures than they should normally. Organic substances for instance were fairly normal. But in the case of acids and bases and salts, the pressure is greater than the normal, and hence the number of molecules is greater than the normal.

Now in the case of the abnormal pressure of gases, such as NH_4Cl, it has been proven that the gas dissociates, here into ammonia and hydrochloric acid.

At this extremity, the genius of Arrhenius of Stockholm (then a co-worker of Ostwald at Leipsic), and Planck, suggested that the apparently abnormal pressures might be explained by abnormal dissociation. But in the case of sodium chloride, NaCl, and the like, dissociation can only result in the isolation of atomic sodium and atomic chlorine. These are, however, the ions of NaCl in electro-chemistry, and thus an ally of the new theory of solutions, was found in,—

Electro-Chemistry.

In passing over the earlier work in electro-chemistry, we notice the work of Faraday in 1833, in establishing the law of "electro-chemical equivalents," i. e., that in different cells, the same quantity of electricity will deposit 108 mg. of silver, $\frac{1}{2}$ of $63{\cdot}3=31{\cdot}6$ mg. of copper, and $\frac{1}{3}$ of $120=40$ mg. of antimony, on the cathodes; and at the same time, the acidiferous radicals NO_3, $\frac{1}{2}$ SO_4, and $\frac{1}{3}$ Cl_3 will be separated at the anodes.

About 1853, Hittorf observed that the change in concentration of the solution bathing the anode during electrolysis is not the same as the change in concentration of the solution at the cathode. From this he inferred a different rate of transportation of the ions. Kohlrausch developed this in 1879, and showed the independent migration or wandering of the ions.

In this state of the question, the whole school of physical chemistry, including Ostwald, van't Hoff, Arrhenius, and others, applied the dissociation theory of solutions to the dissociation of

electrolytes, and *vice versa.* And thus was developed the idea of the electrolytic ion molecule, a unique conception, and one which has already done much as a working hypothesis and which promises much more.

It thus appears that in solutions, acids and bases and salts must be dissociated in order to be chemically active. And thus, among others, Ostwald produced his monumental work on the conductivities of acids and bases, as a measure of their affinity. The results are in very good accord with those obtained by Thomsen by calorimetric measurement, and also with the results obtained for the inversion constants of sugar, for the "catalysis" constants of methyl-acetate, etc.

Again, the new physical chemistry has given fully as much attention to the *energy* relations of matter, as to matter *per se;* and thus a distinctive feature of the new work is found in—

The Doctrine of Equilibria.

The conception of a *kinetic* equilibrium, as distinct from the conventional *static* equilibrium, was aided by the law of "mass action," advanced by Guldberg and Waage, two Norwegian investigators, in 1867, in a book entitled "E'tudes sur les affinites chimiques." This was over-looked at the time and the same idea was afterwards developed independently by Jellet (1873), by van't Hoff (1877,) and others.

Moreover, the subject was further elucidated by the more careful discrimination of the kinds of equilibrium, regarding the number of reacting components and the number of "phases" appearing in any special reaction.

Great service was also done by the abstruse mathematical work of our countryman, Willard Gibbs of Yale, in a paper "*On the Equilibrium of Heterogeneous Substances.*" (*Trans. Conn. Acad. of Arts and Sciences, 1876.*)

The study of equilibria, homogeneous and heterogeneous, on the basis of the new theory of solutions, leads to a remarkable clearing up and extension of old views. Thus in the reaction of ethyl alcohol and acetic acid, the equilibrium attained shows that the status is expressed by the following, viz.: $\frac{1}{3}$ g. mol. alcohol + $\frac{1}{3}$ g. mol. acetic acid + $\frac{2}{3}$ g. mol. ether + $\frac{2}{3}$ g. mol. water.

But here the equilibrium is a kinetic one, not merely static; and calculation shows that in the course of a day, 0.00064 g. mol. of alcohol and acetic acid react with each other; and conversely the same quantity of ether and water react in the opposite sense.

The "Heat Toning of Reaction."

A great battle ground for exact science is marked by the controversy over the amount of heat developed in chemical reaction and the interpretation of this heat as a measure of chemical affinity.

In 1878, the gifted, but eccentric, French investigator, Berthelot, published his "Essai de mecanique chimique." In this masterly monograph, he appears to have over-stepped the mark by advancing the proposition, "that every chemical change gives rise to those substances which occasion the greatest development of heat."

Now this, as a general statement, is true perhaps in seventy-five per cent. of the common phenomena. But it is by no means worthy of being designated as a "law" or "principle." The confusion involved has been productive of much error; but at present, students generally recognize that the proposition fails to take account of the doctrine of equilibria, aside from some incidental errors, such as the failure to consider all the heat phenomena of gases evolved or absorbed.

To give an illustration: bromine, though less acidiferous than chlorine, will yet replace some chlorine in silver chloride; forming the more insoluble silver bromide with an evolution of heat. Now, according to the proposition of Berthelot, *all* the chlorine should be replaced by the equivalent quantity of bromine. But such is not the case, for a small residue of silver chloride remains. This is easily explained by the doctrine of equilibria, on the basis of the law of mass action.

It can not be said that we are yet in the possession of a certain and absolute standard of the measurement of affinity, but we are certainly much nearer it than we were half a century ago.

I have not attempted in this short sketch to give a complete view of the situation. Among the problems which have seen more light in 1894, is that of the "Dissociation of Water." *Pure water*

has probably never been obtained; the purer the water, the lower its conductivity. Supposing that one could obtain pure water, i. e., a compound of H_2 and O, would it consist of molecules of H_2O or its polymers, or would it contain traces of dissociated molecules, resulting in the presence of $+H$ and $-OH$, in small though definite quantities.

As an illustration of the remarkable co-incidence of this sort of investigation, let me give some of the results.

In the following, C_0 denotes electrolytic dissociation of liquid water.

$$25^\circ \begin{cases} C_0 = 0{\cdot}6 \times 10^{-6} \text{ (Kohlrausch 1884, "Conductivity.")} \\ C_0 = 1{\cdot}0 \times 10^{-7} \text{ (Ostwald, 1893, "Electromotive Force.")} \\ C_0 = 1{\cdot}1 \times 10^{-7} \text{ (Arrhenius-Shields, 1893, "Hydrolysis.")} \\ C_0 = 1{\cdot}2 \times 10^{-7} \text{ (Wijs, 1894, "Saponification.")} \end{cases}$$

$$18^\circ \begin{cases} C_0 = 0{\cdot}03373 \times 10^{-6} \text{ (Kohlrausch \& Hydweiler, 1894, "Conductivity.")} \end{cases}$$

The smallest observed conductivity would give a little greater value, the measurements between -2° and 50° indicating that about ten per cent. of the observed conductivity was due to some impurity—perhaps dissolved salts from the glass.

The conductivity of one millimetre of water at 0° is equal to that of 40,000,000 kilometers of pure copper of the same cross section. Common "pure distilled water" is from 20 to 40 times as impure as the sample used by Kohlrausch in his first measurement.

It should also be noticed that the average molecule of liquid water at ordinary temperature is probably represented by the formula $(H_2O)_3$ or $(H_2O)_4$. These results obtained by Eötvös, and by Ramsay and Shields, by the use of some remarkably ingenious apparatus, came from the study of surface tensions of liquids.

As regards the future of physical chemistry, it is clear that it has yet very much to give us. Nernst's hypothesis of "*solution tension*" certainly promises very much in its possibilities for a mechanical explanation of affinity, that conception which we constantly use, but of the real nature of which we know little or nothing.

Comparative Chemistry.

Regarding this great futurity, it will hardly be in place for me to speak on this occasion. I can not attack the question without obtruding my own personal views, which would be quite out of place in an historical address of this nature. My private experimental work still goes on, and it will be quite time to refer to it when there shall be something more definite to refer to. But, in surveying the grand quantitative histories of inorganic, organic and physical chemistry, we all surely feel that a yet brighter day of more complete explanation remains for our elements, atoms, valencies, heat-tonings, conductivities, dissociations, and the like. *Matter and energy* are the two great entities of the world. Ostwald has recently developed an hypothesis that of these, energy is the more fundamental of the two. The view has a certain fascination from the basis of certain mathematical considerations. But on the common-sense basis, we shall probably advance for some time to come, on the obvious dualism of matter and energy. It goes without saying, that we must expand our conceptions of these entities, must render our definitions more exact and yet more elastic, in order to embrace new varieties of matter and energy.

It is worth attention that available energy is what men strive for most of the time in the contest of natural selection. We buy matter in a high state of energy and in using it, whether as food, or coal, or clothes, it falls to a lower state.

As a set of scientific workers we are mainly tied down to the practical study of these great realities, matter and energy; in the future of the Colorado Scientific Society, as in the past, may they be typical, the one of the solid genuine work of all of us, and the other of the enthusiasm and earnestness with which we prosecute research.

Gentlemen, I thank you again for the honor you have allowed me to enjoy at your hands as President of the Society, which I now resign into more able, but not, I trust, more loyal hands.

THE COSTILLA METEORITE.

By R. C. Hills.

Meeting of January 7, 1895.

This meteorite which for several years has been in the possession of the Society, was found in August, 1881, on the north slope of Costilla Peak, about six miles south of the boundary line between Colorado and New Mexico. The date of the fall is unknown. The discoverer was a Mexican sheep herder named Ignacio Martin who, the same year, sold the specimen to an old settler, one Thomas Tobens, receiving in exchange a small pony. Tobens kept the specimen for several years concealed under a manure pile in his barn, until Mr. E. C. van Diest, hearing of its existence, and recognizing its true character, purchased it for the Society. According to Mr. van Diest to whom the writer is indebted for these particulars, it is impossible to obtain more specific information in regard to locality and occurrence, for the reason that Martin and his associates entertain the belief that the mass is native silver derived from a rich lode somewhere in the vicinity of the find, and they are naturally desirous of discovering and locating the bonanza themselves. Previous to slicing, the dimensions of the mass were: Length 32 cm; breadth 23 cm; thickness near center 10 cm. The weight on platform scales was approximately 78 pounds. When viewed in the direction of the shortest diameter, the outline is roughly rectangular. Of the two principal faces, one is rounded and comparatively smooth—the other, if anything, slightly concave with deep flutings and cavernous depressions. Two of the adjacent edges are comparatively thin and beveled. Of the other two, the longer exhibits a series of deep grooves, rudely parallel with the short diameter of the mass though perceptibly divergent; the shorter has a smooth, facet-like

termination. The well preserved surface shows the fine striæ usually ascribed to the flow of the metal while passing through the atmosphere.

The crystalline structure is well shown on the etched face, which is approximately parallel with the direction of the octahedral cleavage. The kamacite bands are from 1 mm. to 2 mm. in width, and of considerable length. The tænite lines which are somewhat irregular in trend and distribution, are of capillary size, and, though bright, are scarcely discernable except through a lens, or in strong reflected light. Occasionally, the crystalline structure is interrupted by broad, irregular bands of less perfect crystallization than those identifiable as kamacite.

Here and there are small nodules of troilite, from 1 mm. to 10 mm. in diameter, some of which enclose a dark-gray substance resembling graphite.

Another prominent feature is a number of irregular cracks, running, in some cases, nearly across the etched surface, and roughly following the planes of cleavage. These cracks are filled with a soft, black substance also thought to be graphite.

The composition of the mass is shown by the following analysis made by Mr. L. G. Eakins on a clean piece cut from one of the slices.

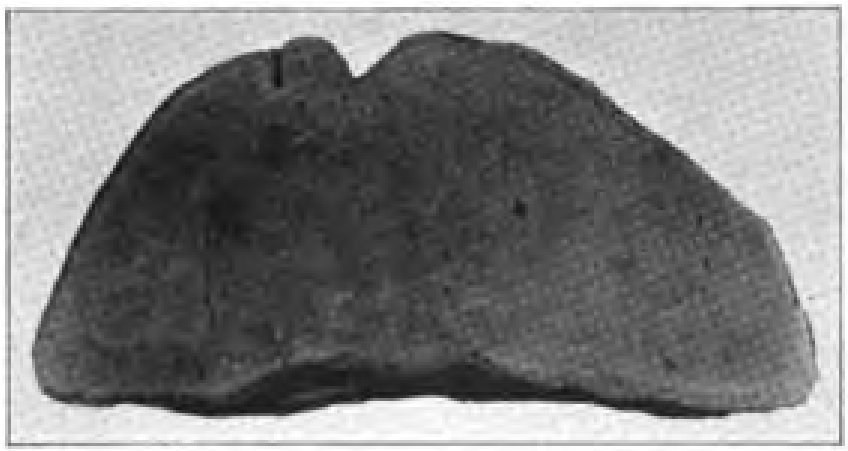
Fe	Ni	Co	P	S		
91·65	7·71	·44	·10	·26	=	100·16

Commenting upon the analysis Mr. Eakins says:

"The sulphur, of course, indicates the presence of troilite which was plainly visible in the piece sent to me, and would be equivalent to about one-half of one per cent. of this substance. The phosphorus is derived from the shreibersite which was evidently present, being noticable as the iron was being dissolved."

The average amount of troilite present is probably less than that indicated, as the sample analyzed contained one of the larger nodules.

The slicing and etching was very creditably carried out under the direction of Prof. Henry A. Ward of Rochester, N. Y., to whom the writer is also indebted for valuable suggestions in relation to the above described facts.



VEIN STRUCTURE IN THE ENTERPRISE MINE.

By T. A. Rickard,
State Geologist of Colorado.

Meeting of February 4, 1895.

The geological structure of the country enclosing the gold and silver veins of the Enterprise mine on Newman Hill at Rico, Colorado, is one of fascinating interest to the student of ore deposition.

Newman Hill consists of a series of sedimentary beds of Lower Carboniferous age overlain by Quarternary drift. The Carboniferous rocks are shales, limestones and sandstones. They are penetrated by a complex system of veins belonging to two distinct periods of formation. The pay ore of the mines comes from a series of nearly parallel northeast-southwest veins crossed and faulted by another series having an approximately north and south trend. The latter are usually barren of pay ore, and have a steeper pitch than the former. They are, therefore, called "cross-veins" in contra-distinction to the "verticals" or "pay-veins."*

The veins only reach the present surface where deep erosion has occurred. They come up through the Carboniferous rocks until they reach a certain horizon marked by the contact of black shale and crushed lime. This contact is dislocated by both series of vein fractures, but by the cross-veins to a greater degree than by the pay veins. Along the plane of this contact, there occur bodies of ore in the form of narrow channels ramifying through the crushed lime and having a strike corresponding to that of the veins underneath.

The richest ore of the mines comes from the contact. The

*The reader is referred for more detailed data to Mr. J. B. Farish's paper—"The Ore Deposits of Newman Hill, Rico," read before the Society on April 4th, 1892.]

cross-veins, though barren in themselves, are related to ore bodies on the contact as rich as, if not richer than, those above the verticals. The latter break up into stringers as they approach within five or ten feet from the contact. In depth, on the other hand, they cease to carry pay ore at a distance varying from 100 to 175 feet from the plane of the contact.

The ore-bearing veins or verticals have an appearance which is of particular beauty when seen by candle-light underground. They are characterized by the frequent occurrence of ribbon structure, due to the alternation of white quartz, pink rhodochrosite and dark galena, blende, etc. They afford many instructive bits of evidence regarding the mode of formation of fissure veins. In the accompanying six drawings, reproduced from sketches made by me while underground, I have endeavored to suggest something of their appearance and structure.

I use the word *suggest* advisedly, because, in the presence of the delicate detail of nature's handiwork, the draughtsman feels almost helpless, and I am fully impressed with the fact that even with the accuracy of a photographic copy, (such as is entirely beyond my power,) it would not be possible to reproduce as faithfully as one would wish those leaves out of nature's book, which tell the story of her modes of operation. Again, however honestly the draughtsman may try to portray the salient points of a geological section, the result of his work must always partake something of himself and his way of looking at things, and therefore his evidence, though intended to be purely objective, becomes tainted with a touch of the subjective.

Five of the drawings are on a scale of, approximately, $\frac{3}{4}$ inch to the foot, the remaining one, in black and white, is on a smaller scale, one inch being equal to $2\frac{1}{2}$ feet. The latter which is marked A, affords an illustration of the general habit of the veins in the Enterprise mine. The drawing was taken in the stopes of the Jumbo No. 3 lode on October 16, 1894.

It is evident that the beds of lime and sandstone have been broken and dislocated, also that there are two lines of faulting and movement, marked AA and BB respectively. The vein follows first one of these fault-planes and then travels along cross-joints until it meets the other, five feet further west. The cross-joints

are marked by the formation along them, in places, of quartz seams, such as CC. The ore occurs on the under side of the fault fractures. The latter are accompanied by a thin selvage of black mud. The lode was small and poor in ore while crossing the country which separates the two sympathetic fault-planes. The vein going west was found, by the evidence afforded by the lower stopes, to be only a branch of the main lode. Another portion which carried better ore, was found lower down, clinging to the foot wall of the eastern fault-plane. It (DD) was separated from the upper branch (EE) by 5½ ft. of a "pinch" or narrow parting unaccompanied by ore. Below the place of the drawing the eastern branch crossed over, as the other had done, to the western fault-plane, and the two, then uniting, formed a lode (larger and richer than either singly) which followed the same "wall" for thirty feet before it was again subject to such irregularity of structure.

The next drawing, marked B, offers further evidence of the habit of the "pay-veins." It represents the breast of the upper level (as it appeared on Jan. 16th, 1895) on the same lode (Jumbo No. 3) as that shown in the drawing labelled A, but at a point about 60 ft. above the place where A was taken.

Here, as in the previous drawing, the lode appears small and poor. When large and rich the veins lose their regularity of outline, the mineralization of the encasing country tending to confuse the structure and diminish the definition. Hence the most instructive drawings are to be obtained where the ore has pinched and where the vein, though interesting scientifically, is least pleasing to the purely commercial side of mining.

Returning to the drawing: the quartz vein (AA) is on the line of the lode proper; on its under side it is accompanied by a casing (BB) of black, tough clay. The smaller vein (CC) to the west is an offshoot or feeder. Both vein fractures (AA) and (CC) are identified with lines of faulting. In the case of the western vein, the dislocation is only a few inches, dying out in a mere distortion; in the case of the other, the eastern vein, the throw of the fault is 2¼ feet. The country between them is marked by disturbed and displaced rock, sometimes (as at E) traversed by stringers of quartz. At one point (marked D) the larger vein has

a "splice," that is, the quartz thins out and is overlapped by the incoming edge of another formation of quartz.

In the colored drawings the details of the lodes are better suggested. The four illustrations represent four different veins. That of the Eureka is an excellent example of clear ribbon structure. It represents 8 ft. of lode as seen in the side of the drift on the Group tunnel level on July 2, 1894. The bed of sandy lime (that is, a transition rock, neither clean sandstone nor clean lime) indicates the extent of the throw of the fault which the lode follows. It is about 2½ feet. On the foot-wall there is a casing (AA) of sandstone, from 1½ to 2½ inches wide. There is a similar, but thinner, casing (FF) on the hanging. In both instances the ore which happens to be quartz, is frozen to, or gradates insensibly into, the sandstone which adjoins it. The casing of the hanging (FF) has no appreciable selvage separating it from the outside country, but that on the foot (AA) has a thin and continuous parting (NN) of clay and is marked by a dark streakiness suggestive of the beginnings of mineralization.

The ribboning of the vein is made distinct by the contrast between the black streaks of zinc blende and the parallel arrangement of quartz and rhodochrosite. At one point (DD) the ore-streaks have been broken and slightly dislocated. Commencing at the foot-wall the succession of minerals is as follows: At the edge there is a narrow rim of quartz (¼ to ½ inch) shading into a band of rhodochrosite (about one inch) which, in turn, merges into quartz (about 1½ inches) to be followed by a fringe (say, 1 inch) of rhodochrosite enclosing a streak of zinc blende (from 1 to 2 inches) which is similarly fringed on its other side by rhodochrosite. The latter in turn shades off into a wide band (4 to 6 inches) of quartz forming the center of the vein. This is succeeded by a reversed repetition of the arrangement just described. The whole width of the vein (just below DD for instance) is about 20 inches, distributed as follows: 4 inches of sandstone casing, 4 inches to the center of the first band of blende, 5½ inches to the next band, 5½ inches from the latter to the casing on the hanging, which is a little more than one inch wide.

The quartz on the hanging is wider but less regular than that edging the vein on the foot-wall. It is also distinguished from the

latter by the occurrence of vughs or geodes (EE) whose longer axes are parallel to the walls of the lode. The band of quartz forming the central division of the ore is crystalline, in patches, and is spotted with fragments of rhodochrosite, which appear to be partially replaced by quartz.

The next drawing represents the Songbird lode as seen in the stopes between Raise 18 and Raise 19 on July 21, 1894. The place of the sketch was about 30 feet below the contact. This vein pitches to the west. The largest and most productive veins of the mine (the Enterprise, Hiawatha, Jumbo No. 2, Jumbo No. 3, and Eureka) pitch to the east. Those having a westerly inclination appear to be large branches thrown out from the main veins in their approach to the contact.

The drawing shows that the vein follows the line of a fault. The ore has a casing of sandstone (AA) 3 to 4 inches wide on the hanging. This casing has a distinct parting separating it from the country west of it, but it gradates gently into the ore to the east of it. It is darker than the outside country, and is banded as it nears the ore. On the foot-wall there is a more evident selvage. In places, also, the sandstone under the vein is in a granular, crushed condition. At two points (marked C) there are clear inclusions of sandstone. Near the top of the drawing (at BB) the pay streak is dislocated by a transverse break. The ribbon structure of this vein is not so clearly marked as that of the Eureka though the arrangement of the streaks of zinc-blende is after the same fashion. The rhodochrosite of which there is a very large portion, is veined with quartz (DD).

The third colored drawing illustrates the Jumbo No. 3 lode as seen in the stopes near Raise 6 on September 21, 1894. The ore occurs along a fault whose throw is nearly 3 feet. On the foot-wall there is a clay selvage between the vein and the country. On the hanging the parting is less distinct. Near the base of the section the lode has, on its upper side, a casing of slightly altered country. It appears to have been sheared from off the enclosing rock since it changes from a sandy (A) to a shaley (B) composition, in accordance with the succession of the immediately adjoining country.

The vein is roughly ribboned, the cross section showing an

edge of quartz, then a band of rhodochrosite, then an irregular streak of zinc-blende, then a central band of quartz to be succeeded by a reverse repetition of the same series.

The ore exhibits a peculiar spottiness in the distribution of the blende. While the arrangement is, on the whole, in the nature of two parallel streaks, yet, taking a small portion of the vein apart, it is seen that the zinc-blende, together with the little galena mixed with it, has a mottled appearance suggestive of its having been either broken into its present irregularity from a previously existing regular arrangement, or that it has replaced another mineral which has been so brecciated and broken. I incline to the latter view. The pieces of zinc are enclosed by thin rims of rhodochrosite and there is a strong suggestion of the replacement of fragments of rhodochrosite by the blende.

The middle part of the vein consists of quartz traversed by a series of geodes (CC) whose longer axes divide the ore into two equal and symmetrical portions. In approaching the zinc-blende this median band of quartz is mottled in a manner suggestive of a former brecciated structure. Other quartz, in the form of veinlets (DD), intrudes through the rhodochrosite which makes up the greater part of the lode. This is also marked in places by cavities lined with quartz crystals. The rhodochrosite is everywhere seamed with such quartz and peppered with specks of iron pyrite. Under the foot-wall there is a branch vein (EE) barren of pay ore, which does not penetrate beyond the bed of lime forming a prominent feature of the section.

The last drawing represents the Kitchen vein as it appeared in the breast of the upper level on January 12, 1895. The Kitchen, like the Songbird, is a west-pitching vein. The place of the drawing is about 40 feet below the contact.

The lode follows a fault fracture. The lime in the right hand corner is a portion of the bed to be seen under the foot-wall two-thirds of the way up the drawing. The throw of the fault amounts to about 4 feet. There is a selvage on the foot, but none on the other wall. The lode contains very little ore that is of value, none save the small irregular streaks of blende (GG) on the hanging, and the beginnings of a pay streak (HH) near the foot-wall at the

bottom of the section. At one place (FF) the vein is slightly dislocated by a cross-fracture.

The rudiments of ribboning are observable. The rhodochrosite is peppered in places by crystals of pyrite. The bulk of the lode-stuff consists of white, hackly quartz containing spots of rhodochrosite, but its most notable feature is the inclusion of large fragments of country. It is interesting to note that the kind of rock enclosed at different places in the lode, bears a seeming relation to the beds which the vein at those places happens to be traversing. Thus, the pieces of sandstone (CC) appear to have been broken from the adjoining bed of sandstone just as the fragments of included lime (DD) may be the shattered pieces sheared off the adjacent limestone. These pieces of enclosed rock have a rim of rhodochrosite around them which, though often faint, is never absent. The quartz of the central part of the vein is mottled with dark spots of irregular outline suggestive of fragments of country which have been replaced by quartz. These also have a faint fringe of rhodochrosite. At other points (EE) there are geodes lined with crystalline quartz.

In the last drawing, as in all of the six, it is evident that the country on the hanging has come down relatively to that on the foot-wall. The direction of the throw of the faults along which the veins have been formed, is made manifest by the bending of the beds of lime and sandstone. On the foot-wall the partings, laminæ or other lines of sedimentation are seen to be bent down while on the hanging they are turned up.

The ribbon structure of the lodes has been presented in both rudimentary and perfected form. In the Enterprise mine, however, the ribboning does not reach such symmetrical perfection as in the examples which are given in geological text-books as occurring, for instance in the Drei Prinzen vein of the Churprinz mine at Freiberg* or in the Huel Mary Ann† and Carn Marth‡ lodes in Cornwall. The ribboning of the Enterprise veins rarely exhibits marked regularity for more than a dozen feet in length, and though

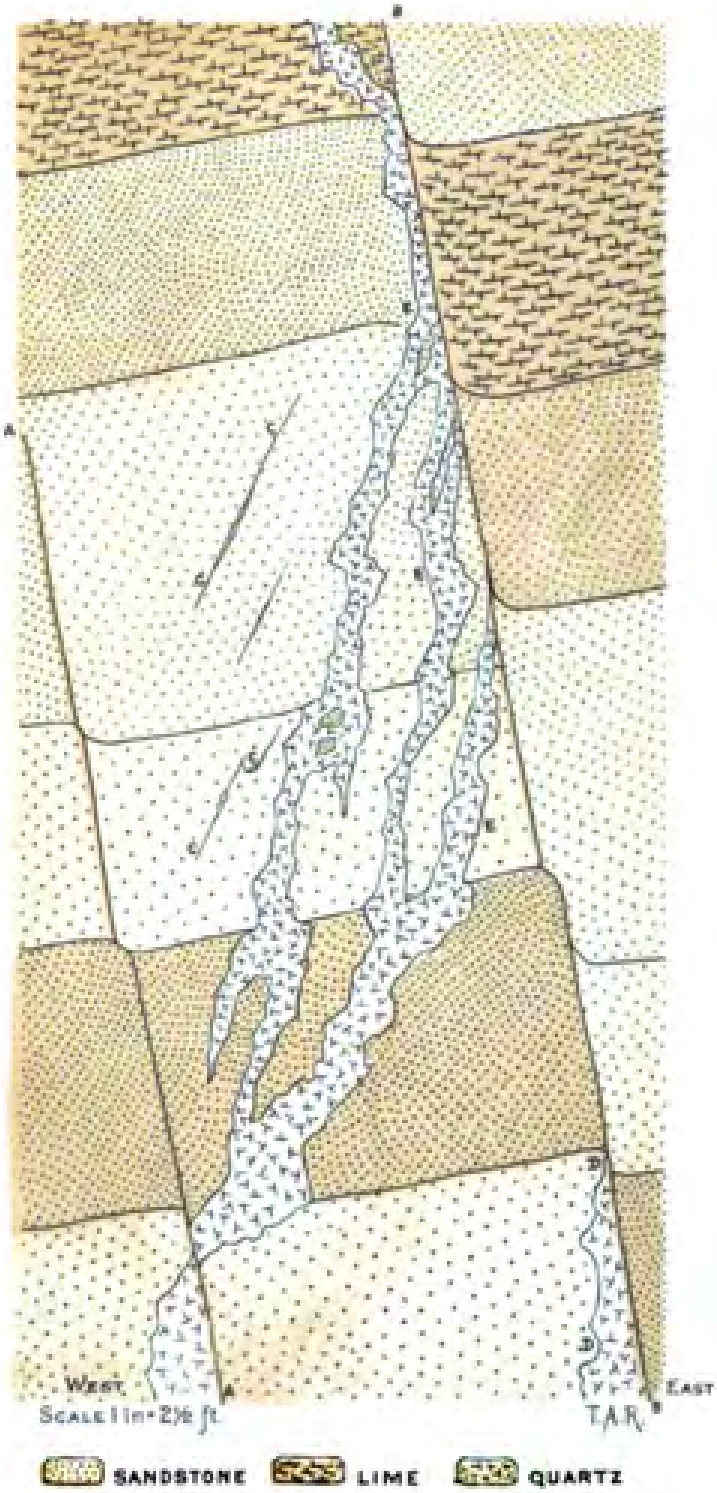
* As drawn by Von Weisenbach in his book published at Leipzig in 1836.

† According to C. LeNeve Foster. Transactions of the Royal Geological Society of Cornwall. Vol. 19, 1875.

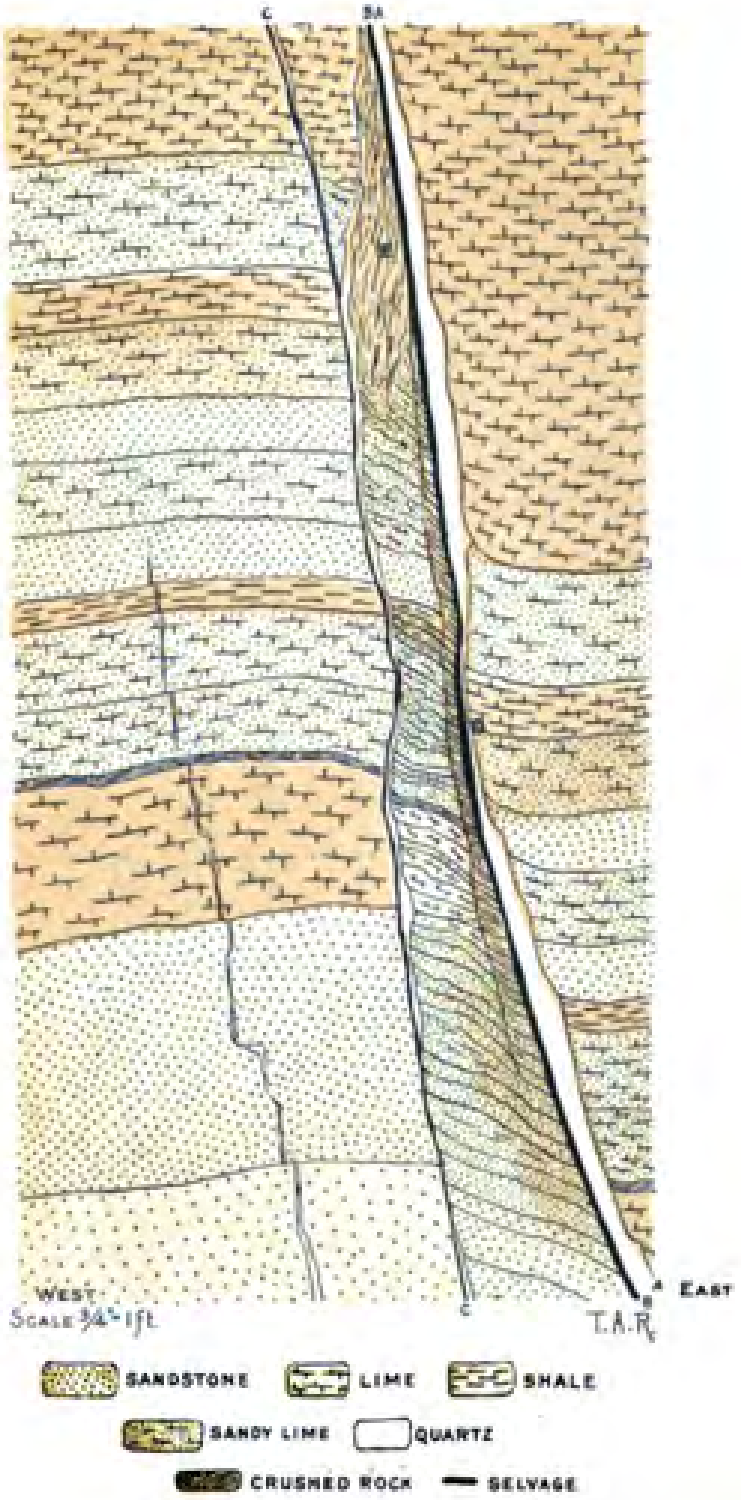
‡ According to J. H. Collins. Proceedings of the Institute of Mechanical Engineers 1873.

the rudiments of it are everywhere present, they are blurred by inclusions of country and other irregularities.

Whether veins such as these have, or have not, been subjected to successive opening and filling, producing a symmetrical arrangement of various minerals; whether the existence of geodes and comb structure means, or need not mean, a gradual growth of crystals from the walls; these are matters the discussion of which my small contributory evidence may incite. At another time I hope to add further evidence as it becomes gathered by the daily experience of underground supervision.



A



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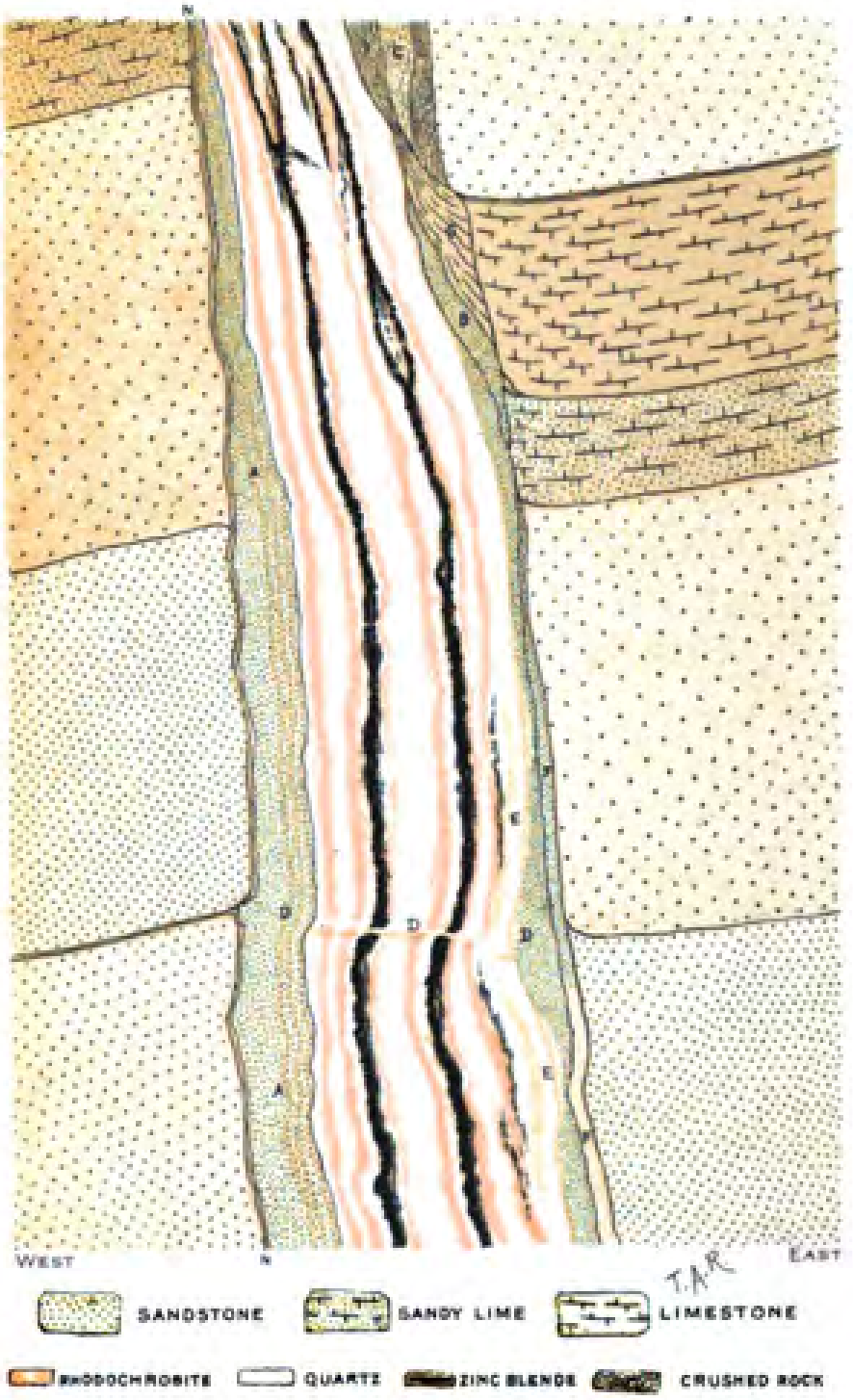
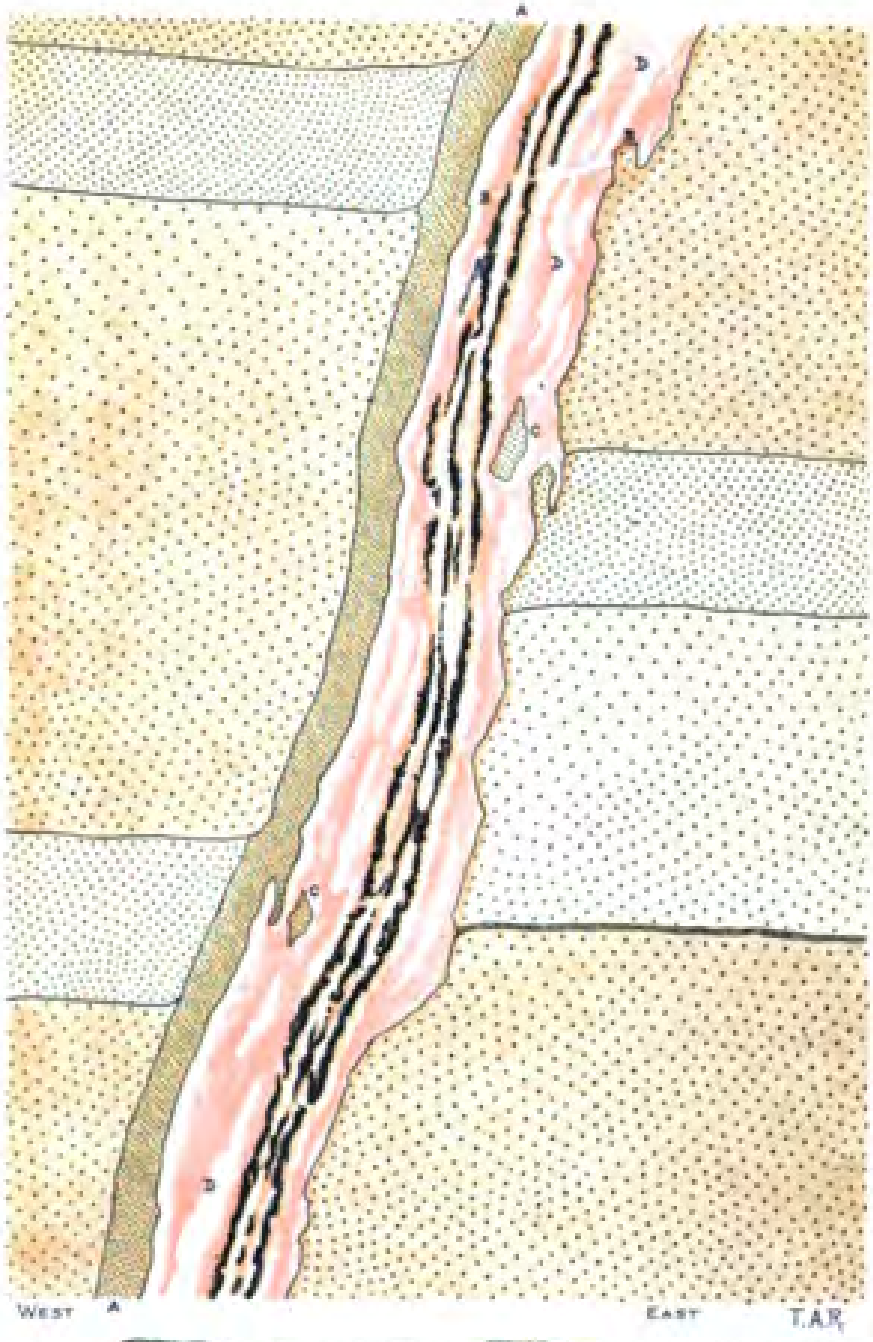


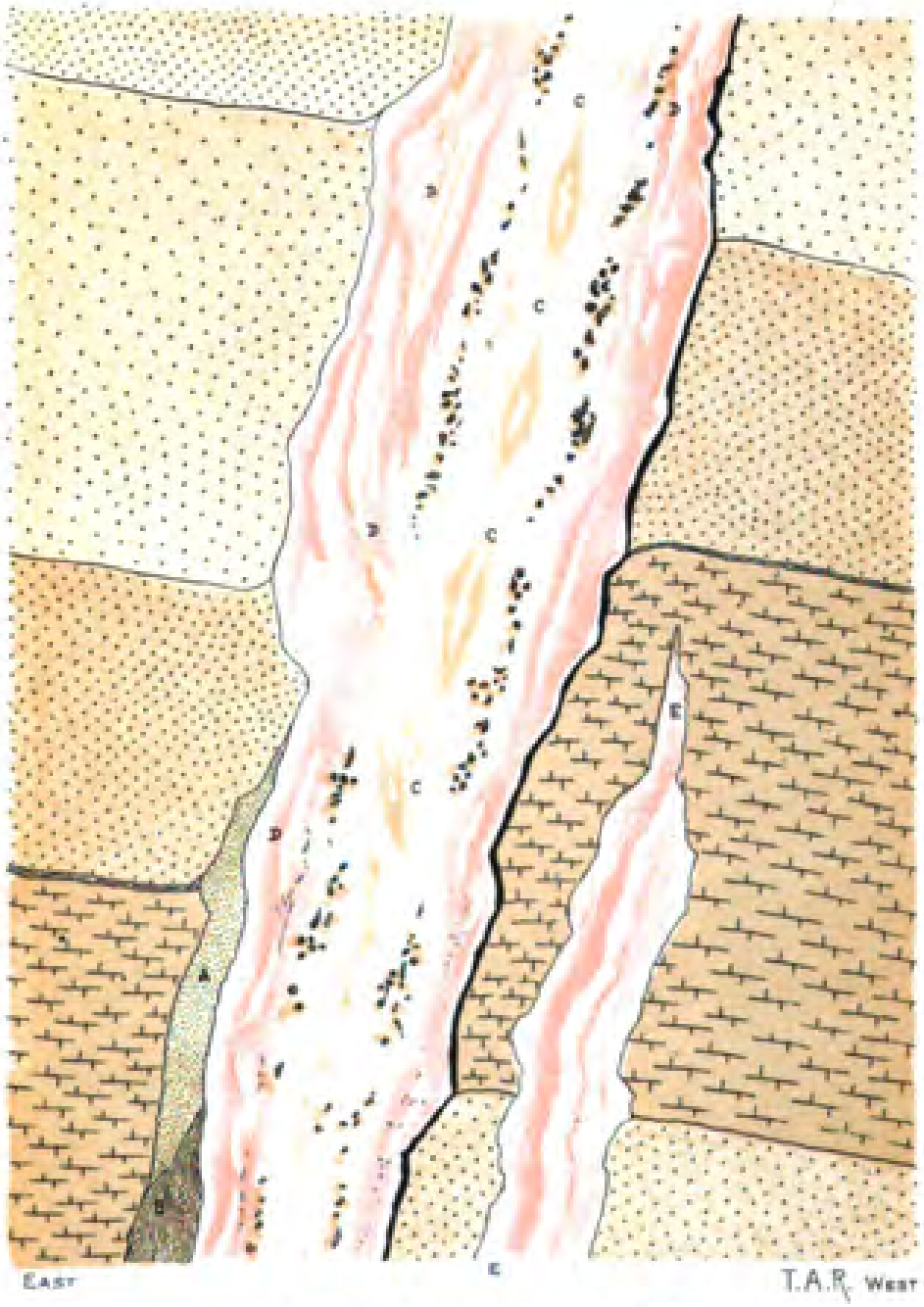
EUREKA VEIN

Scale 3/4" = 1 ft.



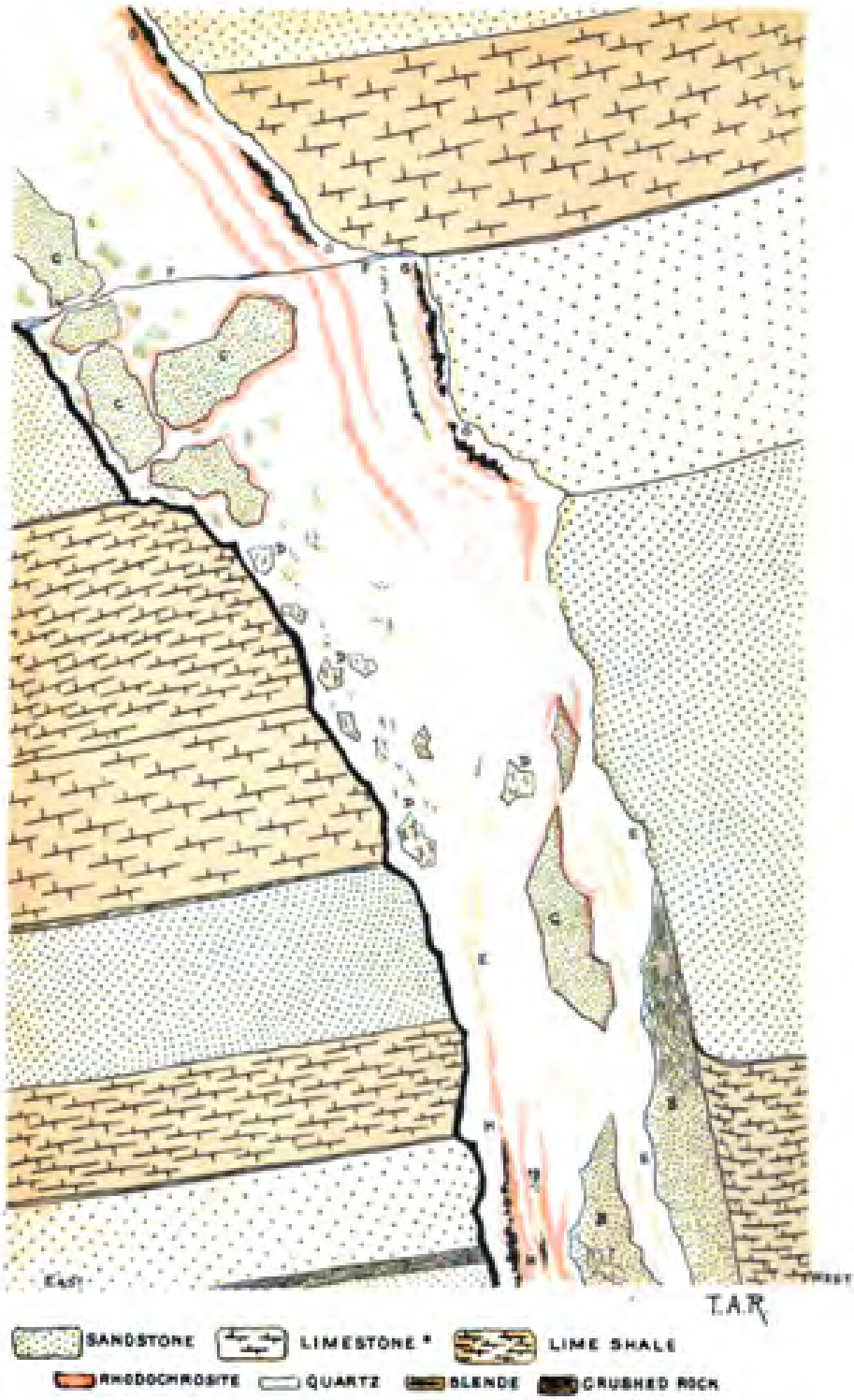
SONGBIRD VEIN

Scale 3/4" = 1 ft.



JUMBO No 3. VEIN

SCALE 3/4" 1 ft.



KITCHEN VEIN

Scale 3/4" = 1 ft.

THE DETERMINATION OF BISMUTH IN REFINED LEAD AND IN LEAD BULLION.

By L. G. Eakins,
Chemist, Philadelphia S. & R. Co., Pueblo, Colorado.

Meeting of February 4, 1895.

It seems to be generally considered that the presence of but very small amounts of impurities in lead is sufficient to render it useless for corroding—that is, for the production of white lead; and, as lead suitable for this purpose commands a higher price than it does for other commercial uses, it has become important for the large producers, as well as for the consumers, to be able to accurately determine the objectionable impurities. Chief among these, and, so far, in fact, the only one that cannot be economically controlled in the refining process, is bismuth, for which element an arbitrary limit of 0·040 per cent. has been established. When it exceeds this the lead is classed as non-corroding, with a consequent lessening of value. Whether or not this limit is justified by facts it is not the purpose of this article to discuss; it seems to be an accepted mode of classification, and has resulted in making the determination of bismuth in the refined lead, and, incidentally, in the lead bullion from which the refined metal is produced, one of considerable frequency. So far, excepting in an irregular way, no special attention seems to have been given to tracing the trouble to its original source, that is, to the ores which are smelted to make the lead bullion. The time required, by present methods, would render such determinations almost impracticable in smelter laboratories, but it would certainly seem desirable to be able to group ores on this basis, at least in a general way; for instance, by having occasional determinations made on general samples, each

representing a large district or group of similar ore-producing mines.

The methods given below are based on well known reactions, and no claim is made for originality. In the case of refined lead the procedure is practically the same as given by Fresenius* in his description of the complete analysis of refined lead. For lead bullion which generally contains, compared with the bismuth, large amounts of arsenic, antimony, silver, and copper, the method is altered somewhat to meet the peculiar difficulties of the analysis. Special attention is directed to those points in the determination where an extended experience has shown errors are likely to occur, and an endeavor is made to cover the important details which the standard text books either fail to give or do not sufficiently emphasize. While this leads to repetition at times the writer thinks it justifiable in the cause of thoroughness.

Refined Lead.

The quantity taken for analysis depends somewhat on the purity of the lead; in ordinary cases, where the bismuth is about 0·040 per cent. or over, 50 grams are enough; in cases of greater purity the quantity should be increased to 100 or 200 grams.

The clean metal is best cut into pieces of 5 to 10 grams each and dissolved in a flask or beaker in dilute nitric acid, using for each gram of lead 1·2 c.c. of strong nitric acid (1·42 sp. gr.) diluted with 3·5 times its volume of water. Solution is aided by appropriate heat, any evaporated water being replaced from time to time to preserve the initial volume, the idea being always to keep the solution sufficienty dilute to prevent the separation of lead nitrate. On this account, too, no more nitric acid than is necessary should be used, as lead nitrate is much less soluble in nitric acid than in water. When solution is complete, precipitate with sulphuric acid, adding enough to combine with all the lead and leave about 10 c.c. excess. Bring the solution and precipitated lead sulphate to a known volume, mix thoroughly, allow to settle and siphon or filter off a measured amount of the clear, or nearly clear, supernatant liquid. This portion is used for the determination.

* Fresenius' Zeitschrift for Analytische Chemie, Vol. 8, p. 148.

the remaining liquid with the lead sulphate being rejected. This procedure is to be preferred to an attempt to filter off and wash this large mass of lead sulphate. Allowing for the space occupied by the precipitate a simple calculation will give the amount of material that the solution to be used actually represents. (The lead sulphate from 100 grams of lead occupies 22·5 c.c.).

For regular use in this work, where determinations are being made constantly, the writer has prepared sets of measuring flasks in pairs, one holding 810 c.c., the other 529 c.c. (Flasks can easily be graduated with a burette, the meniscus being marked on the neck with a sharp file.)

To start the analysis 75 grams of lead are dissolved in a beaker in 90 c.c. of strong nitric acid, diluted to 400 c.c. As soon as every thing is dissolved the solution is transferred to the larger flask in which 30 c.c. of strong sulphuric acid, somewhat diluted, have already been placed; the flask is filled to the mark, corked and well shaken. After allowing the precipitate a few moments to subside the liquid is filtered through a dry, rapid-running paper, into the smaller flask which is filled exactly to the mark. This whole operation is performed so quickly that the very slight change of volume due to cooling can be neglected.

The following calculation shows how much material the 529 c.c. of solution represent:

Volume of liquid and precipitate	810 c.c.
Volume of lead sulphate from 75 grams of lead	16·875 c.c.
Actual volume of liquid	793·125 c.c.

Then:

$$793{\cdot}125 : 529 :: 75 : x.$$
$$x = 50{\cdot}02 \text{ grams,}$$

or, in round numbers, 50 grams are in actual use for the determination.

The solution from which the bulk of the lead has thus been removed, is at once evaporated in a large beaker or other suitable vessel. When sufficiently concentrated it is transferred to a porcelain dish or casserole of about four inches diameter, and the evaporation continued until sulphuric acid fumes come off freely. It is now removed from the heat, and, as soon as cool enough,

diluted with cold water to about 125 c.c.; then boiled briskly for several minutes to insure the re-solution of all the bismuth sulphate.

After allowing the solution to cool and settle for two or three minutes, filter, washing the precipitate of lead sulphate with dilute sulphuric acid (10 c.c. of acid to 1 litre of water). Heat the filtrate nearly to the boiling point, and pass hydrogen sulphide gas through it for ten to fifteen minutes; allow to stand warm until the precipitated sulphides have collected and settled, then filter, washing well with hot water. When washed, without removing the filter paper, return the precipitate to the beaker in which the precipitation took place, using as little water as possible, and add 15–20 c.c. of yellow alkaline sulphide. (The alkaline sulphide, preferably that of potassium, is best prepared from pure materials by the operator; the article of commerce is seldom or never pure.) Heat to boiling, dilute somewhat, allow to settle, and decant through the paper already used for filtering off the sulphides. Repeat the treatment with a fresh portion of alkaline sulphide, finally transferring the precipitate to the filter, and washing with water containing some of the alkaline sulphide. When washed, place the filter and precipitate in the same beaker, add 5 c.c. of strong nitric acid diluted to 25 c.c., warm until the sulphides are dissolved, and filter into a porcelain dish; burn the papers at a low heat, adding the ash to the solution; then add about 3 c.c. of strong sulphuric acid and evaporate, as before, to sulphuric acid fumes. When cool, dilute, boil, allow to cool and settle, filter and wash with dilute sulphuric acid. The amount of lead removed here is generally very slight, but it is not safe to omit this evaporation. To the filtrate add a solution of sodium carbonate until the solution is slightly alkaline (a drop of methyl-orange is a good indicator to use here) and a few drops of a strong solution of potassium cyanide. Boil for a few minutes, and allow to stand warm until the precipitate has collected, and the supernatant liquid is perfectly clear. This operation usually takes about half an hour. Filter through a moderately close paper, washing with warm water; dissolve the precipitate from the filter in warm dilute nitric acid; add ammonia to alkalinity, and about 3–5 c.c. of ammonium carbonate solution.

Heat to the boiling point, and let it stand warm until the bismuth carbonate has settled well; then filter and wash. Dry the paper and precipitate, remove the latter as completely as possible, burning the paper separately; ignite in a small porcelain crucible at a low red heat, and weigh as Bi_2O_3.

$$Bi_2O_3 \times 0{\cdot}3965 = Bi.$$

Lead Bullion.

The determination of bismuth in lead bullion is started in the same way as in refined lead as regards the quantity of material, solution, precipitation of the bulk of the lead, and the taking of a measured portion of the liquid. In this last point the fact that lead bullion is only about 95 per cent. lead can be taken into account, if desired, but it is rather a needless refinement. The only difference in these preliminary steps is, that in the case of bullion just about enough sulphuric acid to combine with all the lead is added, instead of having 10 c.c. excess. Thus, in the case cited above, where 75 grams are taken, only 20–22 c.c. of sulphuric acid are added instead of 30 c.c.

Lead bullion does not make a perfectly clean solution like the refined lead, a considerable residue usually being left after the action of the nitric acid has ceased. This residue is chiefly gold and antimonial compounds, and, in a bismuth determination, can be neglected, it being removed with precipitated lead sulphate.

The measured portion of the solution, from which the bulk of lead has been removed, instead of being at once evaporated, as is done in the case of refined lead, is made ammoniacal, 50 c.c. excess of ammonia water added, and hydrogen sulphide (passed into the hot liquid with the formation of yellow ammonium sulphide). The gas is passed nearly to saturation, then about 20 c.c. more of ammonia are added, and the whole allowed to stand warm until the precipitate has completely subsided. The supernatant liquid should be clear yellow, and the precipitate dark brown. By this means a large part of the arsenic and antimony are kept in solution and gotten rid of at once; although some always remain with the precipitate and must be removed subsequently. Filter and wash slightly; place paper and precipitate in a beaker, add 15 c.c. of strong nitric acid, dilute to 60 c.c., warm until the sulphides are

decomposed, and filter into a four-inch porcelain dish. Burn the paper, and add the ash, then 10 c.c. of strong sulphuric acid, and evaporate to sulphuric acid fumes. This point corresponds with the first evaporation when working on refined lead, and, with slight modifications, the determination is now carried on exactly as in the preceding method. At the stage where the sulphides are treated with alkaline sulphide, more of the latter is usually required than in the case of refined lead, owing to the larger amount of arsenic and antimony to be removed, the quantity of these remaining here being generally larger than the total amount in refined lead.

At the second evaporation it is advisable, on account of the quantity of silver and copper present, to increase the sulphuric acid to 5–6 c.c. instead of 3 c.c. When precipitating with sodium carbonate and potassium cyanide, enough of the latter must be added to bring all the silver and copper (cadmium also if present) into solution.

Special Notes.

By the methods detailed above the complete separation of bismuth from arsenic, antimony, gold, silver, copper, cadmium, lead, iron, and zinc is readily and perfectly effected. The only point to be especially watched is the removal of the arsenic and antimony when working on lead bullion, and no trouble will be experienced here if the alkaline sulphide is used in sufficient quantity.

Preventing the loss of bismuth, and consequently low results, is, however, a more difficult matter, there being several ways in which such loss can readily occur.

Throughout the work hydrochloric acid and chlorides should be rigidly excluded. The tendency of bismuth to form an insoluble oxychloride is so strong that the only safe plan to pursue is to avoid its possibility.

While trying different methods of analysis on lead bullion which often contains over 1 per cent. of silver, the attempt was made to remove most of the silver, at the start, by adding a few drops of hydrochloric acid to the sulphuric acid used to precipitate the lead. While this generally succeeded, in more than one instance bismuth oxychloride was also precipitated and, of course,

lost with the lead sulphate and silver chloride; so this modification was abandoned as too unreliable.

In the same line of investigation was the trial of removing the silver and copper by the use of ammonia and ammonium carbonate as precipitants in the first solution. In spite of the utmost care results obtained in this way were invariably low. To the mass action of the bulky solution and large amount of salts, the loss of bismuth here, owing to incomplete precipitation, is probably due. Of course this scheme was also given up.

When solutions have been evaporated to sulphuric acid fumes, they should, as soon as cool enough, be diluted, boiled and filtered. If such evaporated solutions are allowed to stand cold for a few hours, over night for instance, the bismuth is very apt to separate in an extremely insoluble form, probably as basic sulphate, and, on subsequent dilution and boiling, fail to re-dissolve. In such a case, of course, it would be filtered off with the lead sulphate and lost. Should this happen at the first evaporation, where considerable lead sulphate is separated, it would be completely masked, and could be found out only by analysis of the lead sulphate. At the second evaporation, where the lead sulphate separated is generally so slight as to be scarcely visible, if a white or yellowish white, rather granular precipitate is noticed, which seems insoluble on dilution and boiling, it is almost certain to be a bismuth compound. Prolonged boiling, with occasional decantations and addition of fresh portions of dilute sulphuric acid, will generally effect its solution; but, both here and at the first evaporation there is no danger of loss if unnecessary delay is avoided.

When precipitating with sodium carbonate and potassium cyanide, but a very slight excess of the carbonate solution should be added, otherwise precipitation will be incomplete. Where this trouble is suspected it can be corrected by the cautious addition of ammonium chloride until the carbonate is mostly converted to chloride. With proper care, however, the necessity for this should not arise. In both this precipitation and the succeeding one with ammonia and ammonium carbonate, the solutions should be heated to boiling, or nearly so, until all the free carbonic acid is expelled, and then allowed to stand in a warm place until the precipitate has thoroughly collected. As both of these precipitates have a ten-

dency to run through the filter, papers of fairly fine texture should be used.

Where bismuth carbonate is precipitated to be ignited and weighed, it must always be done by ammonia and ammonium carbonate from a nitrate solution. And care must be exercised to remove the dried precipitate from the paper as completely as possible, for reduction and volatilization very readily take place. A low red heat is best for igniting the carbonate, the change to oxide easily taking place. At bright redness there is no more loss in weight, but the oxide fuses, and is then difficult to remove from the crucible.

When circumstances will permit it is advisable to make determinations in duplicate; at least until considerable practice has been had with the methods.

Bismuth in Ores.

In this connection it may not be amiss to consider briefly the determination of bismuth in ores. This may become of value to the metallurgist with a view of controlling the amount in the bullion.

In ores carrying lead to the extent of 10 per cent. or over, nearly, if not all the bismuth will be found in the lead buttons obtained in the fire assay. And as this method of determining the lead is the one in common use at smelting works, and these buttons are being constantly made, they can be taken, and the above methods applied to them. In iron-lead ores, by the addition of some bismuth—free lead salt, carbonate or sulphate for instance, to the extent of about 15-20 per cent. of the ore—the same plan can be carried out.

A number of buttons from different lots of the same kind of ore can be mixed to represent an average of a very considerable amount of the ore. If it is thought desirable, owing to the presence of arsenic or antimony, these buttons can be scorified together with the addition of some silica and borax glass; the loss of bismuth in a short scorification is very small. In fact scorification has been advised as a preliminary step in determining bismuth in bullion, but is hardly to be recommended excepting where special accuracy is not desired.

Of course, the method suggested here for ores cannot lay claim to strict accuracy, but it offers the advantages of saving time and of concentration, enabling the determination to be made on an amount of ore it would be almost impossible to handle in any other way; a matter of no slight moment where small amounts of bismuth are being sought for; and, for the object in view—the classification of ores on a bismuth basis—it is amply accurate.

While, generally speaking, the metallurgist must use ores as he gets them, a knowledge on this bismuth point might at times be a valuable aid in arranging furnace charges.

For kindness in looking up some of the literature on this subject, the writer is greatly indebted to his friend, Dr. W. F. Hillebrand of the U. S. Geological Survey.

NOTES ON THE PRECIPITATION OF THE PRECIOUS METALS FROM CYANIDE SOLUTIONS BY MEANS OF ZINC.

No. 1. THE NON-EXISTENCE OF CYANIDE OF ZINC IN ALKALINE SOLUTIONS.

By Nicholai Anderson.

Meeting of April 1, 1895.

The Cyanide Process, as now practically applied in most gold and silver producing countries of the world, involves two distinct operations.

(1.) The solution of the gold and silver contents in suitable ores by the use of a dilute cyanide solution.

(2.) The precipitation of the gold and silver in solution by the use of metallic zinc.

This system of precipitation has been much criticised, not on account of the zinc shavings failing to do their work properly, nor on account of excessive cost (the cost of the zinc shavings consumed hardly ever exceeding 7 cents per ton of ore treated) but principally because of more zinc being consumed than actually called for according to the equation:

$$2AuK(CN)_2+Zn=2Au+Zn(CN)_2K_2(CN)_2.$$

The percolate obtained, after leaching a suitable ore with a dilute cyanide solution, contains—besides minute amounts of cyanides of the base metals—cyanide of gold and potassium, cyanide of silver and potassium, uncombined cyanide of potassium, and hydroxide of sodium and potassium; all in varying proportions, according to the nature of the ore and the details of treatment.

When this solution comes in contact with zinc, the double cyanide of gold and potassium, or the double cyanide of silver and potassium react according to the equations:

$$2AuCN,KCN+Zn=2Au+ZN(CN)_2,2KCN;$$
$$2AgCN,KCN+Zn=2Ag+Zn(CN)_2,2KCN.$$

The uncombined cyanide of potassium reacts to a slight extent according to the equation:

$$4KCN+Zn+2H_2O=Zn(CN)_2,2KCN+2KHO+2H;$$

while the hydroxides of sodium and potassium react to some extent thus:

$$2NaHO+Zn=ZnO,Na_2O+2H;$$
$$2KHO+Zn=ZnO,K_2O+2H.$$

Leaving, after precipitation of the values, a solution containing:

(1.) Double cyanide of zinc and potassium;
(2.) Uncombined cyanide of potassium;
(3.) Zincate of potassium.

Some writers declare that zincate of potassium does not exist in solutions containing cyanide of potassium, but that a double cyanide of zinc and potassium and hydroxide of potassium is formed, according to the equation:

$$ZnO,K_2O+4KCN+2H_2O=Zn(CN)_2,2KCN+4KHO.$$

The incorrectness of this last equation I shall show later on in these notes, but a solution of zincate of potassium is at best exceedingly unstable, decomposing, on dilution by contact with the air or by contact with the ore in the leaching tanks, into hydroxide of zinc and hydroxide of potassium.

The precipitation of the gold and silver from an auriferous or argentiferous cyanide solution by metallic zinc may therefore be said to take place with the formation (beside minute amounts of ammonium compounds) of a double cyanide of zinc and potassium and hydroxide of potassium; thus leaving, after precipitation, a solution containing:

(1.) Double cyanide of zinc and potassium;
(2.) Uncombined cyanide of potassium;
(3.) Hydroxide of potassium.

A generally accepted, but erroneous idea, exists concerning the solvent power of double cyanide of zinc and potassium for gold and silver. It is repeatedly stated that said double salt is not a solvent for gold and silver, and as this idea has been given new support during the last weeks by Dr. A. Scheidel's compilation of Cyanide Process literature (Bull. No. 5, Cal. State Mining Bureau) it may be proper for me to bring before the Society the results of my experiments and experience with cyanide of zinc and the double cyanide of zinc and potassium.

1. Double Cyanide of Zinc and Potassium ($Zn(CN)_2,2KCN$).

Numerous determinations have proven to me that this double salt is a solvent for gold and gold compounds, silver and silver compounds, and will extract the gold and silver values from such ores as are adapted for treatment by the Cyanide Process.

Double cyanide of zinc and potassium in dilute solution reacts with gold and silver as if one-half of its cyanogen content was uncombined cyanide of potassium, and quantative determinations show the reactions to take place according to the following equations:

1. $2Au+2Zn(CN)_2,2KCN+O=2Zn(CN)_2+2AuK(CN)_2+K_2O$, or
2. $2Ag+2Zn(CN)_2,2KCN+O=2Zn(CN)_2+2AgK(CN)_2+K_2O$, or
3. $AgCl+Zn(CN)_2,2KCN=Zn(CN)_2+AgK(CN)+KCl$.

2. Cyanide of Zinc ($Zn(CN)_2$).

Experiments made by me some two or three years ago showed that cyanide of zinc (in hydroxides of sodium or potassium) dissolves gold and silver, and that the addition of alcohol to the solution precipitates a zinc salt which, when collected and washed on a filter, is found to be hydroxide of zinc—suggesting a reaction according to the equation:

$$Zn(CN)_2+4KHO=2KCN+ZnO,K_2O+2H_2O.$$

The zincate of potassium being insoluble in dilute alcohol, is precipitated, and, when washed on the filter, decomposes into hydroxide of zinc and hydroxide of potassium, according to the equation:

$$ZnO,K_2O+2H_2O=Zn(HO)_2+2KHO.$$

Some time ago I decided to check these experiments, and, sur-

mising that cyanide of potassium and zincate of potassium might have different rates of diffusion through membranes, I subjected mixtures of cyanide of zinc with hydroxide of sodium, potassium, or calcium to dialysis, and found that a water-soluble cyanide passed through the membrane at a much quicker rate than the zinc; and that when the process of dialysis was carried on for 24 hours, a layer of insoluble hydroxide of zinc would collect on the membrane.

These and other experiments, not necessary to mention, proved to me conclusively that cyanide of zinc is decomposed when dissolved in solutions of hydroxides of the alkaline metals or alkaline earths, and will then act as a solvent for gold and gold compounds, silver and silver compounds, according to the equations:

1. $2Au+2Zn(CN)_2+6KHO+O=2AuK(CN)+2ZnO,K_2O+3H_2O$;
2. $2Ag+2Zn(CN)_2+6KHO+O=2AgK(CN)_2+2ZnO,K_2O+3H_2O$;
3. $AgCl+Zn(CN)_2+4KHO=AgK(CN)_2+ZnO,K_2O+KCl+2H_2O$.

CONCLUSIONS.

First. Double cyanide of zinc and potassium is a solvent for gold, silver and their compounds either in pure state, or as found in ores, one-half of the cyanogen content acting as uncombined cyanide of potassium, forming double cyanide of gold (or silver) and potassium, while insoluble cyanide of zinc is precipitated.

Second. Cyanide of zinc does not exist in alkaline solutions, but one molecule of cyanide of zinc reacts at once with four molecules of the hydroxide of the alkali metal, or two molecules of the alkaline earth, forming a cyanide and a zincate of the alkali, and said cyanide dissolves gold, silver and their compounds.

Third. The reason why zinc does not accumulate in solutions used for treating ores according to the MacArthur-Forrest Patents is this: Zinc does not exist in dilute alkaline solutions as double cyanide of zinc and potassium, but as zincate of potassium, which is an exceedingly unstable compound, and is decomposed by contact with the ore; insoluble hydroxide being precipitated on the pulp.

OCCURRENCE OF TELLURIUM IN OXIDIZED FORM ASSOCIATED WITH GOLD.

By Dr. Richard Pearce.

Meeting of April 1, 1895.

Since my last communication to the Society, having reference to the subject of Cripple Creek ores, I have had further opportunity of extending my investigations of the occurrence of tellurium in an oxidized form associated with gold.

The most interesting and perhaps the most important result obtained in this direction, is the discovery of tellurium in what is called the Potsdam ore in South Dakota. Some samples of this ore were sent me for the purpose of determining to what extent the material could be roasted preliminary to chlorination.

I learn from Mr. Frank Clemes Smith who sent the samples, that this auriferous rock occurs in sandstone, and I will introduce here some quotations from Mr. Smith's letters, descriptive of the locality.

"Mr. C. G. W. Lock has written the most nearly correct description of them in the latest numbers of the London Mining Journal. They are the ores of the Potsdam sandstone occurring in the Bald Mountains and Ruby Basin region. The blue or unoxidized ores frequently show a small amount of very fine arsenical sulphurets. They are very compact, almost aphanatic, and are very much more refractory than the red (oxidized) ore. Even in the oxidized ores where fine gold can be seen, it is very rarely the case that it can be collected to any extent by panning, and these same ores require roasting (though not to the same extent) as do the blue ores."

In reply to Mr. Smith's suggestion as to the origin of the deposit, I ventured the opinion that the rock might be an altered phonolite, as Dr. Cross had referred to South Dakota as being the only locality in the United States with the exception of the Cripple

Creek district where this rock exists. Mr. Smith states in a recent letter that a microscopic examination of the rock has disclosed distinct evidences of its eruptive character.

Samples were sent me of the two kinds of ore, the "blue" ore and the "red" ore. The blue ore consists of a hard, jaspery material, of a bluish caste of color, sprinkled here and there with pyrite, and containing also fluorite.

The red variety is essentially the same ore except that the minerals present in the blue ore have been changed into oxides. An examination with a lens shows the presence of little cavities lined with reddish and yellowish tufts. The appearance of these little tufts led me to suspect the presence of tellurium in an oxidized form, and a test made on fifty grams of ore showed plainly the presence of this element.

At my suggestion Mr. Smith sent me picked specimens of the two varieties of the ore for the determination of the quantity of tellurium existing, in the one case, in the oxidized form, and in the blue variety, in the unoxidized form. The following figures will show the results of the determinations made:

	Au.	*Ag.*	*Te.*
Oxidized	8·68	4·80	0·034% or 9·91 ozs.
Unoxidized	1·45	153·12	0·20% or 58·33 ozs.

The quantity of unoxidized material was so extremely small, only about 20 grams, that my investigations were limited to the determination of gold, silver and tellurium.

The large amount of silver in this variety may be accounted for by the presence of pyrargyrite, as a small speck of that mineral was observed by the aid of the microscope. The presence of selenium was also suspected, but this needs confirmation.

If it is proved that this South Dakota ore is an altered intrusive rock of a type similar to the Cripple Creek formation, the discovery may prove to be of some importance, as demonstrating the existence of gold combined with tellurium as a result of alteration or impregnation of the rock by silicious springs accompanied by fluorite as is the case at Cripple Creek. It may be assumed that the gold exists in the oxidized rock, which has been changed by surface waters, in the form of a soft brownish powder, as it does at Cripple Creek, and in a condition so light and soft as to

escape observation and preservation by the ordinary method of panning.

This condition has led to a great deal of uncertainty as to the form in which the gold exists, more particularly in oxidized tellurium ore, in which the telluride of gold existed, as in the South Dakota rock, in an extremely finely divided condition, and in many varieties of Cripple Creek ores in which bright, lustrous heavy gold is seldom seen, even in the richest ores.

The alteration of tellurium minerals by oxidizing surface waters is similar in many respects to the change which takes place when arsenides are changed into arseniates as in the case of enargite and arsenopyrite being converted into a great variety of arseniates of copper and iron. The brown mineral, pitticite or iron-sinter, has much the same character as the mixture of tellurite of iron, ferric hydrate and basic ferric sulphate found in the altered telluride ores of Cripple Creek.

The affinity of TeO_2 for a ferric salt is well known. Mr. F. C. Knight has shown that when a ferric salt, containing tellurium, is treated with ammonia the whole of the tellurium or nearly all of it, is precipitated with the ferric hydrate as telluride of iron, and, in the last publication of the American Chemical Society, a scheme is suggested for the separation and determination of tellurium in copper bullion by adding to the copper solution ferric nitrate, and precipitating the telluride of iron, mixed with ferric hydrate, by ammonia. Arsenic and phosphorus, as we all know, behave in the same manner.

From experience gained in this connection, I have been led to investigate the behavior of telluride ores when submitted to roasting. I have found, greatly to my surprise, that the elimination of tellurium from an ore, by roasting, is by no means what it has been claimed to be.

An experiment made by roasting a telluride of gold and silver, associated with silica and pyrite, showed that the bulk of the tellurium was left in the roasted product in an oxidized form as TeO_2, either free or combined with ferric oxide. Some further experiments will shortly be made on the oxidation of tellurium in the absence of pyrite, and also in the presence of that mineral. My impression is that in the roasting of tellurium ores the presence or

absence of pyrite will be found to have a very important effect on the volitilization of the tellurium and the loss of gold. On some future occasion I hope to be able to present to the Society some further results bearing on this qnestion.*

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* Since writing the above, the following experiments have been made with a view of ascertaining the effect of pyrite on the roasting of tellurium ore.

Experiment No. 1.—0·5 gram of sylvanite, containing 38·4 per cent. Te, was mixed with 2·5 grams pure quartz. This mixture which should contain 11·13 per cent. Te, was then roasted. After roasting, it contained 10·73 per cent. Te, showing a loss of 3·6 per cent. Te.

Experiment No. 2.—0·5 gram of sylvanite was mixed with 2·5 grams of an ore which contained some pyrite associated with quartz. This mixture, containing 11·13 per cent. Te, was roasted. After roasting, it contained 7·63 per cent. Te, showing a loss of 31·5 per cent. Te.

It will be seen that in the first experiment 96·4 per cent. Te has been converted into TeO_2, and retained, whilst in the second experiment the presence of the pyrite seems to have had the effect of intermittingly reducing the TeO_2 to Te, a certain amount of which was volatilized. A very similar result is seen in the roasting of arsenical ores containing sulphur.

THE VOLCANIC ROCK OF ALUM HILL, BOULDER COUNTY, COLORADO.

By C. Irving Andrews.

Meeting of June 3, 1895.

Alum Hill is situated about five miles south-east of Boulder, in the S. W. quarter of section 2, Township 1 South, Range 70 West of the Principal Meridian. A small portion of the hill is in the S. W. quarter of section 1. It is a triangular elevation extending about three hundred yards N. E. and S. W. and one hundred yards N. W. and S. E. It rises to an altitude of about 150 to 200 feet above the surrounding country. A gulley divides the hill into two elevations of about equal height. The distance between the two summits is about 100 yards. At a distance it resembles the other rolling hills of the neighboring region, and it is only upon closer examination that it shows any peculiarities. Upon approach, however, one is impressed by the large quantity of red clay scattered upon the surface, which seems to have been literally baked. Upon closer examination, black knots and fragments are seen, which are found to be shale, altered and melted in all possible forms. Upon still closer investigation volcanic rock is found of at least three distinct varieties.

The volcanic nature of this rock was first discovered by Dr. H. W. Allen of Boulder, who called the attention of Dr. C. S. Palmer to the outcrop. Dr. Palmer visited the locality, and afterwards announced the discovery to the Colorado Scientific Society, in the month of May, 1892. Later he gave the rock into my hands for investigation and chemical analysis.

The discovery is made very interesting from the fact that this volcanic outcrop is not mentioned in any reports of the U. S. Geological Survey. In regard to the nature of the outcrop it

appears to be the crest of a laccolite, the strata apparently having been raised out of position by the intrusion of lava from beneath. This is not stated as a definite fact, but the indications seem to point to this conclusion.

Two varieties of volcanic rock proper were first found, but later exploration brought to light at least one other variety. On account of lack of time I have been able to make the examination of only the two varieties first discovered, and this work is necessarily very incomplete.

For convenience I will refer to these two kinds of rock as variety A and variety B.

VARIETY A.

Macrocrystalline.—The general appearance of this variety is that of a fine grained, compact crystalline rock. It has a peculiar greenish gray color. It shows no phenocrysts. Some specimens show a somewhat vesicular structure, but this is not a general characteristic of the rock. In some of these cavities was found that modification of hematite known as floss ferri. From this mineral the hill is supposed to have received its name, as the mineral has a slight astringent taste somewhat similar to the taste of alum. This variety shows some evidence of decomposition. It has a specific gravity of about 2·82.

Microcrystalline.—Under the microscope this variety appears to consist principally of feldspar and augite, together with some hematite and a little calcite, cemented together by a nearly colorless glassy base. The feldspar appears to be a variety of plagioclase, but from the microscopic examination alone the exact species can hardly be determined. It contains inclusions, the nature of which I was unable to discover. The augite is of a yellowish-brown color. The crystals are small and their boundaries are not distinct. This mineral contains inclusions of hematite. Hematite is scattered through the rock, and the characteristic frost-like appearance peculiar to calcite is seen in some of the cavities. This variety seems to contain no magnetite or titaniferous iron, nor could I discover any trace of quartz or apatite. The small number of minerals in this rock is rather surprising, especially when considered in the light of the chemical analysis. From the

appearance of the crystals I should say that the order of crystallization was about as follows: Feldspar, augite, hematite, calcite.

Composition.—The chemical analysis of variety A gave the following results:

Water	0·210
Silica	39·224
Titanic oxide	3·492
Ferrous oxide	5·903
Ferric oxide	18·118
Aluminic oxide	4·931
Calcium oxide	19·291
Magnesium oxide	3·609
Potassium oxide	0·678
Sodium oxide	2·509
Carbonic acid	1·244
Phosphoric acid	
Sulphuric acid	
Chlorine	
Total	99·209

The ordinary methods of silicate analysis were used in this case. The titanic oxide was separated from the silica by expelling the silica as silicon fluoride by means of hydrofluoric acid, and from the iron by fusing with acid potassium sulphate, and boiling with a large quantity of water in an atmosphere of carbon dioxide. For the separation of aluminium from the other members of this group, I used a method which recently appeared in the American Journal of Science. The members of the group, in the form of the oxides or hydroxides, are digested with a mixture of 100 c.c. water with 10 c.c. hydrogen peroxide and 1 gram caustic soda. The action is allowed to proceed until effervescence ceases, when the solution is filtered, the filtrate acidified and the aluminium precipitated by ammonium hydroxide. The carbon dioxide was determined by fusing the rock with borax glass. This variety partially dissolves, with effervescence and with gelatinization, in hydrochloric acid. I obtained no tests for sulphates, phosphates or chlorides.

Variety B.

Macrocrystalline.—This variety is a coarse-grained rock of darker color. The only phenocrysts visible are glistening needle-

like crystals which, in reflected light, have a peculiar metallic luster somewhat resembling that of copper or iron pyrites.

Microcrystalline.—Under the microscope this variety discloses some very interesting features. The crystals which appear to the naked eye as glistening needles, here prove to be made up of groups of small crystals of augite arranged in columns, and having parallel extinction. The feldspar does not differ in appearance from that of variety A. Upon examination with a high power, crystals of haüyne are seen. The crystals are small and comparatively rare but the mineral is easily recognized by its blue color and its internal structure. In some of the cavities, tridymite is found, recognized by its peculiar shingle-like arrangement. Magnetite is scattered throughout the rock, and this has the appearance of titaniferous magnetite. This rock also seems to be held together by a colorless glassy base. The proportion of the different minerals seems to be about as follows: Augite 30 parts, feldspar 20, titaniferous magnetite 10, haüyne 1, and tridymite 1. The augite seems to have crystallized first, then feldspar, haüyne, magnetite, and tridymite, in the order mentioned.

Composition.—The analysis of variety B gave the following results:

Water	trace
Silica	44·932
Titanic oxide	2·917
Ferrous oxide	21·088
Ferric oxide	8·698
Aluminic oxide	18·324
Calcium oxide	1·407
Magnesium oxide	0·470
Potassium oxide	0·578
Sodium oxide	2·123
Carbonic acid	trace
Sulphuric acid	
Phosphoric acid	
Chlorine	
Total	100·537

This variety also partially dissolves in hydrochloric acid with gelatinization but without perceptible effervescence. I was unable to obtain any test for sulphuric acid, although the micro-

scopic examination showed the presence of haüyne. However, the amount of haüyne present is so small that the percentage of sulphur would be very slight. No trace of phosphoric acid nor of chlorine was found in this variety.

Upon comparison of the results of the chemical analysis of the two varieties we find some remarkable differences. The amount of silica differs by about four per cent., the total iron oxide by about seven per cent., and, while in variety A, the iron is mostly in the ferric state, in variety B it is principally ferrous. The amount of titanic acid in variety A is greater by about one per cent. than in variety B, notwithstanding the fact that variety B contains titaniferous iron while variety A does not. The difference in the quality of aluminic oxide is still more surprising as variety A contains only 4·9 per cent. while variety B contains 18·3 per cent.

When we attempt to make the calculations for the mineral constituents of these two kinds of eruptive rock we are confronted by many difficulties. They seem to be basaltic, but both are very basic and both contain, apparently, peculiar varieties of the different minerals. The results of the analysis of a typical basalt are as follows:

Silica	43·60
Aluminic oxide	11·76
Ferrous oxide	7·84
Ferric oxide	15·38
Manganic oxide	0·23
Calcium oxide	10·32
Magnesium oxide	3·33
Potassium oxide	1·36
Sodium oxide	3·42
Water	1·00
Titanic acid	0·82
Total	99·06

On comparing the analysis of variety A with this analysis the principal differences observed, are in the amounts of silica, aluminic oxide and calcium oxide. Variety A is very basic, and corresponds more nearly in this respect to limburgite, a typical analysis of which is given below:

Silica	42·78
Titanic acid	0·28
Aluminic oxide	8·66
Ferrous oxide	
Ferric oxide	17·96
Manganic oxide	0·95
Calcium oxide	12·29
Magnesium oxide	10·06
Potassium oxide	0·62
Sodium oxide	2·31
Water	3·96
Total	99·87

Variety A, however, could hardly be a limburgite as it contains augite instead of hornblende, and is still more basic than limburgite. In fact I found no analysis of either a basalt or a limburgite which was as basic as this variety. While the percentage of silica would bring variety B under the basalts, yet it contains less calcium and magnesium than the typical basalts. It is also richer in ferrous iron and aluminum than any basalt whose analysis I have met with.

Calculations.

Variety A.—This rock contains a small amount of calcite. Assuming all of the carbon dioxide to be in this mineral we find the corresponding percentage of calcium oxide to be 1·55 per cent. Regarding the feldspar present as labradorite, and assuming that all the aluminic oxide present is in this mineral, we find from the analysis of typical labradorite, that the amount of calcium oxide corresponding will be 6·86 per cent., and the amount of silica 8·7 per cent. The total amounts of soda and potassa will also be in this mineral. Regarding the augite as an aluminious variety in which all the alumina has been replaced by ferric oxide, and part of the calcium oxide replaced by magnesium oxide, while ferrous oxide takes the place of the magnesium oxide, we can account for most of the silica, calcium oxide and ferrous and ferric oxides. About 2·8 per cent. ferric oxide will be left as hematite. The remainder of the ferrous iron together with the remaining calcium and some of the silica, are left to form the glassy base of the rock, provided that these suppositions are correct. Whether they are

correct or not it is evident that we are dealing with a very peculiar variety of eruptive rock. The question might come up whether this were a true volcanic rock or an altered basalt. It is undoubtedly somewhat altered, and it is probable that contact with limestones and shales has changed its composition to a certain extent. On the other hand, however, it seems to be entirely homogenous and free from pebbles or fragments.

Variety B.—This variety is characterized by the low percentages of calcium and magnesium and the very high percentage of ferrous iron. Regarding the feldspar as anorthite the amount of silica corresponding to the amount of calcium oxide, is 14·9 per cent., and the amount of aluminic oxide 5·8 per cent. Assuming the remainder of the silica to be present in the augite, the calcium oxide must be mostly replaced by ferrous oxide, while the amount of alumina required will be about four per cent. It is probable that the pyroxene molecule is composed largely of the acmite or ægerine molecule, which would contain the sodium and potassium oxides. Regarding the magnetite present as containing most of the titanium, while the haüyne contains only very small amounts of the different oxides, we find that we have alumina and ferrous oxide to spare. Just what this means it is difficult to state without further examination.

Of course the results of these calculations are not to be relied upon as at all trustworthy. To understand perfectly the composition of these rocks it would be necessary to separate the mineral ingredients either by means of a specifically heavy solution or other mechanical means, and to make an analysis of each mineral separately. Lack of sufficient time has prevented me from carrying this work to completion. It is hoped, however, that this investigation, incomplete as it is, may be of some service to those who continue along this line of work.

This discovery of volcanic rock is interesting, coming as it does between the volcanic rock of the Longmont region and that of Golden. The Longmont basalt contains olivine, that of Golden, leucite, while this is characterized by haüyne. In regard to the age of this formation, from the fact that the coal fields of the region are Laramie, this would seem to be even more recent.

In closing this paper I desire to express my indebtedness to Dr. C. S. Palmer for his very valuable suggestions and assistance. I also desire to express my thanks to Dr. H. W. Allen for much valuable information concerning the locality.

I hope that, while my work has scarcely begun to clear up the geology of this one formation, it may yet be counted as a small step towards unravelling the mysteries of the volcanic rocks of Boulder County.

SOME NOTES ON THE OCCURRENCE OF URANINITE IN COLORADO.

By Richard Pearce.

Meeting of September 9, 1895.

This rare and interesting mineral was first discovered in Colorado by the writer in August, 1871, and occurred in what is called the "Wood" lode in Leavenworth Gulch, Gilpin County, about one and one-half miles from Central City, and not at Black Hawk, the locality given in Dana's System of Mineralogy. As the discovery was made nearly twenty-four years ago it may prove of interest to the members of this Society to have recorded a few details regarding its discovery, and the peculiar conditions under which it was found.

In the summer of 1871 the writer's attention was directed to a group of mines in Leavenworth Gulch, owned by the Rochdale Mining Co., and in the course of his examination of one of the several claims belonging to this company, he found on the dump of the "Wood" claim a heavy black mineral which proved to be uraninite coated with a beautiful canary yellow material, uranium vitriol, a basic sulphate of uranium formed from the oxide by lengthened exposure on the surface.

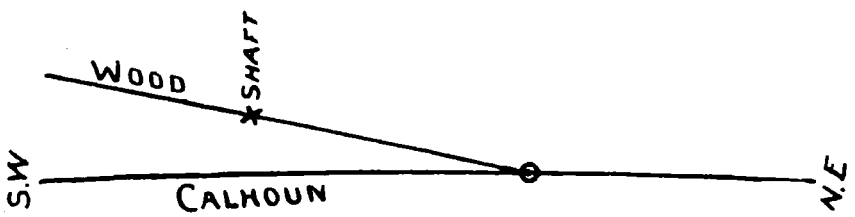
The mine had been worked for gold some few years previous to 1871, and a considerable quantity of ore was mined and sent to the mill, and, it is believed, to the smelter, but the results were not satisfactory, and the mine was abandoned. The agent of the company stated that the mill men objected to the ore on account of its high specific gravity, as it hung most tenaciously to the plates and scoured the amalgam; he also stated that a load of the ore was sent to the smelter to be tested, and, after sampling and

assaying, it was found to contain no gold, pronounced worthless, and thrown into the creek.

The discovery of uraninite thrown broadcast on an old dump, was a source of astonishment to the finder who had been accustomed to see it only in very small quantities, and under very peculiar geological conditions. At first he could hardly venture to trust his own opinion; and a blowpipe apparatus, the property of an old Freiberg friend, being found at one of the mills close by, in Russell Gulch, a quick test proved the existence of uraninite, or pitchblende as it was commonly called.

About 200 pounds weight of the mineral was sorted out of the dump and sent to the writer at Swansea. There it was still further selected and sold to the firm of Johnson and Matthey, London, for the sum of £42 or $210.

The following is a copy of a pencil sketch made at the time, showing the relation of the "Wood" lode to the "Calhoun," another claim owned by the Rochdale Company:



The rock in which the "Wood" lode occurs, is mica schist traversed by veins of feldspar and quartz enclosing magnetite, and the lode which had been explored only to the depth of about 60 feet, was said to be four feet in width with six inches of solid uraninite.

The associated minerals, as seen on the surface, were pyrite, chalcopyrite with small quantities of pyrrhotite and galenite, the gangue being mainly quartz.

A lease of the property was obtained in the following year, and the mine was reopened and worked for uranium.

It was found that the shaft had been sunk through the center of a vertical lenticular deposit of uraninite, and, consequently, the richest and by far the largest bulk of the ore had been lost through

ignorance of its value. That portion, however, which was left, was extracted, and, after careful sorting, about three tons of rich ore, containing about 60 per cent. of pure black oxide of uranium, was shipped to London where it realized about $7,500.

History repeats itself. In 1894, twenty-three years later, the mine was again opened and worked on lease, and in drifting west from the old shaft at a greater depth, another lenticular deposit of uraninite was encountered; but, as the nature of the mineral was unknown to the people who had the lease, the same disappointment from mill returns was experienced as in the first discovery.

A specimen of the ore was brought to the writer by the leaser who had heard from some source that he had found something rare and valuable in the "Wood" lode many years before. The new find proved to be uraninite of exactly similar character as the first deposit which was found in 1871.

The writer purchased a quantity of the ore, but has not as yet been able to find a satisfactory market for it.

The mineral uraninite formed the subject of some highly interesting investigations by a former President of this Society, Dr. W. F. Hillebrand, who pointed out, for the first time, that it contained the element nitrogen. More recently Prof. Ramsey has discovered that the large bulk of the gas thought to be nitrogen by Dr. Hillebrand, proves to be the new element helium.

THE DIKE ON THE COLUMBIA VEIN IN WARD DISTRICT, BOULDER COUNTY, COLORADO.

By Chas. Skeele Palmer and Wm. B. Stoddard.
(Communicated by Chas. S. Palmer.)

Meeting of October 7, 1895.

This paper is designed to be included in the series of papers on the eruptive rocks of Boulder County, Colorado, which appear at intervals in the Proceedings of the Society, from the chemical department of the State University.

This great dike with its attendant vein is well known to every student of the mineral resources of Boulder County. It has been incidentally referred to, in many geological publications, but, so far as known to the writers, it has never been subjected to a detailed examination, and its true character has, curiously enough, escaped detection.

The most important notice of this dike which we have found in the literature, is a paper on "The Mineral Resources of Boulder County, Colorado," by P. H. van Diest, published in the biennial report of the School of Mines for 1886. On page 28 of this report, in a reference which we suppose refers to the dike in question at Ward, he calls it a quartz porphyry and this is the name which most students would give the rock on a casual examination; indeed we have always used this name in referring to it, and were quite surprised to find that it is rather a felsite porphyrite.

The dike in question runs on a strike N. 80°, E. It has been traced a mile or more, from the Niwot mine at the west to and near the various mines of the Columbia lode.

This lode lies just north of the dike which dips towards the north at an angle of about 70° and forms as a rule the foot-wall.

Good mines are also found at the south side of the dike, the

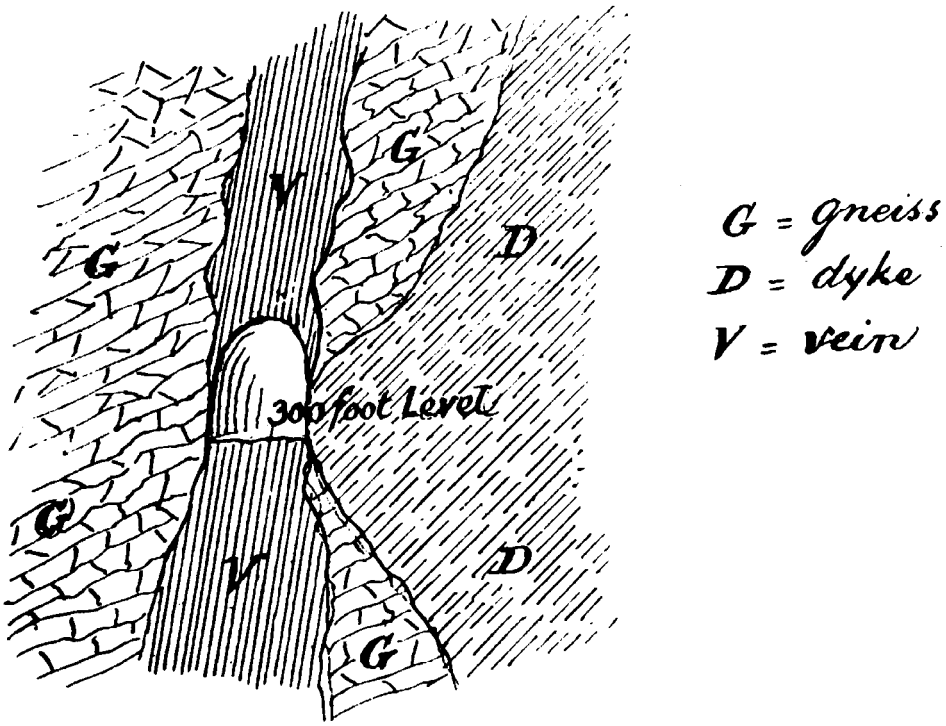
veins dipping under the dike with a parallel dip, the latter forming a hanging wall, but the mines on the south side are not developed to the same profitable extent as those on the north.

The dike is about two hundred feet wide. The surface rock weathers to a light-gray or straw color, somewhat resembling a hornstone; but the fresh rock has a slightly greenish cast. The rock has a Sp. Gr. of about 2·72. There are a very few macroscopic quartzes visible in the unaltered rock of the surface, which probably are responsible for the mistake we have previously made in the rock.

The country rock is a micaceous gneiss, highly laden with mica and much contorted. As one goes south he finds many other smaller dikes. These have not been subjected to a careful examination, but many of them appear more porphyritic, and the whole region east and south seems largely a mass of light andesitic porphyrite, to give it a provisional name.

This dike is one which, from practical results, is definitely connected with the finding of large, valuable and continuous vein mineral, and it is interesting to learn that the more careful examination of the dike indicates just the kind of metamorphism which a mining geologist would expect to find in this particular region. The vein matter is iron pyrites, copper pyrites, and mispickel, deposited in silicious material. I have noted in some cases that a stratified vein material with but little ore, would run higher than much of the massive ore which is unstratified. This, of course, is not a rule without an exception.

The particular specimens examined were obtained about four years ago from some first workings at about the 300-foot level of the Niwot mine, and were so fresh and inviting, that a fair quantity of the material was saved for investigation. At this particular spot, the country gneiss had pinched out, and the vein came in direct contact with the dike, as shown in the diagram on following page:



So little is to be learned from a microscopic examination of the rock that we will not pause to reiterate the little information already given. But we may say that while the rock on the whole is quite aphanitic, yet there are visible to the naked eye crystals of a feldspar, some 1 or 2 mm. in diameter, a few chloritic or micaceous needles of a greenish cast and a few specks of opaque, ore-like material.

Microscopical Examination.

The microscopical examination of the rock is at first quite confusing aud disappointing. The whole rock, ground mass, feldspars, chlorite, and mica needles, all seem to have lost their usual characteristics, such as: extinction-angle, polarization-colors, even natural color. The rock as a whole seems to be an aggregate of a kaolin-like mineral or minerals, opaque, formless, of a very light straw color, with an enormous quantity of secondary quartz.

The feldspars are well banded with a low power, the parallel

zones of growth being well marked by the lines of the residual kaolin-like mineral. Several of the feldspars show a form reminding one of plain untwinned orthoclase; but the analysis of the rock in its present condition calls for triclinic feldspars.

Scattered through the rock at frequent intervals are opaque masses of a peculiar straw-colored opaque substance somewhat resembling leucoxene; these masses have quite frequently associated with them opaque, ore-like granules which, in bright illumination, show a cherry-red color; they may be rutile, but in the absence of any satisfactory test for titanium, the grains are referred to some iron mineral (hematite?) and the straw-colored masses to altered kaolin from feldspars, and the latter with particular emphasis, inasmuch as in one case the masses seemed to resemble the shape of feldspar crystals, yet again in the other cases the imitation shape was that of sphene.

Most of the kaolin and the feldspars are closely connected with the fine quartz ground-mass, to be described later.

The long needles, dark green in color, seem to preserve something characteristic of both mica and chlorite, with here and there a suggestion of actinolite; but the absence of most of the characteristics of these minerals, and the appearance of fine grained secondary quartz in their very cores, show how highly altered they are.

Inasmuch as the more microscopic minerals show themselves to be made up at present of a secondary quartz base, and as the ground-mass also suggests secondary quartz, a careful examination was next made of the ground-mass.

With a low power the ground-mass gives appearances suggestive of an indefinite granophyre structure, made up, as it is essentially, of residual kaolin matter and secondary quartz.

Here and there sphene-like concretions, with a dark chalcedony-like cross between crossed nichols, show up.

A higher power, one-fifth or one-sixth of an inch, shows the same structure, vague and ill defined, only more magnified.

Remembering the suggestion made by Mr. Hills, a few years ago, we next used one-tenth and one-twelfth oil immersion objectives with most gratifying results. Though the sections were rather thick for this treatment yet they readily gave up their secret.

It is this; the whole rock, ground-mass and all, is composed of groups, bunches and rosettes of young drusy quartz crystals which radiate, like bunches of needles, from every residual fragment of the older decomposed minerals. The spaces between these bunches or druses are filled in solidly with larger particles of clear quartz, (and possibly suggestions of feldspar and mica).

Thus the rock has been decomposed and silicified to its core; indeed it might be called a silicious fossil.

The result is precisely in accordance with the anticipation based on the contiguous silicious vein matter and sulphide ores.

Chemical Examination.

The analyses of the dike specimen are as follows:

	First Determination.	*Second Determination.*
Loss by drying at 110°	0·278	0·000
Loss by ignition	7·344	7·453
Sulphides of 2d group	0·977	0·977
SiO_2	63·090	63·848
$Fe_2O_3+Al_2O_3$	20·420	20·400
*Fe_2O_3	3·141	3·141
*Al_2O_3	15·441	15·441
FeO	1·681	1·662
CaO	5·054	4·812
MgO	0·955	1·160
*Na_2O	1·897	1·897
*K_2O	0·082	0·082
CO_2	trace	trace
Totals	99·940	100.473

* Indicates the results of single determinations.

Discussion of the Analyses.

In view of the highly silicious appearance of the sections the 63 per cent. of silica seems rather low. Let us, however, attempt an explanation.

Let us assume that the CaO, about 5 per cent., is present as anorthite; this will call for about 9·25 Al_2O_3, and about 10·75 SiO_2.

Let us next assume that the remainder of the Al_2O_3, viz: about 6·14 is present as some kaolin-like mineral; this will call for about 8 SiO_2, and about 2·5 H_2O.

Now if we allow 10 per cent. more SiO_2 for all the other bases present, FeO 1·6, Fe_2O_3 3·1, MgO 1·00, Alkalies 2·00, we obtain a total of combined silica of about 28·75; and this deducted from the 63·1 of total silica leaves about 35 per cent. of free silica. This quantity will serve very satisfactorily to explain the general appearance of secondary quartz which the rock bears on microscopic examination, and the growth both of the innumerable quartz needles and of the cementing quartz.

The loss on ignition represents water, and, in view of the absence of carbonates and the small quantity of ferrous iron, we may assume that the 7·4 per cent. loss represents about this quantity of water.

Deducting the 2·5 of H_2O in the kaolin we have about 5 per cent. for chemical hydration, with the silicates other than the kaolin.

But again, the determination of the ferrous iron is uncertain on account of the presence of the sulphides, obvious in the microscopic examination, and implied in the 1 per cent. sulphides of group II., (sulphides insoluble in HCl solution.)

The other silicates may well be referred to residual decomposition of mica, amphibole, etc., etc.

Regarding the name of the rock, it seems the rule to name a rock from its original condition, not from its later decomposed condition. As the evidence is that the feldspars were originally triclinic and porphyritic, we will name it a felsite porphyrite.

It may have been an eruptive andesite, bearing feldspar (triclinic) biotite, amphibole, sphene, etc., etc. At present it is altered in keeping with its accompanying fissure vein to an aphanitic impure silicious hornstone-like rock.

We are greatly indebted for much valuable information regarding the location of the dike to Professor Henry Fulton, who was formerly superintendent of the Niwot mine.

SPHERULITES CONTAINING CHALCEDONY AND OPAL IN COLORADO.*

By Horace B. Patton,
Professor of Geology and Mineralogy at the Colorado State School of Mines.

Meeting of November 4, 1895, at Golden.

It was the privilege of the writer this last summer to investigate an exceedingly interesting occurrence of chalcedony and opal, near the head-waters of the Rio Grande, in Hinsdale County, Colorado. Attention was first drawn to these minerals by specimens brought to the School of Mines about a year ago. They were said to occur in large boulders imbedded in a clay bank.

The exact locality was found to lie on Ute Creek, about three-quarters of a mile above its junction with the Rio Grande; that is, about fifteen or twenty miles below the source of the Rio Grande.

The so-called boulders were found to be large spherulites scattered in great abundance on a comparatively level hillside at the foot of a steep, clayey bank, some 200 feet high, out of which they had been washed. It was evident that a good many persons had visited the locality, as all the boulder-like masses in sight had been broken to pieces, and their scattered fragments lay in great profusion over an area of several acres. The writer was told by Mr. Kingman whose ranch lies two miles below on the Rio Grande, and who claims to have located this deposit, that the

*This paper was originally read before the Society and subsequently published in bulletin form under the title "Concretions of Chalcedony and Opal in Obsidan and Rhyolite in Colorado." The writer was not at the time aware of the paper by Mr. Whitman Cross ("Spherulites in Acid Eruptive Rocks," Philosophical Society of Washington, Bulletin Vol. XI, pp. 411-444. See also, "Geology of Silver Cliff and the Rosita Hills, Colorado," U. S. Geological Survey, Seventeenth Annual Report, Part II, p. 298), in which very similar occurrences are described as occurring near Silver Cliff, Colorado, and in which the primary nature of these huge, concretion-like masses was pointed out. A more recent study of the remarkably developed spherulites of Silver Cliff and vicinity, to which Mr. Cross has kindly

"boulders" were broken to pieces in search for precious opal which does occur very sparingly in thin seams.

These masses had already been found by Mr. Kingman to occur in a certain definite bed, situated perhaps 200 feet up the steep, clayey bank, as well as in another bed near the creek, to be referred to later on.

This bed was found to dip gently to the northeast at varying angles. It consists of a brown, clayey layer, varying from six inches to two feet in thickness, lying on top of bluish-black, sandy material. The spherulites vary in diameter from about a foot to two, or even three, feet, and lie very thickly bedded in the brownish clay. They are usually spherical, or approximately spherical in shape. Externally they are very rough. When broken open they appear to be composed of a homogeneous, light-brown, flint-like material, through which are sprinkled small, glistening crystals of glassy feldspar. In the center is usually to be seen a large, gaping, sometimes many-branched, cavity which may be a foot or more in greatest length.

Sometimes these cavities are empty, or nearly so, but usually they are lined with beautiful, botryoidal chalcedony of varying shades of gray or brown and white, or with alternating bands of these shades. In most cases the centers of these lined cavities are empty; but very often the center is entirely filled with a pure white milk-opal. This opal may be structureless or banded in straight layers, in which case, in addition to the milk-opal, may occur also colorless, transparent, glassy opal, or perhaps delicate, straight bands of gray chalcedony, beautifully set off by the enclosing white opal. In still other cases the opal may be clouded with black dentritic material, presumably manganese oxides. Precious opal, as well as fire opal, occur very sparingly as above mentioned, in thin seams, but not enough of this precious opal has as yet been found to justify working the beds. A beautiful clear, light-green chalcedony, filling the whole cavity, is also to be

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drawn the writer's attention, has convinced him that the large roundish bodies here described are, like those of Silver Cliff, of the nature of primary spherulites. This conclusion has been arrived at after a careful study of the Silver Cliff spherulites both in the field and in thin section under the microscope.

The writer, therefore, takes this occasion to recast the original paper as far as relates to the origin of the roundish masses under consideration.

met with, and appears to be always straight banded, not infrequently alternating with milk opal. (See illustrations 1-8.)

Upon careful examination the brown, clayey bed containing these spherulites, was found to be the extremely rotted and stained upper portion of an obsidian flow, and the black, crumbling, sandy material, immediately underlying this bed or layer, to be the disintegrated but less altered portion of the same flow.

It was further found that at this locality there are two such obsidian flows, separated by perhaps 200 to 300 feet. The lower flow is very near the creek, and apparently crosses it, being well exposed on the eastern or opposite side from the place where the opals and chalcedony are mainly found. The lower flow on both sides of the creek has the same brown, clayey, rotted upper portion, and encloses the same spherulites as does the upper flow. In no case could the exact thickness of either of these obsidian flows be determined, but the lower flow which is hardly more than thirty or forty feet above the creek bed, is seen, on the east side, to be at least fifteen or twenty feet thick. The lower portion of this exposure is seen to be composed of black, or greenish-black, glassy obsidian with many enclosed minute crystals of glassy feldspar. But the upper portion, for a distance of ten feet or more, becomes increasingly granular, so that near the upper surface it crumbles into small fragments at the first blow of the hammer, and can be readily excavated by means of a pick and shovel. Together with this crumbling character seems to be associated the occurrence of small, roundish spherules, about the size of a pea or less. In the middle portion of the flow, where the obsidian is comparatively tenacious, these occur but sparingly, and increase in number toward the surface, where they form, in some cases, nearly one-half the whole bulk. The rotted, clayey layer, upon close examination, is seen to contain the same brownish spherules, together with the very soft, kaolinized remains of the enclosed feldspar crystals; but the whole layer is so evenly stained that the spherules are not easily seen.

The upper obsidian flow has been traced for, perhaps, one-half mile, but exposures are scarce and poor, as the whole mountain side, being composed mainly of rather soft rhyolitic tufas, is covered with the loose detritus derived from their weathering or is

covered up with a dense growth of timber. Except in the uppermost rotted layer, the brownish spherules have a firmer texture, and resist weathering better than the main mass of the obsidian, so that they weather out like little pellets, and, when broken, indicate by their radial lines of fracture a radiated internal structure.

In the summer of 1894 another locality for chalcedony was visited by the writer on the south side of Specimen Mountain, a rhyolitic peak on the summit of the continental divide, west of Estes Park, and almost at the source of the Grand River. Here, too, were found small hollow spherulites containing chalcedony, and occurring in obsidian just at the junction of rhyolite. In this case the obsidian was much firmer, and the small spherulites of a dark, brownish-red color. The size of these spherulites varied from an inch or less to six or eight inches. (See illustration 11.)

On the same mountain was also found a bed of light-gray rhyolite, thickly studded, in one place, with small, nodular balls, which readily weathered out of the rock. These balls, in the rhyolite, showed plainly developed the doubly terminated hexagonal pyramids of quartz which are characteristic of the rock itself; they, too, are often hollow and filled with chalcedony. (See illustrations 12–15.)

Aside from the above localities there were found in the collections of the State School of Mines, reddish-brown spherulites from Middle Park, Colorado, very similar in appearance to those obtained on Specimen Mountain; also light-gray, spherical masses from Del Norte, very similar, except for their color, to those from Ute Creek. (See illustrations 9 and 10.)

An investigation of thin sections prepared from the obsidian and from the spherulites of these various localities, show, beyond any doubt, that, with exception of the nodules in rhyolite from Specimen Mountain, all these spherulites were formed directly in the obsidian, and partake of the structural features of the asssociated rocks.

As an illustration we will take a thin section of the spherulitic obsidian from the east side of Ute Creek, and compare this with a section taken almost at random from among six or eight thin sections prepared from the brownish, flint-like spherulites in

the same. Under the microscope the mass of the obsidian is seen to be an isotropic glass showing strongly marked flow structure, accentuated by white and gray, more or less clear or cloudy, wavy streaks; the grayish colors being produced by countless indeterminate, blackish, enclosed specks. Occasional rectangular sections of sanidine, also of plagioclase, as well as a few plates of biotite, are to be seen, with the wavy flow lines of the glass lapping around and between them. Throughout the whole mass occur countless opaque looking trachitic particles that remind one of straight and curved chopped hairs.

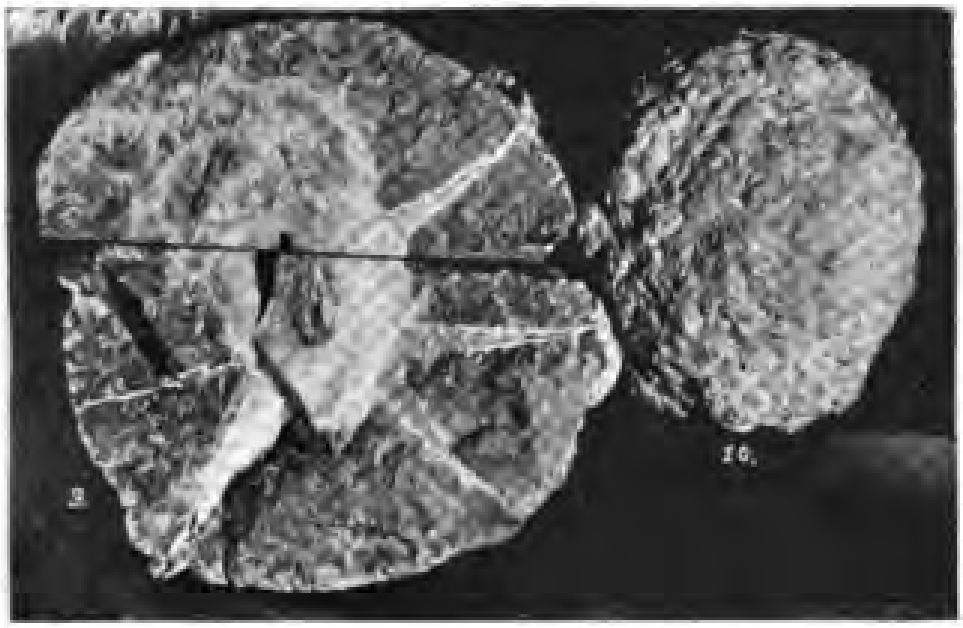
The brownish spherules appear in ordinary light to differ in no respect from the surrounding glass except in color, as though these spherical portions were merely stained spots in the obsidian. In polarized light, however, these roundish spots are quite distinct from the surrounding glass and are plainly crystallized, with an exceedingly fine radiated structure, common to all spherules.

With crossed nicols they always show the black cross characteristic of spherulitic aggregates. In spite of this radiated fibrous structure these spherules disclose the same flow structure, and the same black trachites as are to be seen in the rest of the rock. These spherules, therefore, have been formed directly in the obsidian through the local devitrification of the glass, which must have occurred after the solidification of the lava.

Similarly, thin sections prepared from the large brown spherulites show the identical structures described above as characteristic of the obsidian, viz.: the flow lines, together with enclosed crystals of glassy felspar and biotite, and also the peculiar, minute, hair-like, opaque trichites. There is this marked and instructive difference, however. The original, isotropic glass appears to have been entirely devitrified, and, in its place, occur thin, wavy streaks; and strings of more or less radiated, fibrous roundish portions are to be seen — the exact equivalents of the spherules described above as occurring in the obsidian. In ordinary light, on account of the nearly uniform brownish color of the rock, the boundaries of these spherulitic portions can hardly be distinguished, but in polarized light they are easily recognized. These bear a close resemblance to some of the compound spherulites of Silver Cliff.

It is not the intention in the present paper to give a minute or detailed description of these structures, or to trace more exactly the character of the alterations. Suffice it to say at this time that, not only in case of Ute Creek, but also in all the other cases mentioned above, thin sections have disclosed that the boulder-like masses containing the chalcedony and opal, are simply spherulites or original, devitrified portions of the obsidian glass, except in one case where the whole rock became more thoroughly crystalline, and developed into a rhyolite.

It is probable that most of the geodes of chalcedony that come from South Park and from other Colorado localities, are of a similar origin to these hollow spherulites from Ute Creek.



Chalcedony spherulites in obsidian. Del Norte, San Luis Park, Colorado

Spherulites in obsidian, Specimen Mountain, west of Estes Park, Colorado.

Chalcedony and opal spherulites in obsidian. Ute Creek, Hinsdale County, Colorado.

Outside of spherulites in obsidian. The same as No. 3 and 4.

Spherulites in rhyolite. Specimen Mountain, west of Estes Park, Colorado.

PECULIAR GEOLOGICAL FORMATIONS AT THE HEAD WATERS OF THE RIO GRANDE, COLORADO.

By Horace B. Patton,
Prefessor of Geology and Mineralogy at the Colorado State School of Mines.

Meeting of November 4, 1895.

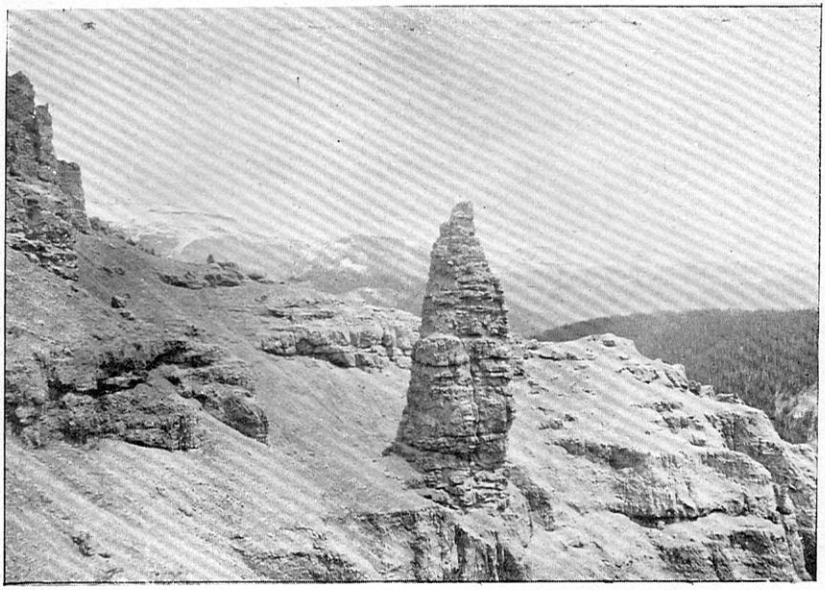
It is well known, as was indicated in the Hayden Survey report, that large portions of the San Juan Mountains that are drained by the Rio Grande and its upper tributaries, consist of extensive lava flows and enormous deposits of volcanic conglomerates and breccias. During the past summer it was the privilege of the writer to make a visit, though a hasty one, to this region. It was impossible at the time to do anything more than give a passing glance at the formations, and to take a few photographs of some of the more interesting erosion structures. Some of the photographs taken, were deemed of sufficient interest to justify presenting them to the Society by means of a lantern. The views were selected for the purpose of illustrating the effect of rain erosion in these volcanic conglomerates when exposed on a steep mountain slope.

The most striking exposures were seen on the north side of the Rio Grande above the junction with Lost Trail Creek, also above the junction with Pole Creek. The latter place is known as the "Sheep-licks."

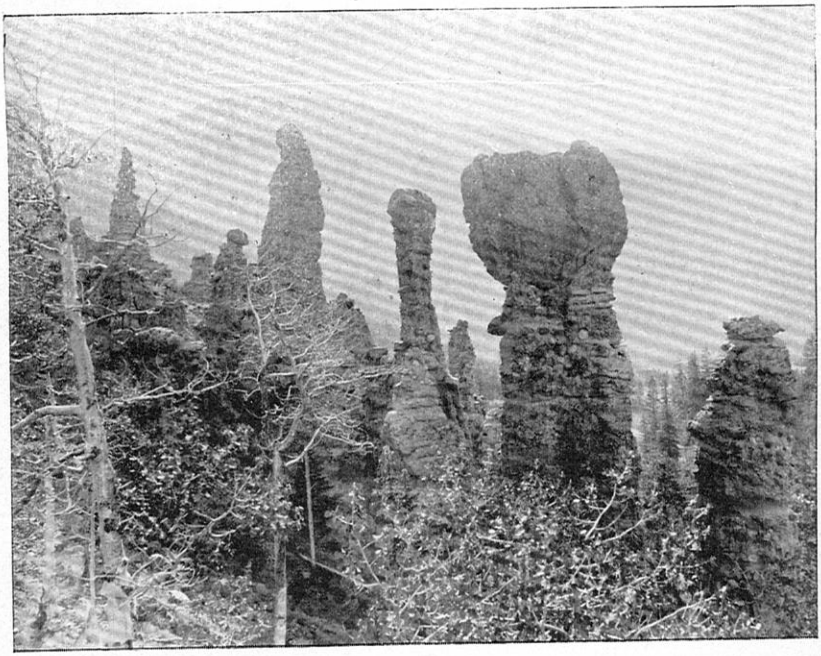
The depth of the volcanic conglomerate formations at these places appear to be enormous, probably thousands of feet. As far as observed the rock is usually rather basic, and would, at first glance, be classed as basalts and andesites. In the case of the andesites, or what was taken for andesites, the boulders and pebbles presented a greenish appearance similar to that of most propylites, and the alteration was advanced so far as to render a

determination on the spot uncertain. Until an opportunity has been found to investigate these pebbles microscopically, they are termed provisionally andesites.

In many cases the mass consists of large and small boulders of this altered rock, enclosed in a fine, tenacious ash. The ash is usually much more abundant than the enclosed boulders, and holds them very firmly cemented, but softens and washes away under the influence of the rains. Thus there results, by the irregular distribution of the boulders, erosion effects of the most fantastic character, that simply defy description. The few reproductions of the photographs here presented give a faint idea of these rain-sculptured conglomerates. Some of the largest boulders, seen perched on the top of the columns, are as much as ten or fifteen feet in diameter.



Effect of erosion in horizontally bedded volcanic conglomerate. "Sheep-licks," near the head of the Rio Grande, Colo.



Details of rain erosion in horizontally bedded volcanic conglomerate. Rio Grande valley above junction with Lost Trail Creek, Colo.

Effect of erosion in horizontally bedded volcanic conglomerate. Lower "Sheep-licks," near the head of the Rio Grande, Colorado.

Details of rain erosion in horizontally bedded volcanic conglomerate. Rio Grande valley above junction with Lost Trail Creek, Colorado.

Fig. 1. View of Cow Creek Valley from Piney Mountain, with Works of the International Nickel Mining Company in Foreground.

NICKEL.

[SECOND PAPER.]

THE NICKEL DEPOSITS NEAR RIDDLE'S, OREGON.

By W. L. Austin, Ph.D., Denver, Colorado.

Meeting of January 6, 1896.

1. Geographical.

The metal nickel has for some time been known to exist in Southern Oregon in various forms and in very considerable quantities, but up to the present its exploitation upon a commercial scale has not been undertaken.

The mineral josephinite,* an alloy of nickel and iron, presumably of terrestrial origin, is found in Josephine County, and deposits of nickeliferous pyrrhotites† have been discovered in both Jackson and Douglas counties; but the silicious ores of Douglas County are the only ones which have so far received other than a passing notice, and even these have been more the object of scientific interest, or of curiosity on the part of those engaged in the nickel trade, than of serious commercial consideration.

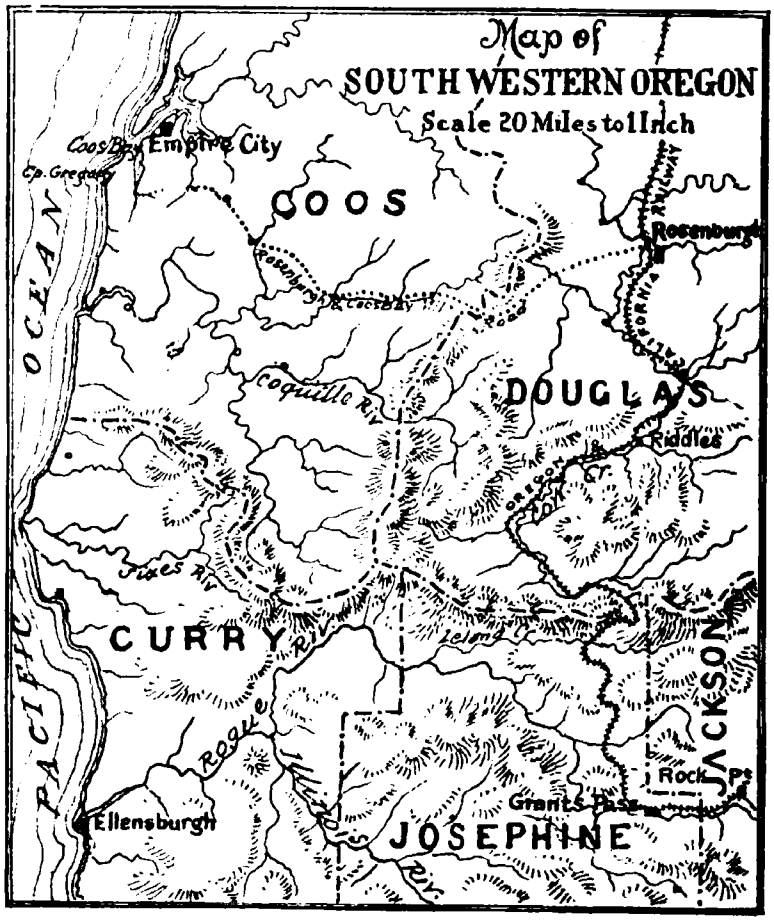
The remoteness of the Oregon ore-bodies, in the sense of cost of freighting the ore, or nickel products, to commercial centers, together with the active development of similar deposits in New Caledonia, and the discovery in late years of nickeliferous ores in the Dominion of Canada, have all militated against the exploitation of the Riddle's deposits; but they have been visited from time to time by a number of foreign as well as native scientists, some of

*American Journal of Science XLIII, p. 514.
†Mineral Resources of the U. S. 1887, p. 127.

whom have recorded their observations in the representative journals* of their respective countries.

The deposits occur near the small village of Riddle's, which lies in the fertile Cow Creek Valley in the southern part of Douglas

Fig. 2.



County, and is a station on the line of the Oregon and California Railroad, 226 miles distant from Portland, and 546 from San Francisco. This section of Oregon is densely timbered and well watered.

The valleys are cultivated to considerable extent, grain fields

*H. B. v. Foullen, on Riddle, Oregon. Jahrbuch d. k. k. geol. Reichsanstalt, Vienna, 1892. XLII. p. 223.

alternating with fruit orchards. The climate is mild and healthy, like that of the western coast in northern California and Oregon, and permits working the mines every day in the year. Cow Creek, a sufficient stream of water for any probable demands likely to be made upon it for mining purposes, is within three miles of the mines and empties into the Umpqua River, which, in turn, empties into the ocean in the northwestern portion of the same county. The ocean is distant not over sixty miles in a direct line from these mines, and the elevation of the railway station above tide water is given by the railroad company as 733 feet.

The nickel mines lie on "Piney" mountain, about three miles a little north of west from Riddle's, and are connected with the village by an excellent wagon road, of easy grades, and about seven miles in length, which reaches most of the present openings. The mountain upon which, as far as known, these deposits of nickel silicates alone occur is, as its name indicates, thickly timbered. It rises to an elevation of about 3,400 feet above sea level, and is an isolated ridge in a sea of other mountains. It is approximately one and one-half miles long by one mile broad, and runs in a northeasterly and southwesterly direction, comprising in all an area of about one and one-half square miles of nickeliferous territory.

2. Historical.

The first Discovery of ore in this locality is said to have been made by sheep herders about 1864, and specimens of both chromic iron and nickel ore were brought into the settlements by them. At that time the chromite was thought to be tin ore and the nickel silicates were mistaken for copper minerals. A man named Briggs, then living in Canyonville, experimented to some extent with these ores and succeeded in a small way in reducing metallic nickel out of the supposed copper ore; but the chromite alone received any considerable attention, and more or less of it was mined and shipped from that time. In the fall of 1881 Mr. W. Q. Brown, recognizing the true character of these deposits, secured control of what appeared to be the most valuable portions, and the property then acquired by him (comprising an area of about 815 acres) was subsequently conveyed to an incorporated company known as the "Oregon Nickel Mines," which is the present owner. It is stated

that about $30,000 has been expended in development work upon this property. In 1891 some of the nickeliferous territory (about 285 acres) not owned by the Oregon Nickel Mines, was secured by a Chicago corporation called the "International Nickel Mining Company," which is said to have since expended some $60,000 on surface improvements. Extensive preparations were made for opening up this property. A large Corliss engine with boiler plant, etc., were purchased and set up, and foundations were laid for a concentrator. Smelting machinery was also acquired; but only the power plant and a saw mill were ever put into operation. Unfortunately very little effort was made by this company to open and prove the mines, their extent and richness being apparently taken for granted.

The "Anglo-American Nickel Company," incorporated under the laws of Illinois in 1893, own some 160 acres of ground in the vicinity of Piney mountain, but the property appears to lie outside of the known nickeliferous area. An unsuccessful attempt was made to float this company in England.

Besides the companies named there is still a fourth operating in this field. It is known as the "Southern Oregon Nickel Mining Company," and owns territory on the extreme northern end of the mountain.

The relative positions of these various properties are shown in Fig. 4, page 180.

3. Geological.

Piney mountain apparently consists of a rock which has been pronounced by Dr. J. S. Diller,* of the U. S. Geological Survey to belong to the peridotites. It is of high specific gravity and dark yellowish-green color, and is composed essentially of olivine and enstatite with a small percentage of accessory chromite and magnetite. According to the same authority the olivine predominates so that the enstatite forms less than one-third of the mass. It shows a holocrystalline, granular structure and the rock, even when fresh, is completely permeated by a multitude of cracks filled with serpentine. The name "saxonite," suggested by Wadsworth,

*Clarke. Amer. Jour. of Science, XXXV. p. 485.

has been applied to this rock, but it has also been referred to as lherzolyte by Biddle. Analyses made by Dr. Diller, both of the saxonite and of the olivine, of which it is mainly composed, showed the following composition :

	Saxonite.	*Olivine.**
Ignition	4·41	0·57
Silica	41·43	42 81
Alumina	0·04	....
Chromic oxide	0·76	0·79
Ferric oxide	2·52	2·61
Ferrous oxide	6·25	7·20
Nickel protoxide	0·10	0·26
Manganese	....	....
Calcium oxide	0·55	....
Magnesium oxide	43·74	45·12
	99·80	99·36

The saxonite is easily decomposed by the elements, the resulting product being a clayey mass often of a bright-yellow cast which, upon the surface, has become a dark-red. The fact that this dark-red soil is mostly confined to the immediate surface of the ground is said by some to be due to annual fires formerly started by the Indians with a view to improving the grazing qualities of the section by burning off the underbrush ; but specimens of the decomposed rock embedded in the soil some feet from the surface, often show, when broken open, a dark-red exterior with a bright-yellow interior, and the dark-red earth is also observed associated with the genthite in the veins themselves.

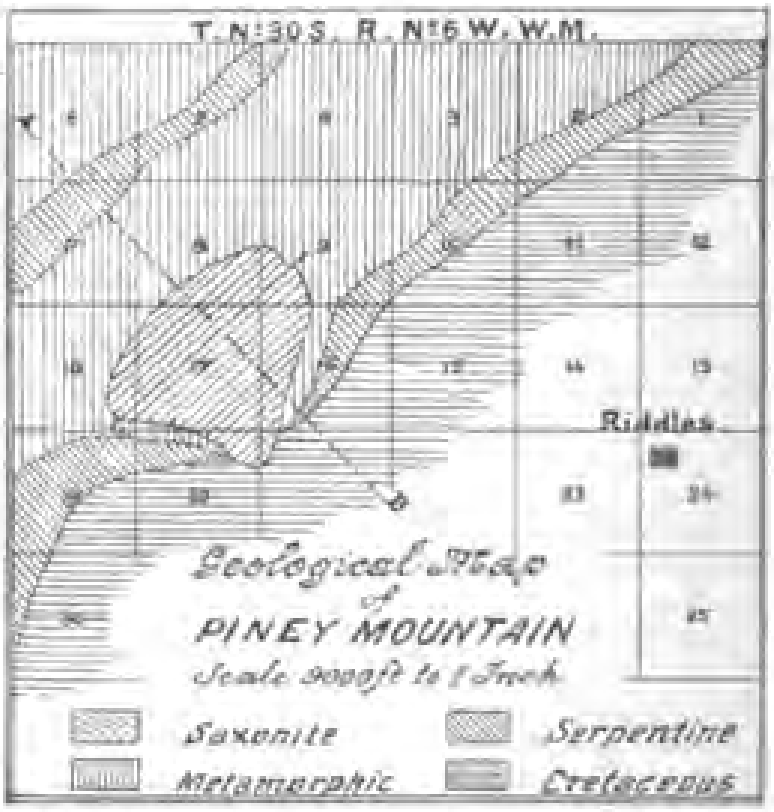
The extent of the saxonite is clearly marked by this dark-red soil which is characteristic of the whole mountain, so that although the rock itself, owing to its inability to withstand the action of the elements, is rarely exposed in a fresh state on the surface, it may still be traced with exactness, and its limits accurately defined. Away from this particular mountain no soil of a similar nature has yet been observed in this section.

This isolated ridge of saxonite is completely surrounded by a belt of what is locally termed "metamorphic rocks," varying from 150 feet to a mile in width. These consist of altered slates, con-

*This sample was not absolutely free from enstatite and chromite.

glomerates, sandstones, and massive rock which at times bears a close resemblance to intrusive eruptives and contains particles of metallic sulphides and patches of crystalline spar. The conglomerates and breccias are particularly prominent, and even the apparently homogeneous masses of eruptive or slatey appearance show upon their weathered surfaces that they, in many cases, con-

Fig. 3.



sist largely of breccia, so that it is quite possible that they are merely highly metamorphosed breccias. At no point in these metamorphosed rocks, not even in the slates, have any fossils been as yet discovered.

Outside of this concentric belt of metamorphic rocks occur the serpentines (showing crystals of bastite) in more or less extensive belts which entirely surround the hill, but in only one locality

is the serpentine known to touch the saxonite.* The exact limits of these various formations are clearly marked by the great variations in the color of the superincumbent soil as well as by the different classes of vegetation which grow on them, the light-brown soils of the metamorphic belt contrasting with the deep Indian-red of the decomposed saxonite on one side, and with the black soil and sparce vegetation which covers the serpentines on the other.

Beyond the belt of serpentines† are found shales, conglomerates, sandstones, and occasional streaks of lime rock in the shales. These all belong to the Crecateous period as shown by the characteristic Aucella concentrica as well as various Ammonites, Pecten and Arca of that age.‡

The sandstones often contain beautiful specimens of Ammonites while Belemnites are found in the shales.

4. Ore Deposits.

The average of the Oregon ore, as mined, appears to the eye more silicious than that of New Caledonia,§ but the relative proportions of silica contained in the ores of these two localities may be found to more closely approximate each other when greater depth is reached in the Oregon mines. At present, much of the so-called ore exposed is merely the residual silicious skeleton after the nickeliferous material has been removed by weathering, and this is what gives it its very silicious appearance. This silicious gangue is white and comparatively free from combined nickel as a general thing; though, on some portions of the mountain, sheets of greenish silica traverse the veins.

The amount of work done on the various veins and deposits of mineral on Piney mountain is not sufficiently extensive to demonstrate their actual commercial value. Numerous open cuts,

*The southeast portion of the peridotite area as represented in Fig. 3, is probably a slip from the mountain, and covers the metamorphic rocks, the serpentine belt and a part of the Cretaceous rocks. The serpentine belts unite beyond the limits of the map.

† No analyses are known to have been made of the serpentines of this vicinity, and no nickel ore is known to occur in the true serpentines, nor in the serpentine belt surrounding the saxonite.

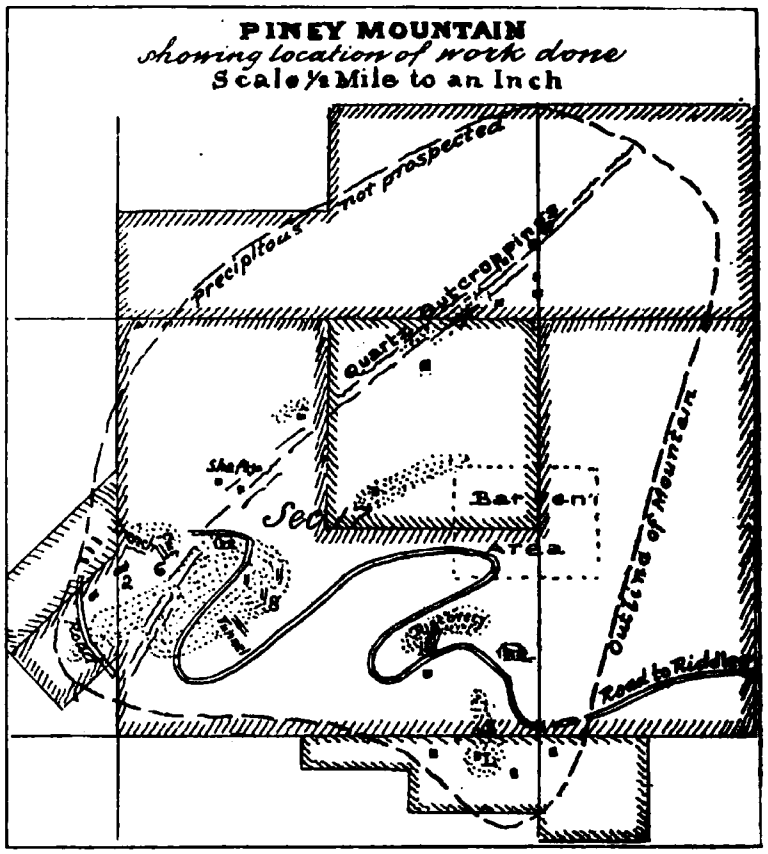
‡ Among the fossils said to be found in this locality are: Ammonites traskii, Arca breweriana, Pecten operculiformis, Pleuromya laevigata, Belemnites impressus, and Ammonites brewerii.

§ For analyses see page 190.

short tunnels, and shallow shafts, from 20 to 40 feet deep, have been made, but nowhere has a vertical depth of over 50 feet been reached. Sufficient openings have been made, however, to conclusively demonstrate that the genthite occurs in large quantities.

The extent of these veins is very considerable, the silicious

Fig. 4.



nickeliferous croppings on the summit of the mountain being, in places, eighty feet wide. As far as yet observed the lowest point at which nickel has been found (marked L on Fig. 4) is about 2,000 feet above sea level, but there is no reason why it should not be found deeper in the mountain when the deposits are better exploited, for it is only by chance that these are the lowest excava-

tions made so far. The nickel ores therefore are known to be distributed over the outside of the mountain for the entire distance from where it emerges from the metamorphic rocks to its extreme summit. At the point marked L (Fig. 4) the genthite occurs in green veinlets and detached masses, lying in a soft, bright-yellow, ochrey bank, resulting from the decomposition of the saxonite. Two "grab samples" said to have been taken from this point, gave respectively six and nine per cent. of nickel oxide. Although the genthite is very generally distributed over the mountain with the exception of a barren area of about twenty acres, the largest aggregations of the mineral appear to be intimately associated with the silicious veins cutting through the saxonite. These veins have a northeasterly and southwesterly strike,* conforming with the general trend of the mountain.

Their dip is variable, at one point being observed to change from an easterly to a westerly direction in a comparatively short distance, and at others standing almost vertical. At some of the first excavations made, the deposits were found to lie more or less flat, having an appearance as though the silicious gangue matter, resisting the action of the elements better than the more decomposable enclosing country rock, had finally fallen over from lack of support after the latter had been removed by decomposition. It is not claimed, however, that such was the origin of these flat-lying deposits. Owing to the crumbling away and subsequent leaching out of the nickeliferous minerals from the silicious matrix when exposed, the croppings do not show their original nickel contents on the surface, and samples taken by chipping off the surface rock are not a true index of the amount of nickel which probably is in the veins at greater depth. On some parts of the mountain the ore is less silicious than at others, and consists of a breccia formed of fragments of saxonite and genthite cemented together by a silicious material which is sometimes wholly chalcedonic quartz. The easily decomposed saxonite, etc., having been leached out of the cropping, there has been left behind a silicious skeleton which, as "float," serves as a guide to the prospector.

*The direction of these fissures appears to be the same as of those in New Caledonia.

But the genthite also occurs massive, and this, when first taken out, is often soft, and can be cut with a knife or kneaded between the fingers. Upon exposure to the atmosphere it loses its dark-green color, often almost wholly, and after being exposed for some time, if immersed in water, decrepitates audibly and falls to a greenish-white powder. For this reason the intensity of the green coloring of the exposed ore cannot be relied upon as a guide in estimating its nickel contents. Often the chalcedonic quartz which cements the genthite breccia or conglomerate, is stained greenish, and some specimens of chrysoprase* have been found, notably at the point marked "Discovery Tunnel" on Fig. 4. In some of the veins the fragments of bright-green nickel silicates enclosed in the silicious matrix, are in the form of pebbles, often resembling marbles; in others they show sharp corners. Some pieces are striated as though they had been fragments of slickensides.

Fig. 5.

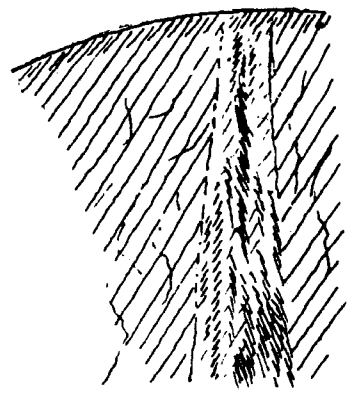


Fig. 5 shows a vein of genthite as seen at point marked 2 on Fig. 4. This is probably the best showing of massive genthite on the mountain. The vein, as it approaches the surface, breaks up and the genthite disappears, being replaced by yellow and red earthy clay. Ten feet from the surface there is about two feet of almost solid dark-green genthite, and at 40 feet it is more silicious, carrying only 7 per cent. nickel but six feet wide. Fig. 6 represents the aspect of another deposit. This is the open cut at "Discovery Tunnel." The tunnel is 175 feet long, one hundred feet of which is in ore. The cut is sixty feet long. At the mouth of the tunnel there is a shaft twenty feet deep with good ore in bottom. There is ground for believing this deposit to be a slide from the mountain above, this phenomenon having been already referred to in foot note on page 179.

*Geo. F. Kunz, "Gems and Precious Stones," p. 122.

There are some 500 tons of ore piled up at this point, and, in all, there are about 3,000 tons of ore mined at the different openings on the mountain. The average nickel contents of this ore is said to be 5 per cent., but some of it will go as high as 15 and 20 per cent. It would be difficult however, to get any quantity of it that would average above 8 per cent. from the present surface openings. Most of the soil of the mountain is nickeliferous, and runs from ½ of 1 per cent. to 2 per cent.

As the excavations so far made are almost wholly open cuts, and the ore exposed is clearly leached to a great extent, it is hardly reasonable to accept 5 per cent. as the average of the ore it may be expected will be found in deeper workings.

The manner in which these veins were formed becomes, in the case of the Riddle's deposits, of more than theoretical interest, because, as has been stated, the very limited amount of work done is insufficient to demonstrate their commercial value, and it is desirable to forecast the results to be expected from future development as far as practical. For if, after the mountain had been fissured in a northeasterly and southwesterly direction as is apparently the case, these fissures were then filled with mineral matter carried into them by lateral infiltration from the country rock, or deposited therein out of solutions emanating from below, we may in either case expect that these veins, already of importance upon the surface, will continue downward, and that their contents will be of economic value.

It is evident upon examination of these ore-bodies that they were deposited from an aqueous solution. Emmons* states that the admission that ore-bodies have been deposited by currents of circulating waters, logically involves the further admission that they may have been upward, downward or lateral currents, according as the conditions at time of deposit favored either direction of approach to the place of deposit. The determination of this direction in a special district is of the utmost importance from an economic point of view, since by it the explorations for the continuations of ore-bodies must be largely guided.

If these veins are the result of lateral infiltration from descend-

* Monograph XII, U. S. Geol. Sur., p. 571.

Fig. 6. View of Open Cut and Tunnel, Showing Vein of Nickel Ore on Right.

Fig. 7. Showing Cropping of Vein at 6 on Fig. 4.

ing percolating surface waters alone, then it is difficult to understand where the large masses of chalcedonic quartz came from with which the nickel silicates are intimately associated. This quartz constitutes the backbone of the mountain, occupies its highest elevations, and is in places eighty feet wide; and if the mineral solutions filtering through the country rock had a downward direction they could not have deposited their burden upon the apex of the mountain. The same reasoning applies to currents having a lateral direction.

It is also not easy to explain how a large fissure of the size indicated, situated as is this one, could be kept open for a length of time sufficient to permit its being filled up with minerals carried into it by the small amount of aqueous solutions which would be able to traverse a dense rock* such as the saxonite under consideration, yet such must have been the case if we are to accept the lateral infiltration theory in explaining the genesis of these deposits. Besides, what became of the iron of the olivine, which, under the conditions of lateral infiltrations, would be more or less converted into hydrated ferric oxide, and stain the gangue matter with its characteristic coloring? In addition to the objections already named in applying the theory of lateral infiltration† to the formation of these deposits, we have the breccias and conglomerates which it is difficult to reconcile with the peaceful working of this theory of formation.

But if these deposits were not formed by infiltration from any direction, then the only other theory admissible under the circumstances is that they have been deposited from thermal waters circulating through fissures in the rock. In support of the thermal spring theory there is: (1) the general similarity in direction of the silicious croppings showing that the mountain must have been fissured from northeast to southwest, affording a vent for such

* Emmons states that it is well known that percolating waters circulate freely in every direction through massive or eruptive rocks, owing to the effect which cooling and weathering have of splitting them into irregular blocks; but in the case under consideration the deposit is on the top of an abrupt mountain, and if cracks had existed the tendency would have been for the solution to run out of the main fissures and not into them.

† Brown, in speaking on this subject, says: "The theory of lateral infiltration has been advanced and by this theory it is possible to account for some of the vein formations. * * * I will admit that this theory is not applicable to all the ore deposits of the mountain, for by it we cannot account for the breccia and conglomerate found in some of the deposits."

springs had they existed; (2) the magnitude of these quartzose veins traversing a very basic rock that could hardly have yielded up so much silicic acid without showing more decomposition than is evident;* and, (3) the character of the deposited mineral in the veins themselves. It is evident that previous to the filling of these fissures, nickel-magnesian silicates already existed in a more or less pure condition, because the quartzose gangue is full of fragments of this mineral. Pebbles of silica and fragments of decomposed saxonite are also found enclosed in the silicious gangue matter. This occurrence of pebbles of both silica and genthite, these pebbles being often so worn as to resemble marbles, is evidence that they were either brought from a distance, or that these fragments have been subjected to a prolonged or violent ebullition. In places the whole vein-filling has the appearance of having been poured into the crevice in a more or less viscuous state, for fragments of genthite and saxonite seem to have been in suspension when the mass solidified, as they are surrounded by silicious material and yet are not close enough together to touch each other; fragments were cracked open, yet the cracks are not filled with the cementing material, and the whole has a semi-porous appearance. One peculiar feature of these genthite conglomerates is that some of the pebbles of the same outward appearance as those of the solid mineral, when cracked open are found to be pebbles of silica with only an outward coating of nickel-magnesian silicate. The silicious cement uniting these conglomerates and breccias is usually of a greenish cast but also white and brown.

In connection with the thermal-spring theory it is interesting to compare results arrived at by competent observers in the case of the New Caledonian deposits which are of a generally similar

* The substitution theory has also been advanced as a possible but improbable origin of these deposits. It is well known that peridotite alters into serpentine and it is possible that veins of serpentine were formed in the saxonite from the decomposition of the walls of fissures prior to the deposition of the nickel minerals. By subsequent decomposition of the serpentine the remaining rock would have become fitted for the reception of the nickel bearing solutions, and the precipitation of their nickel contents. Becker states (Monograph XIII, U. S. Geol. Sur., p. 127): "When serpentine is directly exposed to the action of the atmosphere, it is often bleached, and converted to a porous mass which is nearly pure silica, containing very little magnesia or iron. Where serpentine has been subject to solfataric action in the immediate neighborhood of ore bodies, the bases have often been removed, and silica has replaced nearly or quite all the original mass."

habitus to those under discussion. Levat,* who made a careful study of the New Caledonian deposits, ascribes their formation to the action of thermal springs, and in this Benoit† concurs with him. Both of these observers state that the nickel-magnesian silicates have been brought up from below through pre-existing fissures, and deposited in their present form where they are now found. In New Caledonia, however, the waters were first charged with manganiferous, cobaltiferous and ferriferous salts, and it was subsequent to the deposition of these minerals that the nickel-magnesian silicate deposits were formed. In the Oregon‡ ores manganese and cobalt are, as far as observed, almost wholly lacking, and the absence of oxide of iron in the vein-filling is also notable.

If, therefore, these veins which occur on Piney mountain almost continuously over a horizontal distance of more than a mile, and for a vertical height of 1,400 feet, had their origin in the depths of the mountain, then it is reasonable to assume that, in following them downward, large quantities of material will be found very similar to that on the surface, but richer in the easily decomposed minerals which have so evidently been removed from the croppings. In that case the possibilities of the mountain are considerable, and this is of the greater importance, because, as far as known at present, the nickel ore-bodies of southern Oregon are the only ones of their kind of any magnitude in the United States.

Mr. W. Q. Brown states that the age of the saxonite has not yet been firmly established, and that there is some evidence which indicates that it is pre-Cretaceous, but its intrusion is certainly pre-Tertiary as are all the peridotites of northern California.§ He is also of the opinion that the geological history of the Klamath Mountains by Dr. Diller applies to the region under discussion. which is in fact a portion of what has been denominated, geologically speaking, the Klamath Mountains.‖ Diller states,** that:

*D. Levat, in pamphlet published by the "Association Française pour l'avancement des sciences," 1887.

†Soc. de l'ind. miner. Compt. rend. 1891. Août.

‡Voight found 2 86 per cent. nickel and 0·004 per cent. cobalt in an analysis made of ore taken from the croppings of these veins in 1883.

§W. H. Turner, Journal of Geology, Vol. III No. 4, p. 414; also J. S. Diller, Geol Atlas U. S., Lassen Peak Sheet.

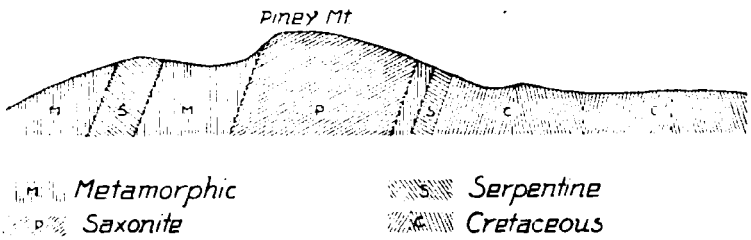
‖Annual Report, U. S. Geol. Sur., Pl. XL., p. 404; also Bull. Geol. Soc. of America, Vol. IV, pages 205 to 224.

**Geol. Atlas, U. S., Lassen Peak Sheet.

"During the Cretaceous the land formed at the close of the Jurassic gradually subsided so that the sea again swept over and covered a part of it. The Klamath Mountains during the latter part of this period were almost, if not altogether beneath the ocean, but the Sierra Nevada has remained above the sea ever since its development at the close of the Jurassic. * * * At the close of the Chico epoch the Klamath Mountains were again raised above the sea and the Cretaceous strata over portions of these mountains were much folded and broken."

Assuming that veins of genthite existed in the saxonite before it was raised to its present elevation, the folding and faulting disclosed in the Cretaceous rocks, must necessarily have had the same effect on the peridotite, and such veins as were approximately vertical would have been thrown in a nearly horizontal position, for

Fig. 8.



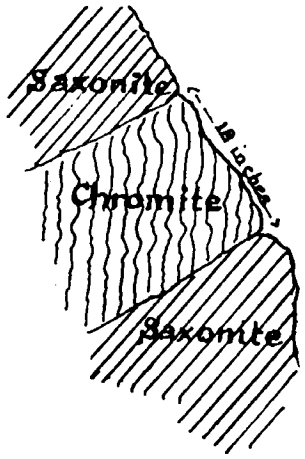
Section Through A. B. (Fig. 3) Illustrating the Folded and Broken Condition of the Cretaceous Strata Described by Diller.

the Cretaceous sandstones which, prior to the upheaval, were nearly horizontal, are now found standing vertical in some places, and at a high angle everywhere. If then, we accept the thermal spring theory we must assume that new fissures were opened during, or subsequent to, the upheaval, and that it was accompanied by solfataric action. If these assumptions are correct, and they certainly appear plausible, the occurrence of the brecciated nickel ore can be accounted for in this way, the rounded pebbles of genthite being derived from the folded and broken veins which existed prior to the upheaval at the close of the Cretaceous. The occurrence of the flat-lying veins at the surface can also be accounted for by this hypothesis, the hanging walls having been removed by denudations. The slickensided and striated masses of

ore found in these flat-lying deposits, which are very much broken, indicate and confirm the correctness of this theory.

With reference to the occurrence of chromite at Riddle's, this mineral does not seem to occur in the form of veins traversing the saxonite, but more as detached masses or blocks, lying in the rock without any apparent order. Figure 9 represents a block of chromite as it is found at the open cut marked 8 on Fig. 4. The planes of separation from the saxonite are distinct. Masses of chromite are also found in the cut at "Discovery Tunnel" and elsewhere on the mountain.

Fig. 9.



Large masses of chromite occur in the serpentine near Piney mountain as well as at a locality two miles southwest. Copper occurs in the serpentine several miles southwest of Piney mountain, as chalcocite, cuprite and native copper. About four miles northwest of Piney it occurs as chalcopyrite. No copper has been detected in any of the nickel ores of Piney mountain.

5. Mineralogical.

As yet no nickel minerals have been observed on Piney mountain, other than the hydrated nickel-magnesian silicates. It is not known whether the so-called genthite of Oregon is a definite compound associated with various impurities, or whether there are a variety of combinations of nickel, magnesia, silica and water, but it is probable that the latter is the case. The color of the mineral varies in different localities, and even in different layers of the same specimen. When fresh it is usually a bright emerald-green, but the shades vary to pale-apple or yellowish-green in reflected light. The pebbles of genthite found in the conglomerate, are mostly firm and compact, of a fatty, waxy appearance, and a sea-green color; but alongside of these are fragments of a light-green talcose appearance, and others of a bright emerald-green. These pebbles and breccia appear to be of a different origin from

that of the soft massive genthite which occurs as a filling in the veins near the croppings, for they do not crumble or lose color, whereas the latter cracks upon exposure to the atmosphere and falls to a powder when placed in water. The probabilities are that these variously appearing green minerals are mechanical mixtures of hydrated magnesian and nickel silicates, their relative proportions differing according to the conditions under which they were formed. It would be expected that the genthite, which was formed under heat and pressure at unknown depth, and subsequently brought to the surface as pebbles, etc., and redeposited in the form of conglomerates or breccia, would have a different composition from that of the mineral deposited from solutions at or near the surface. In appearance and behavior the massive genthite closely resembles the so-called "garnierite" and "noumeaite" of New Caladonia.

The following analyses, made by Clarke, Hood, and others, both of the Oregon genthite and of the New Caledonian minerals, are given for the sake of comparison.

Analyses Nos. 1 and 2 are by Hood,* and are made from samples of garnierite and noumeaite respectively. The first named was amorphous, showed a hardness of 2·0 to 2·5 and a specific gravity of 2·25. The color was apple-green. It adhered to the tongue, was not unctuous, and fell to pieces in water. The latter was also amorphous, with hardness 2·5 and specific gravity 2·58. The color was dark apple-green. It did not adhere to the tongue and was unctuous, and did not fall to pieces in water.

Analysis No. 3 is an average of several analyses made of the pure mineral, and is given by Levat.

Analysis No. 4 is given by the same authority† as an average of the New Caledonian smelting ores.

Analyses Nos. 1 and 5 may be formulated as follows: 5 (Mg, Ni) O, $4SiO_2+1\frac{1}{2}$ aq.

Analysis No. 6 made by Throllier may be reduced to the forula (Mg, Ni) O, SiO_2+n aq.

Analysis No. 7, made by Garnier, is from a coating which was

* Mineral Resources of the U. S., 1882, p. 404; also Mining and Scientific Press, Vol. 44, p. 416.

† Annales des mines, 1892, Livr. 2, p. 141 to 224.

Table of Analyses of Hydrated Nickel-Magnesian Silicates.

	New Caledonian Ores.								*Oregon Ores.*			
	1	2	3	4	†5	†6	†7	†8	9	10	11	12
Loss at 110° C	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8·87
Loss on ignition	5·26	12·73	13·00	$(H_2O+O)=14$	20·00	10·00	10·34	22·00	6·63	7.00	7·86	6·99
Alumina }	1·66	3·00	3·00	3 to 5	0·60	.....	1·68	.....	1·38	1·33	2·51	1·18
Ferric oxide }				Fe=14 to 16	.....	3·50	.....	7·00				
Silica	47·23	47·90	45·00	45 to 50	41·00	50·00	44·40	38·00	48·21	40·55	63·81	44·73
Magnesia	21·66	12·51	13·00	10 to 12	16·30	15·75	3·45	15·00	19·90	21·70	12·86	10·56
Nickel protoxide	*24·01	*24·00	26·00	Ni-7 to 8	19·00	18·50	38·51	18·00	*23·88	*29·66	12·25	27·57
Calcium oxide	tr	.....	.....	0	.....	2·65	1·07	.....	.....	.....	tr	.....
Ferrous oxide	.....	.....	.....	.....	.....	.....	0·43	.....	.....	.....	.....	.....
Quartzose gangue	.....	.....	.....	.....	3·00	.....	.....	.....	.....	.....	.....	.....
	99·82	100·14	100·00	.....	99·90	100·40	99·99	100·00	100·00	100·24	99·29	99.90

*These amounts are given as "nickel-oxide" in the Mining and Scientific Press, still there is no question that nickel protoxide is meant.

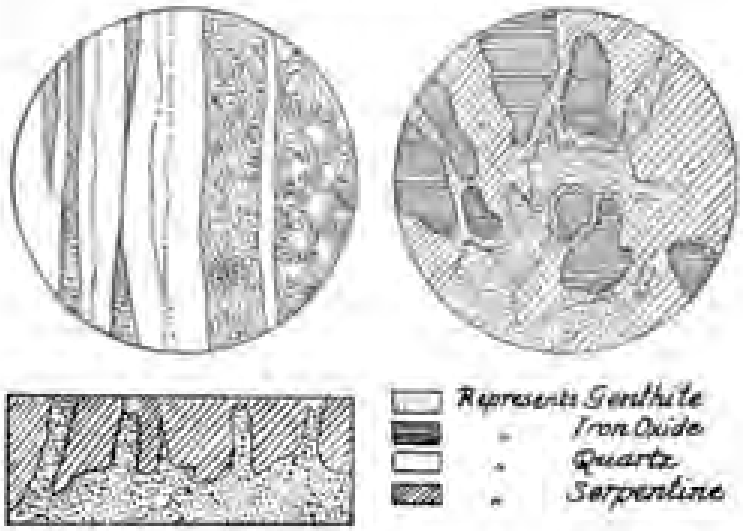
†These four analyses are taken from the Oesterreichische Zeitschrift für Berg-und Hüttenwesen, No. 3, 1879.

found upon a magnesian substance. The formula (Mg, Ni) O, SiO_2+n aq. also applies to this case.

Analysis No. 8 is given in the Berg-u. Hüttenmannische Zeitung, 1876, p. 272, as an average of the ore then being shipped from New Caledonia to Europe.

Analyses Nos. 9 and 10 are by Hood. No. 5 was amorphous with hardness 2·5 and specific gravity 2·45. The color was pale apple-green becoming lighter by exposure. It adhered to the tongue, was not unctuous, and did not fall to pieces when placed

Fig. 10.
Sections of Riddle's Ore, After Clarke.*



in water. No. 6 was amorphous. Hardness 2·0 to 2·5. Specific gravity 2·20. Color dark apple-green, becoming lighter upon exposure. It adhered to the tongue, was unctuous, and fell to pieces in water.

Analysis No. 11 was made by the chemist of the Naval Torpedo Station at Newport, R. I., from an average sample taken of Piney mountain ores by Lieutenant Buckingham of the U. S. Navy. There was no phosphorous, sulphur or arsenic detected in this sample.

* F. W. Clarke, Am. Jour. of Science, XXXV, p. 486, 487.

Analysis No. 12 is given by Clarke. He states that neither calcium oxide, sulphates, chromium oxide, nor cobalt could be detected.

In the compact Oregon genthite the different particles or grains are often separated by a whitish film and sometimes show a concentric arrangement of light- and dark-green mineral substance. In the greenish mass occur cavities containing minute transparent colorless crystals, probably of quartz, and small dark particles of apparently magnetite are often plentifully scattered through it Rounded grains of either magnetite or chromite occur in this silicious matrix side by side with the nodules of nickel silicate. The glassy appearance of some of the nodules of the latter mineral may sometimes be due to a coating of silica.

Clarke states that under the microscope genthite usually appears to be an aggregate of irregular grains which have, in transmitted light, a pale yellowish-green to coffee-brown color and a peculiarly clouded, waxy aspect. When the grains are very thin it may be said to be transparent or isotropic, but in the majority of cases it is only translucent. Narrow seams of genthite lying between seams of quartz are distinctly fibrous and feebly double refracting. In small veins it is free from grains of other minerals, but elsewhere it is very intimately commingled with quartz, making it evident that both were deposited from solution in circulating waters, genthite first, because veinlets of quartz cross it.

The purest genthite occurs with quartz, but the mineral most commonly associated with it, is serpentine.* The genthite and serpentine are thoroughly intermingled, but the former is generally present in such small quantities as to be overlooked unless it is the object of special research. It occurs in the serpentine 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.

6. Metallurgical.

So far, nothing of a metallurgical nature has been attempted

*It must be borne in mind that Clarke is here speaking of specimens sent him for examination, and not of the deposits at large.

upon a working scale with the Riddle's ores. Two or three cars of the ore have been shipped away for experimental purposes, but nothing has been accomplished looking to the treatment of this ore *in situ* commercially. The International Nickel Mining Company acquired some smelting machinery, among which were a revolving dryer, a rotary roaster, and a furnace designed for treating argentiferous lead ores, besides a lot of accessory smelting paraphernalia; but it has been lying at the station at Riddle's several years, and has never been set up. It was apparently the intention of this company to first concentrate their ores and then to smelt the concentrates in this Colorado lead-smelting furnace; but as coke is very dear at Riddle's, and as the furnace referred to is designed only for the low temperatures required in reducing leady ores, it is perhaps fortunate for the stockholders of the Company that the attempt was never made to carry out these ideas.

The very low specific gravity of the nickel-magnesian silicates (from 2·20 to 2·58), and the quality some of them possess of falling to a powder when placed in water, practically precludes the use of wet concentration. But still it is desirable, if possible, to effect a concentration of the valuable contents of these low-grade ores by some cheap and efficacious method before subjecting them to any of the existing methods of treatment, and Brown, after much experimenting, has succeeded in demonstrating that such a concentration is practical. By the use of an ingenious method which he has devised, he has produced concentrates from Riddle's ore, which, upon analysis, gave the following results:

Analysis of Brown's concentrates from Riddle's ore, made at the Naval Station, Newport, R. I.

Silica	55·58
Alumina and Ferric Oxide	6·88
Magnesia	18·72
Nickel Protoxide	18·88
Water	0·39
Total	100·45

These concentrates were made from an ore carrying 3 per cent. nickel, the gangue being chalcedonic quartz, and about 85 per cent. of the original nickel contents of this ore was recovered in the

concentrates. In carrying out this method of treatment the ore is first crushed dry, then heated with a reducing agent to produce a magnetic nickel combination, which is afterwards extracted with the help of a magnetic separator. As the gangue of the Riddle's ore is largely chalcedonic quartz, free from combined nickel, this method lends itself especially well to the separation of the richer nickeliferous compounds from the almost barren gangue matter in the manner designated.

There are, of course, richer portions of the veins which are sufficiently high grade to permit of treatment without any preparation, which in fact would be unadvisable to concentrate by any method, and such ores, together with the concentrates, are amenable to several methods of treatment. The metallurgy of the Riddle's ores is by no means a difficult problem, but the geographical situation limits the choice of a method among those which do not require the importation of expensive fuels or heavy chemicals. This is because the freight rates over the only existing line of railway are, in the absence of competition, excessive; and hence it is that the only methods of reduction which can be economically applied to these ores for the present, are such as can be put into operation by the help of the local resources of the district.

During the past thirteen years, Brown has been continually experimenting upon these ores. He has produced as much as 350 pounds of ferro-nickel at one time, in an experimental way, working along the lines of the fusible lime-magnesia silicates. His first large experiments were conducted with steel melting crucibles, mixing 50 per cent. of lime and "a large double handful" of coke dust with the nickel-magnesia silicates. This mixture gave a perfectly fluid slag and a nickel regulus, but it is a wholly impractical method, for the Oregon ores, on account of the small amounts of this low grade of material which it is possible to handle in a crucible furnace, the cost of the crucibles and the large quantities of fuel consumed. Later, Brown smelted several tons of the richer silicates in a cupola furnace, using simply lime as a flux, but the heat necessary to carry out the operation was so great and the corrosive action of the slag so strong, that the furnace lining only lasted a very short time. The ferro-nickel produced in this way contained from 70 to 80 per cent. nickel and from 20 to 30 per cent.

iron, and was too hard to cut with ordinary tools in a lathe. The simple fusion of the nickel-magnesian silicates in cupolas is not a practical solution of the metallurgical treatment of these ores. It is far too expensive an operation because of the preponderating amount of gangue it is necessary to flux off, and of the large quantity of coke burned in carrying out this method of treatment. It will be found much more economical to matte the Riddle's ores with the help of the nickeliferous pyrrhotites found at other points in southern Oregon, even if in this way more or less copper and cobalt become alloyed with the pure nickel of the first mentioned ore. A matte produced in this way, could be blown in Manhès converters to an enriched product, and the latter could be reduced to crude, or refined, metal by means of the alkaline-sulphide process. The proximity of the alkali deposits of California is particularly fortunate if the latter process should be adopted, but it is probable that it will be found more profitable, commercially speaking, to bring the enriched matte and the alkalies together at some convenient point further south, rather than transport the alkalies to Riddle's and refine at that place.

The Mond process* has been suggested as applicable in beneficiating these ores, and it has been estimated that by it pure nickel can be reduced from them, and put on the market at a profit, for 15 cents per pound. But to bring about these results it would be necessary to make radical changes in the plants first designed by Mond, for their capacity was too small to permit economic work. The practice of passing the gas over each charge of ore a great number of times limits the capacity† of a plant to the treatment of a small quantity of ore.

Brown has also made some attempts to leach nickel out of the earth of the mountain by converting that metal into chloride through preliminary roasting with salt. This treatment was suggested by observing that bricks made from this soil mixed with a small amount of salt to prevent cracking, on being exposed to the weather, were soon covered with green crystals of nickel chloride

*Metallic Carbonyls by Ludwig Mond. Proceedings Royal Institute of Great Britain, Friday, June 3, 1892. Also English patent, No. 12626, of 1890.

†According to the Chem.—Ztg. (1895. No. 25, p. 2126) liquid nickel—carbonyl is now produced in large quantities at the Winnington alkali works.

When these bricks were laid in the walls, the rains leached out the chloride, which precipitated as oxide when it reached the mortar, coloring it green. This gives the brick-kilns and the walls of the building a peculiar moss-covered appearance at present. The amount of salt used in making these bricks was approximately two-thirds of a ton of salt to 350,000 bricks.

Besides the methods enumerated for the reduction of nickel from these hydrated nickel-magnesian silicates, there are others which perhaps lend themselves still better to the object in view.

A full discussion of the metallurgical processes of reducing nickel from its ores which might be made available in this region, would far exceed the proposed limits of the present paper, and will be left for separate consideration on a future occasion.

Before closing, the writer wishes to express his obligation to Mr. W. Q. Brown of Riddle's for having unreservedly placed the results of his experiments, and of his long study of the geological conditions existing in that portion of Oregon, at the disposal of this Society.

Acknowledgements are also due to Professor P. H. van Diest for kindly preparing from the originals the cuts contained in this paper.

THE TECHNICAL DETERMINATION OF IRON.

By L. J. W. Jones.

Meeting of February 3, 1896.

The determination of iron by the chemist for a lead smelter is a very different problem from the determination of iron by the chemist for an iron works, or iron mine. In the latter case the ore is nearly always in the oxidized condition, will readily dissolve in hydrochloric acid, and rarely contains substances likely to interfere with its volumetric determination.

Even under these favorable circumstances the *accurate* determination of the iron needs a great many precautions; among which may be mentioned the correct determination of the strength of the standard solution *under the same conditions as the assay is to be made;* the purity of the zinc used, and others which will be found in most text books.

A large amount of work has been done by our eastern and European chemists, and by a process of evolution, the two methods which have survived, and which are now almost entirely used are titration by bichromate of potassium, or by permanganate of potassium, the methods of reduction being usually by stannous chloride in hydrochloric acid solutions for the bichromate titration, and reduction by zinc in a sulphuric acid solution for the permanganate titration.

These are the two methods used in the West, but owing to the complex character of the ores, the chemist for a lead, or copper smelter has not been able to adopt the improvements now so much used in the East, among which I may mention Jones' reductor, and the titration of hydrochloric acid solutions (reduced by stannous chloride) by permanganate of potassium.

Several years ago I investigated the general accuracy of the

iron determination, made in the regular course of work and found much less accuracy than I expected. In spite of the statements of several text books and published notes I found that titration by permanganate in hydrochloric acid solutions containing more than 5 c.c. of the strong acid in 300 c.c. water was unreliable, and as I found it difficult to keep the amount of acid below 12 c.c. to 15 c.c. on ores containing lead, I never attempted to use it in daily practice.

Perhaps it will be well for me to describe briefly these two methods as I have seen them generally used. *The permanganate* as used by the *busy* chemist, consists in treating ores—generally ½ gram to 1 gram—with nitric, hydrochloric and sulphuric acids, evaporating until white fumes of sulphuric acid appear, (this being the accepted indication of the elimination of all the nitric and hydrochloric acids), cooling, diluting, reducing with granulated zinc, decanting, and washing by decantation; diluting to about one-half litre with cold water and titrating with permanganate of potassium solution.

The sources of error are the presence of arsenic, antimony, copper and lead, besides those previously mentioned. All this is well known but frequently disregarded, simply because to remove these sources of error requires time which cannot be given.

I have frequently found that unless particles of precipitated copper and lead are removed by filtration the results are too high, and the pink color will always fade in a minute, whereas the filtered solution will retain its color for several hours. This also applies to arsenic, antimony and bismuth.

The removal of these particles of copper, lead and bismuth, can be very quickly effected by filtration through a plug of absorbant cotton placed in the neck of a large funnel, and the filtration takes place as rapidly as the solution can be poured through. Arsenic and antimony, however, are precipitated in such a finely divided condition that filtration through paper is necessary to remove them.

This error is due to the action of ferric salts upon these finely divided metals, the metals being readily dissolved, reducing the iron to the ferrous condition.

The following results will illustrate the effect of these particles of lead and copper.

The ores used in most of these experiments were five samples of Leadville fluxing ores, chosen at random from the ordinary smelter samples regularly received at the Omaha and Grant Smelter, Denver. They were originally analyzed for silica (residue insoluble in acids), iron and manganese. The analyses which formed the basis of settlement were as follows:

		SiO_2	*Fe*	*Mn*
I.	Grey Eagle.....	7·1	17·3	32·3
II.	Grey Eagle.....	11·8	16·3	32·3
III.	Little Chief.....	10 5	31·1	19·0
IV.	Little Chief.....	8·5	31·9	20·0
V.	Little Chief.....	8·8	34·0	18·5

Table Showing Influence of Particles of Metallic Lead and Copper.

A. Results obtained by $SnCl_2$ and $K_2Cr_2O_7$ titrated.	*B. Results obtained by reduction with gran. Zn and straining through absorbent cotton.*	*Results same as B only not strained through absorbent cotton.*
1 Fe..... 17·3	17·5	18·0 fades to 18·2
2 16·3	16·1	16·9 fades to 17·5
3 31·1	31·2	32·6 fades to 33.2
4 31·9	31·7	32·6 fades to 33·4
5 34·0	33·9	34·6 fades to 35·1

The details of the above determinations are here given.

A. 0·5 gram ore treated with 2 c.c. strong nitric acid, 10 c.c. strong hydrochloric acid evaporated to dryness, dissolved with 10 c.c. strong hydrochloric acid, boiled, diluted with 20 c.c. boiling water and filtered through a 9 c.m. Munktell's No. 0 filter; the residue in the casserole again treated with 5 c.c. strong HCl, boiled, diluted, filtered and the insoluble residue washed into the filter; the filter washed with boiling water four or five times bringing the volume of the solution to about 100 c.c. This solution contained in a No. 2 beaker is boiled, then whilst boiling a strong solution of stannous chloride is dropped in until the solution becomes colorless, two additional drops being added to insure complete reduction. The beaker is now set aside until cold, when 20 c.c. of a saturated solution of mercuric chloride is added, and the titration with bichromate completes the analysis.

B. 1 gram ore evaporated with 2 c.c. strong HNO_3, 12 c.c. strong HCl, 5 c.c. strong H_2SO_4, until the flask is filled with white fumes, cool, add 10 c.c. cold water then 50 c.c. hot, shake till dissolved; add 6 grams granulated zinc (coarse granules), allow to stand four hours, strain through absorbent cotton, wash by decantation with 350 c.c. water, add 40 c.c. dilute H_2SO_4 (1 to 4) and titrate with permanganate of potassium solution of which 1 c.c.= 0·01 gram Fe.

The effect of leaving these metallic particles in the solution is seen to be very great.

The effect of arsenic is shown by the following experiment—an ore containing 42·2 per cent. Fe was used.

To 1 gram of ore 0·05 gram of arsenious anhydride was added and treated exactly as described under B, including the straining through the cotton.

The result was 55 c.c. of permanganate solution used instead of 42·2 c.c.

The experiment repeated, but the solution filtered through paper, required 42·8 c.c. instead of 42·2, showing that it was mainly the fine particles of metallic arsenic which caused the error.

Having once tried the bichromate method I gave it the preference for accuracy, although the titration is not quite as neat or rapid as by permanganate.

On Leadville fluxing ores the results are almost always correct to within one-tenth of one per cent. and two different operators will check as closely, which is not my experience with the permanganate method as used in Colorado.

The bichromate method has two disadvantages, copper and antimony interfere unless removed before reduction by stannous chloride, and tellurium, which is quite frequently present, gives a black looking solution, in which it is difficult to see when stannous chloride in *just* sufficient quantity has been added.

The usual method is to remove the copper by precipitating the iron by ammonia, filtering and washing, redissolving in hydrochloric acid, and reprecipitating until the filtrate is colorless. This when much copper is present requires from three to four precipitations. The ferric hydrate is finally dissolved in hydrochloric acid, reduced with stannous chloride and titrated as usual.

Either through ignorance, or lack of time, this removal of the copper is frequently neglected. It was this removal of the copper that lead me to the use of granulated lead. I found that by boiling well with granulated lead I not only removed the copper, but at the same time completely reduced the iron, and on testing with sulphocyanate of ammonium only the merest trace of ferric iron could be detected. I then tried this method of reduction by making duplicate determinations, using granulated lead as the reducing agent in one set, and stannous chloride in the other. I found the results to be quite as accurate as those obtained by stannous chloride on ores which were free from copper and antimony, and as the result of a large number of experiments I found that the reductiou by lead was the only accurate method under all conditions. That is, I found that none of the elements which interfere with our present methods vitiated the results when the reduction was made by lead.

The following determinations and experiments will illustrate the above statements :

Experiments Comparing the Results Obtained by Reduction with Lead and Those Obtained by Reduction with Stannous Chloride, on Ores Free from Copper and Antimony.

	Stannous Chloride Reduction.		*Granulated Lead Reduction.*	
1	17·3 Fe	Leadville Ores.	17·4 Fe	Leadville Ores.
2	16·3		16.1	
3	31·2		31·2	
4	31·9		31 9	
5	34·0		34·1	
6	9·4	Sulphide Ores containing about ½ per cent. Cu.	9·3	
	28·9		28·6	
	28·6		28·7	
	6·4	Gold Ore containing Tellurium.	6·4	Gold Ore containing Tellurium.
	10·1	Flue Dust.	9·6	

*The tin reduction was black and it was almost impossible to see when sufficient $SnCl_2$ was added.

Experiments in which a Known Amount of Impurity was Added—The Ore Used Contained 42·2 per cent. Fe.

Copper.—

Reduction by $SnCl_2$.	Reduction by Pb.
(1). ·0085 gram Cu was added to ·5 gram of the ore. Percentage of Fe found, 42·5 Error ·3 per cent. +	
(2). ·050 gram Cu added to ·5 gram ore. Fe found, 48·7 per cent. Error, 6·5 per cent. +	·050 gram Cu added to ½ gram ore. Fe found, 42·0 per cent. Error, –·2 per cent.

Antimony.—

·10 gram metallic Sb added to ·5 gram ore. Fe found, 55·0 per cent. Error, 12·8 per cent. +	·10 gram Sb added to ·5 gram ore. Fe found, 42·0 per cent. Note—The antimony was precipitated in a finely divided condition and was filtered out before titration

Arsenic.—

·10 gram As_2O_3 to ·5 gram ore. Fe found, 43·3 per cent. Error, 1·1 per cent.+	·10 gram As_2O_3. Fe found, 42·0 per cent.

Cobalt.—

·2 gram Cobalt nitrate added to ½ gram ore, evaporate to dryness with HCl, dissolve in HCl, &c., to eliminate nitric acid. Fe found, 42·2 per cent.	·2 gram Cobalt nitrate evaporated with HCl, &c., reduced with lead. Fe found, 42·2 per cent.

Nickel.—

No interference.	No interference.

Note.—In both the above titrations the nickel or cobalt reaction with ferricyanide did not occur for several seconds, so that no difficulty was experienced in reading the end reaction.

Note (*2*).—Antimonic and cupric chlorides are reduced to antimonious and cuprous chlorides, and again oxidized to antimonic and cupric chlorides, just as accurately as the ferrous oxidation, and allowance could be made for their presence, if the exact amount were known.

SOME EXPERIMENTS MADE TO DETERMINE ONE OR TWO MINOR POINTS.

First. Would the presence of a few particles of lead cause error? After the solution had been titrated it was poured back upon the lead and immediately returned to a clean beaker, again tested on the spot plate with ferricyanide, a blue color showed reduction, which required 0·50 c.c. $K_2Cr_2O_7$ to remove, showing very rapid reduction.

Second. Several experiments, made to determine the time required for perfect reduction, showed that in most cases three minutes was sufficient, and five minutes always accomplished it. Brisk boiling is required and where considerable amounts of copper are present the addition of small amounts of fresh lead is advisable.

Third. Since ferrous chloride oxidizes much more rapidly than ferrous sulphate, a chloride solution which had been reduced with lead was allowed to stand in a No. 2 beaker covered with a watch glass for 36 hours, it was then well stirred, decanted from the lead and titrated. The result was correct.

MISCELLANEOUS EXPERIMENTS.

First. Action of hydrochloric acid in titration of ammonium ferrous sulphate:

100 c.c. of a solution of ferrous ammonium sulphate with 40 c.c. dilute H_2SO_4 (1 to 4) was titrated with a solution of potassium permanganate (1 c.c. = .01 gram Fe.) It required 23·3 c.c., color permanent.

Repeated above, added 5 c.c. strong HCl, it required 23·4 c.c., color faded in about two minutes; with 10 c.c. strong HCl, it required 23·7 c.c., color faded in about two minutes; 15 c.c. strong HCl, it required 23·9 c.c., color faded in about two minutes; 20 c.c. strong HCl, it required 23·8 c.c., color faded in about two minutes.

Second. Determinations on ores by titration with permanganate of potassium in hydrochloric acid solutions:

0·5 gram of a 42·0 per cent. ore was dissolved in 10 c.c. strong

HCl, reduced with $SnCl_2$, solution of $HgCl_2$ added to destroy excess of $SnCl_2$, then a strong solution of $MnSO_4$ and H_2SO_4 added, diluted to 300 c.c. and titrated with permanganate. The first evanescent pink showed at 41·6 per cent. (20·8 c.c.). The pink color was evanescent up to 46 per cent. when the experiment was stopped. An attempt to dissolve the ore in 5 c.c. HCl was unsuccessful.

Third. 0·5 gram ore was dissolved in 10 c.c. HCl, reduced by boiling with lead, added to 300 c.c. cold water containing 1 gram $MnSO_4$ and 10 c.c. H_2SO_4. The result was 21 c.c.=42·0–; but the pink color faded too quickly to be satisfactory. Other determinations were made in the same way with the following results.

The ores were lead ores containing small amounts of copper.

Results obtained by standard method, reduction with $SnCl_2$ and titration with $K_2Cr_2O_7$.

I	10·4
II	4·5
III	28·6

Results obtained by reduction with lead in hydrochloric acid solution, titration in presence of $MnSO_4$ and H_2SO_4 as above.

I	10·4
II	4·6
III	29·6

The last determination was repeated and the first pink was obtained at 28·6 per cent., but was so evanescent that unless it were previously known the end point would be missed. Reduction by lead and titration by bichromate of potassium gave 28·7 per cent. Fe.

I will now describe the method more in detail, as used at the Omaha & Grant Smelter, where it has been in constant use for more than two years.

Half a gram of ore is placed in a No. 3 royal Berlin casserole, treated with a mixture of nitric, and hydrochloric acids, adjusting the proportion of nitric acid to the character of the ore, 10 c.c. for a heavy sulphide and 2 c.c. for an oxidized ore. The casserole is then covered with a watch glass and the contents evaporated to complete dryness on a hot plate. Remove from the heat and when

cool add 10 c.c. strong HCl, boil, remove from hot plate, wash off the cover with boiling water, then wash down the sides of the casserole, replace the cover and bring to a boil; remove from the heat, allow to settle about one minute, decant solution through a small filter paper (9 cm.), wash by decantation with about 10 c.c. boiling water, rinsing the cover and sides of the casserole.

To residue still remaining in the casserole add 5 c.c. strong HCl, again boil, dilute with boiling water and filter, this time washing the insoluble residue into the filter paper, remove all adhering matter from the casserole with a rubber finger-cot or glass rod tipped with rubber; finally wash into the filter, and wash filter with boiling water until perfectly colorless. The filtrate should measure 100 to 150 c.c. Now add about 20 grams granulated lead,* boil for five minutes or until the yellow color has completely disappeared, add another 10 to 20 grams lead and boil three minutes; the solution should now be perfectly colorless, and clear, and is ready for titration.

The titration is performed as follows :

Decant as nearly half of the solution as can be approximately guessed at into a No. 3 beaker and run in rapidly from a burette the solution of bichromate of potassium until the solution just turns yellow from excess of bichromate. This takes somewhat close observation and requires a little practice, but the solution can be run in and tested on the spot plate with ferricyanide of potassium if preferred. One of the best methods to adopt where the amount of iron is entirely unknown is as follows :

First test the half of the solution decanted by placing a drop of the ferricyanide solution on the spot plate, notice the depth of color, this will at once indicate whether there is much or little iron ; a deep blue indicating a good deal of iron, while a faint blue shows one to three per cent. Having ascertained roughly about how much iron can be expected, add a corresponding amount of bichromate. For example, if a faint blue add only a few drops and test again; if a deep blue add at once 5 c.c. then test; if a deep blue is obtained add 10 c.c. at once and again test; if still deep

*The lead sold by The Denver Fire Clay Co. was used in all my work. it is very finely granulated and free from impurities. It is an advantage to sift out and reject the very finest particles on an 80-mesh sieve.

blue add 20 c.c. and again test; if the color is no longer blue we know that 35 c.c. is too much and that 15 c.c. is too little. Now decant nearly all that remains in the original beaker, keeping the lead carefully back, test again on spot plate, the color will be an indication of how much solution can be added; usually it is safest to add only 1 or 2 c.c. at a time until the end point is passed, then decant the remainder carefully from the lead; pour upon the lead about 10 c.c. cold distilled water, stir well with a rubber tipped rod breaking up any clots that may be formed, then while allowing it to settle add more bichromate until the end point is again passed. Now decant the wash water into the main solution and wash by decantation in this way three times, being careful when decanting not to allow any lead to fall into the beaker in which the titration is being conducted; the titration is now finished in the usual manner.

The object of dividing the solution is of course to gain time, and avoid having to test every 2 or 3 c.c. of volumetric solution, and while this description sounds tedious, practice soon enables the operator to attain rapidity.

The great advantages of this method are:

(1). Obtaining the silica and iron in one operation, the silica being quite free from lead, this being accomplished by the liberal use of HCl, hot solutions, and rapid filtration.

(2). The reduction by the lead is very rapid. I have timed a number with the watch and find that from the time the solution begins to boil until it becomes colorless is generally less than three minutes.

(3). There is no frothing or bumping and no floating particles requiring removal by filtration as by the use of granulated zinc.

(4). There are no interferences.

(5). Cheapness. Lead costs 18 cents per lb., granulated zinc c.p. $1.50. The experiments performed to test this method led me to try granulated, amalgamated zinc. I used Merck's c.p. and I amalgamated it with a little solution of mercuric chloride and a few drops of HCl, then washed by decantation. I found that boiling with this, reduced the iron almost as rapidly and perfectly as the lead, but had the disadvantage of frothing and boiling over re-

quiring careful watching. I also found that the use of the amalgamated zinc entirely avoided the errors produced by the precipitation of Cu, Pb, As and Sb, which remained amalgamated with the mercury, rendering filtration unnecessary.

Reduction by this fine amalgamated zinc is fully as accurate as by the lead, provided a sulphuric acid solution is used, but in practice I object to a sulphuric acid solution. It is slower since two weighings must be made, one for iron and the other for silica, and sulphuric acid solutions have a very annoying way of bumping when one attempts to boil them.

Reduction of Ferric to Ferrous Solutions.

The following table shows the results of experiments on the reduction of ferric to ferrous solutions:

Series I. Run in the regular way reduced with lead.

Series II. 1 gram ore, 2 c.c. HNO_3 12 c.c. HCl, 5 c.c. H_2SO_4, evaporate in flask to white fumes, add 10 c.c. cold water then 5 c.c. hot, shake till dissolved, then add 6 grams coarsely granulated zinc, allow to stand four hours, strain through cotton, wash by decantation with 350 c.c. water add 40 c.c. dilute H_2SO_4 (1 in 4) and titrate with permanganate.

Series III. 1 gram ore, 2 c.c. HNO_3 10 c.c. HCl, evaporate to dryness, dissolve in 10 c.c. HCl, filter into flask (8 oz.) treat residue with 3 c.c. HCl, boil and filter into flask, washing free from Fe, add 6 grams granulated zinc to reduce; the zinc did not completely dissolve—treat exactly as in series II, washing by decantation, etc., finally adding 50 c.c dilute H_2SO_4.

No 1 only ran 16 0 the first time, showing incomplete reduction, so 3 c.c. strong H_2SO_4 was added to each of the others—the No. 1 was repeated—end reaction fairly permanent.

Series IV. Treat exactly as in Series III only use 5 c.c. HCl the second time, making a total of 15 c c. HCl; before adding the zinc add 5 c.c. strong H_2SO_4, then add 8 grams zinc (Merck's) coarsely granulated ; allow to stand about four hours then strain through cotton and titrate.

It was believed that in Series III there was not sufficient acid to effect complete reduction—testing with sulphocyanate did not

Results of Various Experiments on the Reduction of Ferric to Ferrous Solutions.

Ore Taken.	*Original com'l results $SnCl_2$*	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*	*VII.*	*VIII.*	*IX.*	*X.*	*XI.*	*XII.*
1. Grey Eagle	17.3	17·4	17·5	17·0	17·2	16·9	18·0 faded up to 18·2	17·2	17·8	17·5	17·4	17·35	17·60 1 gr.
2. Grey Eagle	16.3	16·1	16·1	15·4	15·6	15·9	16·9 faded up to 17·5	16·0	16·9	16.3	15·8	15·8	16·5
3. Little Chief	31·1	31·2	31·2	30.5	30·8	31·0	32·6 faded up to 33·2	31·2	31·2	31·2	31·05	30·4	30.9
4. Little Chief	31·9	31·9	31·7	31·2	31·5	31·8	32·6 faded up to 33.4	31·9	32.3	31·9	31·7	31·2	31·6
5. Little Chief	34·0	34·1	33·9	33·6	33.6	33·9	34·6 faded up to 35·1	34·2	34·3	34·3	34·0	33·4	34.1

indicate this. The only explanation of the low results is that there was mechanical loss in the evolution of the hydrogen.

Series V. Treat exactly as in Series II, but after adding 50 c.c. hot water to dissolve the sulphate add 15 c.c. strong HCl, then 10 grams of zinc—the object being to determine if any loss of iron has taken place in the preliminary treatment in Series III and IV.

Series VI. Exactly as Series II only not strained through cotton, particles of lead, copper, etc. allowed to remain in solution during titration.

Series VII. Exactly the same as Series III only not strained through cotton.

Series VIII. Run exactly as Series I only use granulated, amalgamated zinc instead of lead, using 10 c.c. HCl and 5 c.c. HCl for final solution.

Note:—The solutions were perfectly colorless after boiling five minutes.

Series IX. Repeat Series VIII only strain through a plug of cotton.

Series X. Evaporate with the three acids to white fumes, dilute with water, boil and filter, add granulated, amalgamated zinc, boil till reduced, strain through plug of cotton and titrate with permanganate, wash silica back into casserole, boil with HCl and water, again filter, wash, ignite and weigh. Silica is quite white.

Series XI. Evaporate with 2 c.c. HNO_3 and 5 c.c. HCl to dryness, take up with 10 c.c. HCl then 5 c.c. HCl exactly as the regular determination; reduce by boiling with granulated, amalgamated zinc; titrate with permanganate of potassium, in solution containing $MnSO_4$ and H_3PO_4 as per Mixer and Dubois.*

The solutions after reduction stood about three hours on the zinc before titration—they were tested with sulphocyanate and all showed ferric iron.

Series XII. Repeat exactly as Series XI only titrate immediately after reduction, and test for ferric iron; only traces found.

*Journal of Am. Ch. Society, Vol. 17, No. 5.

ON PEARCEITE, A SULPHARSENITE OF SILVER, AND ON THE CRYSTALLIZATION OF POLYBASITE.

By S. L. Penfield.

Meeting of April 6, 1896.

Pearceite.

The mineral to be described as pearceite in the present article is a sulpharsenite of silver, Ag_9AsS_6 or $9Ag_2S.As_2S_3$, analogous to polybasite, Ag_9SbS_6, and, like the latter, characterized by having a part of the silver replaced by copper, and often by small quantities of zinc and iron. It cannot claim to be a *new mineral*, for as an arsenical variety of polybasite, it has previously been recognized although no special name has been assigned to it. H. Rose* first described polybasite, and gave the name to species in 1828, and in 1833 he published† an analysis of a specimen from Schemnitz containing arsenic, with only a trace of antimony, while in the original polybasite from Durango, Mexico, described by him, both antimony and arsenic were present, and he recognized the fact that these elements were isomorphous, and could mutually replace one another.

The polybasites from Durango in Mexico, Freiberg in Saxony, Pribram in Bohemia, the Two Sisters' mine near Georgetown, the Yankee Boy mine near Ouray, and the Sheridan mine near Telluride in Colorado, the Comstock Lode in Nevada, and apparently from most localities, are essentially the antimony variety, and, in mineralogical literature, the composition of polybasite is usually given as a *sulphantimonite* of silver. Rammelsberg‡ gives an

*Pogg. Ann., Vol. XV, p. 573, 1829.
†Loc. Cit., Vol. XXVIII, p. 56, 1833.
‡Mineralchemie, p. 102, 1860.

analysis by Joy of polybasite from Cornwall, England, where antimony and arsenic are present in about equal molecular proportions; and the author, in connection with Mr. Stanley H. Pearce, has published* analyses of arsenical polybasite (*pearceite*) from the Mollie Gibson mine, Aspen, Colorado. This latter material was not distinctly crystallized, but was found in great quantity, and was the mineral which carried the bulk of the silver in the most productive silver mine in Colorado at that time.

The author's attention has recently been called to the occurrence of beautifully crystallized pearceite, or arsenical polybasite from the Drumlummon mine, Marysville, Lewis and Clarke counties, Montana.

The mineral was first sent by Mr. R. F. Bayliss of the Montana Mining Co., to Dr. Richard Pearce of Denver, with the request that it should be investigated, and the following analysis was made by Mr. F. C. Knight under Dr. Pearce's immediate supervision:

	Found.	*Ratio*		*Theoretical Composition where* $Ag_2 : Cu_2 : Fe = 255 : 143 : 19$.
S	17·71 ÷ 32 = ·553		11·95	17·96
As	7·39 ÷ 75 = ·098		2·11	7·02
Ag	55·17 ÷ 216 = ·255	·417	9·00	55·61
Cu	18·11 ÷ 127 = ·143			18·34
Fe	1·05 ÷ 56 = ·019			1·07
Insol.	·42			
	99 85			100·00

Dr. Pearce recognized that the mineral belonged to the polybasite class, where arsenic played the roll usually taken by antimony, and forwarded the specimens, together with the analysis, to the author for an expression of opinion. As may be seen from the ratio, the proportions of $S : As : (Ag_2 + Cu_2 + Fe)$ is very nearly 12:2:9, which is that demanded by polybasite formula, and, taking the metals in the same proportions as they are found in the analysis, $Ag_2 : Cu_2 : Fe = 225 : 143 : 19$, and calculating the theoretical composition, results agreeing very satisfactorily with the analysis, are obtained.

* American Journal of Science, Vol. XLIV, p. 15, 1892.

Although recognizing that antimony and arsenic are isomorphous, and may mutually replace one another, it is customary, and has been found convenient in mineralogy, to consider the sulphantimonites and sulpharsenites as distinct species, and to designate them by different names, and the author proposes that, hereafter, the name polybasite shall be restricted to the antimony compound Ag_9SbS_6, and to make of the corresponding arsenic compound Ag_9AsS_6 a distinct species. For the arsenical mineral he takes pleasure in proposing the name *pearceite* as a compliment to his friend, Dr. Richard Pearce of Denver, whose keen interest in mineralogy, and connection with one of the large smelting and refining works of Colorado, have made him known both to scientific men and to those interested in the development of the mining industries of the Rocky Mountain region. The author furthermore takes pleasure in expressing his thanks to Mr. Bayliss who has taken a great interest in the investigation and naming of mineral, and has most generously placed at his disposal all of the available material.

It seems best to give at this point the analyses of pearceite, already referred to, which have previously been published as arsenical varieties of polybasite. In the theoretical composition given with each, the ratio of the metals is the same as in the accompanying analysis.

I. H. Rose, $Ag_2:Cu_2:Zn:Fe = 335:24:9:6$.

II. Penfield, after deducting 12·81 per cent. of impurities, mostly PbS, $Ag_2:Cu_2:Zn = 263:117:43$.

III. S. H. Pearce, after deducting 28·18 per cent. of impurities, mostly PbS, $Ag_2:Cu_2:Zn = 276:102:49$.

	I. *Schemnitz.*	*Theory.*	II. *Aspen, Colo.*	*Theory.*	III. *Aspen.*	*Theory.*	*Theory for $Ag_9As S_6$*
S	16·83	16·19	18·13	18·13	17·73	18·02	15·50
As	6·23	6·32	7·01	7·08	6·29	7·03	6·05
Sb	0·25	.....	0·30	.....	0·18	.....	.....
Ag	72·43	73·47	56·90	57·07	59·73	59·06	78·45
Cu	3·04	3·08	14·85	14·91	12·91	12·77	.....
Zn	0·59	0·60	2·81	2·81	3·16	3·12	.....
Fe	0·33	0·34	.....	.....	.....	.....	.....
	99·70	100·00	100·00	100·00	100·00	100·00	100·00

CRYSTALLIZATION.

The crystallization of pearceite is *monoclinic*, but with a close approximation to rhombohedral symmetry. The habit is commonly hexagonal, with the basal planes prominent, and the zones of bevelling forms between them often highly modified. The material from which crystallographic data could be obtained, came wholly from a single specimen where the crystals were implanted upon a gangue of quartz, and imbedded in calcite, and were obtained by dissolving the latter in dilute acid. Unfortunately the crystals had grown close together, thus interfering more or less with one another, and they also were cracked, probably owing to the severe shocks received in the processes of blasting and mining; consequently, when liberated by dissolving the calcite, they fell to pieces, so that usually only parts of crystals were available for measurement. The faces had a beautiful metallic lustre, and, when free from striations and vicinal planes, gave excellent reflections on the goniometer. The determination of the crystalline form and the axial ratio proved to be a difficult matter, owing to the fragmentary character of the crystals, their grouping, often in nearly parallel position, a probable twinning, and their close approximation to rhombohedral symmetry, and it was not until many measurements had been made upon a series of crystals that a satisfactary solution of the problem was obtained.

As fundamental measurements the following were selected:

$$m \wedge m,\ 110 \wedge \bar{1}10 = 60^\circ\ 2'$$
$$c \wedge d,\ 001 \wedge \bar{1}02 = 25^\circ\ 3'$$
$$c \wedge a,\ 001 \wedge 100 = 89^\circ\ 51'$$

from which the axial ratio was calculated:

$$a:b:c = 1{\cdot}7309:1:1{\cdot}6199$$
$$\beta = 001 \wedge 100 = 89^\circ\ 51'$$

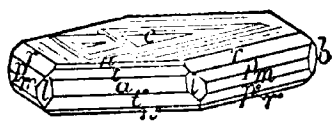
The crystals are quite highly modified, and it seems best, before giving a list of the forms, to explain the different kinds which were observed, and to state something concerning their occurrence. The basal pinacoid *c*, 001 is prominent, is hexagonal or triangular in shape, and is characterized by triangular markings and vicinal planes, Fig. 1, so that it was often impossible to obtain accurate measurements from it. The prism *m*, 110 and the

pinacoid *a*, 100 are nearly at right angles to *c* and 60° from one another, so that the combination approaches very closely to a hexagonal prism, and it is sometimes impossible to distinguish *a* from *m*, or, without accurate measurements, to decide whether the forms between *c* and *a* or *c* and *m* modify the acute or obtuse angles. It is very probable that a twinning is present, similar to that of the micas and chlorites, where the twinning plane is at right angles to *c* in the zone $m \wedge c$, and where the parts are superimposed upon one another with *c* as the composition face, but no absolute proof of this was obtained. The crystals are opaque, so that optical tests could not be applied as was done by Miers,* who has described this kind of twinning on polybasite. If the twinning occurs on pearceite, as it probably does, it must cause uncertainty as to the identification of some of the forms in the zones between *c* and *a*, and *c* and *m*, and it may also account, in part, for the decidedly rhombohedral aspect of many of the crystals. As far as could be observed, similar faces are often developed about equally above and below *m* and *a* in the zones between the basal planes, but to what extent this is due to twinning it is impossible to state. The faces in these zones are, moreover, commonly striated parallel to their mutual intersection, and while *r* and *p*, r° and p°, *n* and *t*, and n° and t° (compare Fig. 1 and the list of forms beyond), are the most prominent, other faces, especially *e* and e°, *f* and f°, *s* and s°, and *u* and u°, are very often present. When *q* was observed it was always a prominent, dull face, not sharing in the horizontal striations of the other faces of the zone. It was only occasionally that forms were observed between *c*, 001 and *l*, 310, and they were always small, while the corresponding forms were not observed between 001 and –310. The pinacoid *b* 010 was identified, not only by the symmetrical arrangement of the forms with reference to it, but also by the similarity of the angles measured from it on to similar adjacent forms. The prism *l*, 310 is often developed about equal in size to *b*, and with the latter would correspond in rhombohedral symmetry to a hexagonal prism of the second order. The prism *h*, 130 and the horizontal

*Min. Mag., Vol. VIII, p. 204, 1889.

prism k, 021 were found together on only one crystal as small faces symmetrically located with reference to the pinacoid b.

1.



2.

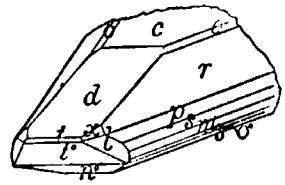


Figure 1 shows the prevailing type of crystal, with hexagonal aspect, the characteristic triangular markings on the basal plane, but with only the most prominent of the bevelling faces present.

Two fragments were found which in habit were essentially like Fig. 2. These had a decidedly monoclinic habit and were the most free from striations, vicinal faces and indications of a possible twinning of any crystals that were observed, and from them the fundamental measurements previously given, were obtained.

A few crystals were quite remarkable for their size, the hexagonal plates being 3^{cm} in diameter and 1^{cm} thick: but they were coated with drusy quartz, and could not be used for crystallographic measurement. The specimen showing the largest crystals was presented by Mr. Bayliss to the author for the Brush collection at New Haven. The crystals from which the measurements were obtained, averaged less than 4^{mm} in diameter.

The following list includes the forms which have been observed, but, as already stated, twinning may account for a similar form being found modifying both the acute and obtuse angles of the crystals, and being repeated in the zones between c and a, and c and m.

a, 100	d, 102	t°, -201	s, 221	s°, -221
b, 010	n, 101	e°, -401	u°, 331	u°, -331
c, 001	t, 201	f°, -601	o°, -114	x, 311
l, 310	e, 401	o, 114	q°, -113	y, 313
m, 110	f, 601	r, 112	r°, -112	z, 31·12
h, 130	Δ, -203	p, 111	p°, -111	
k, 021	n°, -101	v, 332	v°, -332	

The forms corresponding to these found by Miers* on polybasite are c, m, n, t, p, s, r, and w, 109.

*Loc. cit.

The following table of measured angles includes a series which was selected wholly on account of the character of the reflections, due to the freedom of the faces from striations and other disturbing influences.

They were mostly made on the two fragmentary crystals, already mentioned, having a habit like Fig. 2, and, where several measurements are given, they represent independent ones in different zones or on different crystals. As may be seen, the measured angles show a fairly good agreement with the calculated values, and it may, therefore, be assumed that the axial ratio has been determined with a fair degree of accuracy.

		Calculated.	*Measured.*
$c \wedge a$.	001 ∧ 100	89° 51′	89° 51′ *, 89° 49′
$c \wedge l$.	001 ∧ 310	89° 52′	89° 48′, 89° 54′
$c \wedge m$.	001 ∧ 110	89° 55½′	89° 55′
$m \wedge m$.	110 ∧ -110	60° 2′	60° 2′ *
$b \wedge m$.	010 ∧ 110	30° 1′	30° 1′, 30° 1′
$a \wedge l$.	100 ∧ 310	29° 59′	29° 58′, 29° 57¼′
$b \wedge h$.	010 ∧ 130	10° 54′	10° 53′
$b \wedge k$,	010 ∧ 021	17° 9′	17° 5′
$c \wedge d$,	001 ∧ 102	25° 3′	25° 3′ *, 25° 2½′
$c \wedge n$.	001 ∧ 101	43° 2′	43° 4′, 43° 5′
$c \wedge e^{\circ}$,	001 ∧ 401-	104° 49′	104° 53½′,
$c \wedge t^{\circ}$,	001 ∧ 201-	118° 00′	117° 56′
$c \wedge n^{\circ}$,	001 ∧ 101-	136° 49½′	136° 52½′
$c \wedge r$,	001 ∧ 112	43° 3′	43° 3′, 43° 6′, 43° 0′
$c \wedge p$,	001 ∧ 111	61° 49′	61° 56′
$d \wedge r$,	102 ∧ 112	36° 14′	36° 12′, 36° 16′
$b \wedge p$,	010 ∧ 111	40° 15′	40° 12′, 40° 12′
$b \wedge p$,	010 ∧ -111	40° 10½′	40° 8′
$b \wedge s$.	010 ∧ 221	33° 12′	33° 12′
$c \wedge y$,	001 ∧ 313	47° 9′	47° 10′, 47° 7′

In the following table the calculated angles of most of the faces on to the basal plane are given, arranged so as to show the slight variation from one another, and from rhombohedral symmetry of the forms d, o and o°; Δ and q°; n, r, n°, and r°; t, p, t°, and p°; v and v°; e, s, e°, and s°; and f, u, f°, and u°.

$c \wedge d = 25° \; 3'$	$c \wedge n' = 43° \; 10\frac{1}{2}'$	$c \wedge v = 70° \; 19'$	$c \wedge f = 79° \; 45'$
$c \wedge o = 25° \; 3'$	$c \wedge r' = 43° \; 7\frac{1}{2}'$	$c \wedge v' = 70° \; 27'$	$c \wedge u = 79° \; 49\frac{1}{2}'$
$c \wedge o' = 25° \; 4\frac{1}{2}'$	$c \wedge t = 61° \; 46\frac{1}{2}'$	$c \wedge e = 74° \; 54'$	$c \wedge f' = 80° \; 2'$
$c \wedge \Delta = 32° \; 0'$	$c \wedge p = 61° \; 49'$	$c \wedge s = 75° \; 00$	$c \wedge u' = 79° \; 58'$
$c \wedge q' = 31° \; 58'$	$c \wedge t' = 62° \; 00'$	$c \wedge e' = 75° \; 11'$	$c \wedge z = 15° \; 6\frac{1}{2}'$
$c \wedge n = 43° \; 2'$	$c \wedge p' = 61° \; 56'$	$c \wedge s = 75° \; 6'$	$c \wedge y = 47° \; 9'$
$c \wedge r = 43° \; 3'$			$c \wedge x = 72° \; 44'$

Physicial Properties.—Pearceite is brittle, has an irregular to conchoidal fracture and no distinct cleavage. The hardness is about 3. The specific gravity was taken with a chemical balance on three different portions of carefully selected material, and gave 6·125, 6·160 and 6·166, the mean of these being 6·15.

The lustre is metallic, and the color of the mineral and the streak is black. The material, even in thin particles, is opaque. In the ruby silvers the arsenical compound proustite is more transparent than the antimony one pyrargyrite, and we might, therefore, naturally expect pearceite to be more transparent than polybasite, but that this is not the case may be due to the fact that the variety of pearceite under examination, contains over 18 per cent. of copper, while the published analyses of polybasite indicate usually about 5 and never over 10 per cent. of this element.

Pyrognostics and Other Tests.—Before the blowpipe, pearceite decrepitates slightly, and fuses at about one. Heated on charcoal in the oxidizing flame, a slight coating of As_2O_3 is formed, and, by addition of borax or sodium carbonate and continued heating, a globule of metallic silver is obtained. In the open tube SO_2 is given off, and a volatile sublimate of As_2O_3 is formed. In the closed tube the mineral fuses, yields a yellow sublimate of sulphide of arsenic, and, above the latter, a very slight one of sulphur. The powder is readily oxidized and dissolved by nitric acid, the solution yields, with hydrochloric acid, an abundant precipitate of silver chloride, and, on addition of ammonia in excess, the blue color characteristic of copper is obtained, while a slight precipitate of ferric hydroxide is formed.

Occurrence.—According to information received from Mr. Bayliss, the pearceite crystals were formed with quartz and calcite lining a vug at only one place in the Drumlummon mine, and, although a diligent search has been made for similar crystals in other parts of the mine, none have been found. A few chal-

copyrite crystals were observed intimately associated with the pearceite. High-grade silver and gold ores are taken from the Drumlummon mine, and, on one of the specimens of the ore, argentiferous tetrahedrite, freibergite, was observed.

The Crystallization of Polybasite.

Rose originally described polybasite as rhombohedral, and it was thus considered until 1867, when DesCloizeaux* observed that the transparent plates showed, in convergent polarized light, a biaxial and not a uniaxial interference figure, and that the mineral, therefore, could not be rhombohedral. The crystals were then referred to the orthorhombic system, but the close approximation to rhombohedral symmetry has always been prominently noted in descriptions of the mineral. The earlier measurements of polybasite by Breithaupt† are untrustworthy, probably owing to the difficulty of securing suitable material, and we are indebted to Miers‡ for the first careful series of measurements, which were made upon a suite of crystals in the British Museum. He also evidently experienced some difficulty in obtaining reliable measurements, for the angles between similar faces show a considerable variation amounting usually from a quarter to one-half of a degree. The crystals are regarded by him as orthorhombic, and the following forms were observed:

c, 001	*w*, 109	*t*, 201	*p*, 111
m, 110	*n*, 101	*r*, 112	*s*, 221

Prominent angles are $m:m, 110 \wedge -110 = 60° 10'$; $c \wedge n, 001 \wedge 101 = 42° 24'$, and $c \wedge p, 001 \wedge 111 = 61° 14'$, the axial ratio being $a:b:c = 1{\cdot}7262:1:1{\cdot}634$. He also observed that the crystals when examined in polarized light, did not become dark in any position, and concluded, therefore, that they were twinned, as already explained on page 213, for pearceite. He points out the impossibility of distinguishing the bevelling faces *r* and *p* in the zone between *c* and *m*, from *n* and *t* in the zone between *c* and *a*, and calls attention to the fact that the only form in these zones at right angles to the

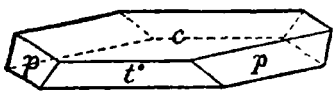
*Nouvelles Recherches, p. 85, 1867.
†Charakteristik des Mineral-Systems, 1832, p. 266.
‡Min. Mag., Vol. VIII, p. 204, 1889.

base is the prism m, and that the pinacoid a, 100 fails. When six faces occur in the zone of the prisms, the ones which occupy the positions of the pinacoid a, are the prismatic faces m in twin position.

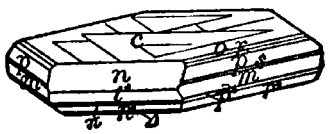
Dana* accepts the measurements of Miers as fundamental, but shifts the position of the crystal so that the obtuse angle of the prism, $m \wedge m$, is in front.

Among the specimens in the Brush collection at New Haven, one was found from the Himmelfahrt mine, Freiberg in Saxony, showing crystals like Fig. 3, which is *apparently* a combination of base and rhombohedron. On revolving the crystals in polarized light, they never became dark, showing thus that a twinning was

3.



4.



present, while in convergent light a confused interference figure was usually obtained, although, in places, the normal biaxial one was seen. There is nothing in the external aspect of the crystal to indicate twimming except perhaps the uneven character of the base c, which may result from a twinning about m, 110, and a slight deviation from 90° of $c \wedge m$. The crystal did not give satisfactory reflections, but the angle of c on to the apparent rhombohedrons was approximately 61½°, and of the latter faces on to each other 81½°. It is difficult to explain this apparently rhombohedral development on the assumption that the crystallization is orthorhombic, while it is known that monoclinic minerals whose prismatic angles are near 60°, the micas, chlorites and leadillite, for example, exhibit, in a marked degree, a tendency to imitate rhombohedral symmetry, while orthorhombic compounds, chalcocite, aragonite and witherite, for example,do not show this tendency. It seems reasonable, therefore, to assume that the crystallization of polybasite, like that of pearceite, is *monoclinic*, and the apparently rhombohedral forms on Fig. 3 have, accordingly, been

* System of Mineralogy, 6th edition, p. 146.

lettered p and t° with the understanding that there is an uncertainty regarding their identification.

In the summer of 1891, while the author was engaged in some mineralogical work in Colorado for the United States Geological Survey, a collection of minerals was made at the Yankee Boy mine, near Ouray, and thanks are due to Dr. F. M. Endlich, manager of the mine, for his courtesy and the interest which he took in making the collection as complete as possible. On the specimens associated with pyrargyrite, and implanted upon quartz, were some small but remarkably perfect crystals of polybasite. The occurrence of the mineral from this locality has been noted by Endlich*, the identification being based, in part, upon measurements by the author of the prismatic angle $m \wedge m$ = near 60°.

The forms which were observed on a single crystal of polybasite, having a habit like Fig. 4, are as follows, the orientation being derived from the symmetrical arrangement of the faces with reference to the prism l, 310 which, however, was only slightly developed, and not represented in the figure.

c, 001	Δ, -203	o, 114	u, 331?
l, 310	n°,-101	r, 112	o°,-114
m, 110	π, -403	p, 111	r°,-112
n, 101	t°, -201	s, 221	p, -111

The crystal was too opaque to admit of optical tests being made, but thinner crystals from the locality transmitted a deep red light, and showed indications of twinning.

The following angles were taken as fundamental:

$$c \wedge m \quad 001 \wedge 110 = 90^{\circ}\ 0'$$
$$m \wedge m \quad 110 \wedge -110 = 60^{\circ}\ 2'$$
$$c \wedge n \quad 001 \wedge 101 = 42^{\circ}\ 23'$$

from which the axial ratio was calculated:

$$a:b:c = 1{\cdot}7309:1:1{\cdot}5796$$
$$\beta = 90^{\circ}\ 0'$$

The following table gives a record of the measurements which were made mostly on one crystal. The ones in brackets represent approximate measurements from very narrow faces.

* American Journal Science, Vol. XL, p. 424, 1890.

	Calculated.	Measured.	Limits obtained by Miers.
$c \wedge m$, 001 ∧ 110	90° 0′	90° 0′* 90° 4′	
$c \wedge l$, 001 ∧ 310	90° 0′	90° 0′ 90° 2′	
$m \wedge m$, 110 ∧ -110	30° 2′	60° 2′* 60° 0′	60° 10′
$c \wedge n$, 001 ∧ 100	42° 23′	42° 23′* 42° 23′	40° 48′ 42° 30′
$c \wedge \Delta$, 001 ∧ -203	31° 19′	31° 22′	
$c \wedge n^{\circ}$, 001 ∧ -101	42° 23′	42° 23′	
$c \wedge \pi$, 001 ∧ -403	50° 35′	50° 44′	
$c \wedge t^{\circ}$, 001 ∧ -201	61° 17′	61° 25′	61° 8′ 61° 17′
$c \wedge o$, 001 ∧ 114	24° 31′	(24° 43′)	
$c \wedge r$, 001 ∧ 112	42° 22′	(42° 43′) (42° 9′)	40° 48′ 42° 30′
$c \wedge p$, 001 ∧ 111	61° 16′	61° 15′ (61° 7′)	61° 5′ 61° 24′
$c \wedge s$, 001 ∧ 221	74° 40′	(74° 48′)	73° 55′ 75° 50′
$c \wedge u$, 001 ∧ 331	79° 39′	(78° 2′)?	
$c \wedge o^{\circ}$, 001 ∧ -114	24° 31′	(24° 36′)	
$c \wedge r^{\circ}$, 001 ∧ -112	42° 22′	42° 24′	
$c \wedge p^{\circ}$, 001 ∧ -111	61° 16′	(60° 35′)	
$l \wedge p$, 310 ∧ 111	40° 35½′	40° 36′	
$p \wedge r^{\circ}$, 111 ∧ -112	49° 26′	49° 27′	
$r^{\circ} \wedge t^{\circ}$, -112 ∧ -201	49° 24½′	49° 38′	
$t^{\circ} \wedge l$, -201 ∧ -3$\bar{1}$0	40° 34′	40° 34′	

Certainly, as shown by the above table, the agreement between the measured and calculated values is very satisfactory, and it may be assumed, therefore, that the axial ratio has been determined with a fair degree of accuracy. That the crystallization is really monoclinic is shown by the development and arrangement of the faces, but the angle β differs so little from 90° that the variation, if any, falls within the errors of observation. Of four measurements that were made of $c \wedge l$, the faces being free from striations, and giving excellent reflections, two were 90° 0′, and the others 90° 2′. Six independent measurements of $c \wedge m$ were made, varying between 90° 0′ and 90° 6′, but the m faces were slightly striated so that the measurements are not quite as reliable as those of $c \wedge l$.

Relation of Pearceite and Polybasite to each other, and to other Minerals.

Pearceite and polybasite show, as would be expected, a very close relation to one another in everything which concerns their crystallization. The tendency of arsenic is to make the vertical

axis of its compound a little longer than that of the antimony one, as shown by the following ratios, and by the angles $c \wedge p$ or $p°$:

	a:b:c.	*β.*	*c∧p and p°.*	
Pearceite.....	1·7309:1:1·6199	89° 51′	61° 49′	61° 56′
Polybasite	1·7309:1:1·5796	90° 0′	61° 16′	

Perhaps the next most interesting relation of these minerals which imitate rhombohedral symmetry, is their very close similarity to the rhombohedral ruby silvers, proustite Ag_3AsS_3 and pyrargyrite Ag_3SbS_3, as shown by the relations of the vertical axes and the angles.

		c∧p or p°.				*c∧s.*
Pearceite...	$\frac{1}{2}c=0·8099$	61° 49′	61° 56′	Proustite....	$c=0·8039$	61° 41½′
Polybasite..	$\frac{1}{2}c=0·7898$	61° 16′		Pyrargyrite..	$c=0·7891$	61° 15′
Difference....	·0201			Difference....	·0148	

The vertical axes are longer in the arsenic than in the antimony compounds and to about the same extent in the two classes. In proustite and pyrargyrite *s* is the –2 rhombohedron, $02\bar{2}1$.

The orthorhombic sulphides chalcocite Cu_2S and stromeyerite CuAgS, also exhibit a close and striking similarity to the minerals in question, best seen when the positions of the former are changed by a simple interchange of the *a* and *b* axes, making thus the obtuse angles of the prisms at the extremities of the *b* instead of the *a* axes, as follows:

	a:b:c	*β*	*m∧m, 110∧-110*	*c∧p or p°.*	
Chalcocite.....	1·7176:1:1·6663	90° 0′	60° 25′	62° 35½′	
Stromeyerite	1·7176:1:1·6603	90° 0′	60° 25′	62° 30′	
Pearceite.....	1·7309:1:1·6199	89° 51′	60° 2′	61° 49′	61° 56′
Polybasite.....	1·7309:1:1·5796	90° 0′	60° 2′	61° 16′	

Although widely separated in our chemical classification, the differences in chemical composition of the two former from the two latter is not so very great, for Cu and Ag being isomorphous, we have, as the general composition of the former, R'_2S, and of the latter, $R'_2S+\frac{1}{3}As_2S_3$ respectively Sb_2S_3.

On examining the whole group of sulpharsenites and sulphantimonites, it is quite interesting to note that the majority of them which are well crystallized, exhibit prismatic angles of nearly 60°,

and show forms in other zones which can be referred to vertical axes nearly like those of the chalcocite and polybasite groups. These relations are shown in the following table, where the com-

Name.	*Composition.*	*System.*	*a : b : c*	*β*	*m ∧ m*	*c ∧ p or Equivalent.*	*Change of axes from Dana's position.*
Chalcocite	Cu_2S	O	1·718 : 1 : 1·666		60° 25′	62° 35′	$a=b$
Pearceite.....	$9Ag_2S.As_2S_3$	M	1·731 : 1 : 1·620	89° 51′	60° 2′	61° 49′	
Polybasite.....	$9Ag_2S.Sb_2S_3$	M	1·731 : 1 : 1·580	90° 00′	60° 2′	61° 16′	
Stephanite.	$5Ag_2S.Sb_2S_3$	O	1·589 : 1 : 1·633		64° 21′	62° 37′	$a=b.\frac{3}{2}c$
Geocronite.	$5PbS.Sb_2S_3$	O	1·723 : 1 : 1·732		60° 16′		$a=b.2c$
Jordanite	$4PbS.As_2S_3$	M	1·861 : 1 : 1·883	90° 33*	56° 30′	65° 01′	$a=c.\frac{1}{2}c$
Meneghinite.....	$4PbS.Sb_2S_3$	O	1·891 : 1 : 1·831		55° 45′		$a=b.2\frac{2}{3}c$
Proustite.....	$3Ag_2S.As_2S_3$	R	1·732 : 1 : 1·608		60° 0′	61° 41½′	$2c$
Pyrargyrite	$3Ag_2S.Sb_2S_3$	R	1·732 : 1 : 1·578		60° 0′	61° 15′	$2c$
Xanthoconite.....	$3Ag_2S.As_2S_3$	M	1·919 : 1 : 1·523	88° 47′	55° 4′		$\frac{3}{2}c$
Prostilpnite	$3Ag_2S.Sb_2S_3$	M	1·946 : 1 : 1·646	90° 00′	53° 21′		$\frac{3}{2}c$
Bournonite.....	$3(Pb,Cu_2)S.Sb_2S_3$	O	1·875 : 1 : 1·793	$f \wedge f=$	56° 8′	63° 48′	$2a.\ 2c$
Freieslebenite	$5(Pb,Ag_2)S.-2Sb_2S_3$	M	1·703 : 1 : 1·580	92° 14′*	60° 48′		$a=b.$
Dufrenoysite	$2PbS.As_2S_3$	O	1·531 : 1 : 1·876	$i \wedge i=$	66° 18′		$a=c.2c$
Jamesonite	$2PbS.Sb_2S_3$	O	· ? : 1 : 1·830				$a=c.2c$
Sartorite	$PbS.As_2S_3$	O	1·856 : 1 : 1·722		56° 38′		$a=b.\frac{3}{2}c$
Zinkenite	$PbS.Sb_2S_3$	O	1·794 : 1 : 1·709		58° 17′		$a=b.\frac{3}{2}c$

M—Monoclinic. O—Orothorhombic. R—Rhombohedral.

* Owing to the change of position of the axes, the inclination for jordanite becomes γ instead of β and for freieslebenite α instead of β.

pounds are arranged according to variations in basisty. The axes and angles have been taken from the sixth edition of Dana's Mineralogy, with the exception of those of xanthoconite and pros-

tilpnite, which are taken from Miers,* and jordanite, taken from Baumhauer.†

In the majority of cases in the above table the change from the position given by Dana has been made by a simple interchange of the a and b axes, and by multiplying the vertical axis in its new relation by a simple factor. Bournonite and dufrenoysite are exceptions, and the forms f, 120 for the former, and i, 011 for the latter, have been taken as unit prisms, 110. The isomorphous relations of jordanite and meneghinite, studied by Miers,‡ Krenner,§ Schmidt‖ and Groth** are not at all clear. The factor $2\frac{2}{3}$ given for the vertical axis is a rather unnatural one, which, if adopted, would give to the forms on meneghinite very complicated indices. The axial ratio suggested by Schmidt, $a:b:c=0{\cdot}4862:1:1{\cdot}8465$, would give, by interchange of a and b, and using the factor $\frac{1}{2}$ for the vertical axis, $a:b:c=2{\cdot}0568:1:1{\cdot}8984$, and $m \wedge m=51^\circ\ 52'$, values which show the widest variations of any in the table from polybasite. It will be noticed that the vertical axes of the arsenical compounds pearceite, jordanite, proustite, dufrenoysite, and sartorite are greater than those of the corresponding antimony compounds, while xanthoconite and pyrostilpnite form an exception to this rule, which may, however, be due to inaccuracy in the measurement of the small crystals of these exceedingly rare minerals.

The relations shown in the table may be accidental, but the close approximation of the axial ratios to that of chalcocite would seem to indicate that the sulphide of the metal has had a controlling influence on the crystallization. Sternbergite, $Ag_2S.Fe_4S_5$, with $m \wedge m=60^\circ\ 30'$ and enargite, $3Cu_2S.As_2S_5$, with $x \wedge x''$, $320 \wedge 320$ (twinning plane)$=60^\circ\ 17'$ might be added to the table.

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* Min. Mag., Vol. X, p. 185, 1893.
† Sitz. Ber. Akad. d. Wiss., Berlin, 1891, p. 697.
‡ Min. Mag., V, p. 325, 1884.
§ Földt. Közl., XIII, p. 297, 1883.
‖ Zeitschr. Kryst., VIII, p. 613, 1883.
** Tabellarische Uebersicht, p. 33, 1889.

LABORATORY OF MINERALOGY AND PETROLOGY,
SHEFFIELD SCIENTIFIC SCHOOL, NEW HAVEN,
MARCH, 1896.

IGNEOUS ROCKS OF THE TELLURIDE DISTRICT, COLORADO.*

By Whitman Cross.

Meeting of September 7, 1896.

During the summer of 1895 the geological survey of the Telluride sheet in Colorado was made by a party of the U. S. Geological Survey in my charge. The Telluride atlas sheet embraces the area defined by the parallels 37° 45′ and 38° north latitude, and the meridians 107° 45′ and 108° west longitude. Its northeastern corner is on the western slope of Potosi Peak and the southwestern corner in the valley of East Dolores River, a few miles above Rico.

This investigation gave me an opportunity to study the volcanic complex of the western San Juan Mountains, and also the eruptive rocks which penetrate the Cretaceous area to the westward. As no kind of a systematic review of the igneous geology of this district has been published since the time of the Hayden Survey, I feel justified in presenting a preliminary sketch of the results obtained.†

The igneous rocks of the region may well be considered in three divisions, namely :

The bedded volcanic rocks, forming a large part of the western San Juan Mountains; the cross-cutting stocks of granular rocks which pierce the entire bedded series ; and the intrusive stocks and laccoliths of the adjoining Cretaceous area.

Bedded Volcanic Series.

The western face of the San Juan Mountains as exposed in the

*Published with the permission of the Director of the U. S. Geological Survey.
†The Telluride folio will be issued as soon as possible.

area of the Telluride sheet, affords excellent exposures of the nearly horizontally-bedded surface volcanic formations which are known to play a very important part throughout the whole group of the San Juan. The survey of the Telluride region permitted a careful examination of a very good vertical section of this volcanic complex, but no definite statements can as yet be made concerning the lateral extent of the rocks to be described. It is certain that there are considerable variations in the relative developments of the rocks; although, from present knowledge, it appears that the same general types extend over a large area. The formations to be described may be quite clearly distinguished everywhere, unless extreme alteration has obliterated the original characters to some extent. The present description will, however, apply chiefly to the region north of Telluride as one of the best known localities in the area, and as thoroughly typical.

In another paper presented before this society this evening, I have especially described the San Miguel conglomerate, a sedimentary deposit of much interest, lying immediately beneath the volcanic rocks of the region, and, while containing little volcanic material among its pebbles, it is clear that the San Miguel formation belongs to the general period which witnessed the beginning of the volconic outburst in southwestern Colorado. The San Miguel conglomerate forms very conspicuous cliffs on both sides of the San Miguel River above Telluride. Upon it rests a stratified and, as I now believe, waterlaid series of volcanic tuffs and breccias, constituting the lower member of the volcanic complex. This bedded formation, consisting almost entirely of andesite debris, has a thickness varying from a little more than 1,000 feet to somewhat more than 2,000 feet. Its lower limit is seen on the trail leading up Marshall Creek at an elevation of 9,800 feet, and it extends to the level of the Sheridan mine in Marshall Basin at an elevation of nearly 12,000 feet. As the beds have a gentle dip it appears that the thickness of the formation in this section can not be less than 2,000 feet.

It is proposed to call this stratified series of andesitic tuffs and breccias the San Juan formation, as it clearly plays an important part in the make-up of a large portion of the San Juan Mountains. The texture of the San Juan beds varies from a

thin-bedded, fine-grained tuff, containing no large fragments, to a tuff-breccia consisting of large subangular blocks imbedded in a finer-grained matrix. The proportion of large fragments varies a great deal, but I have not seen the formation to be made up of large fragments exclusively at any one point, although, where it is indurated, in proximity to some of the large diorite stocks, and near mineralized areas, it has the appearance of a massive breccia.

The upper limit of the San Juan formation may not be always clearly definable; in the mountains about Marshall Basin it is, however, very sharply defined by the appearance of the first massive lava flow of augite-andesite.

The microscopical study of the material of the San Juan formation shows a considerable variety of hornblende, mica, and augite-bearing andesites. Apparently hornblendic forms are most common, and I incline at present to the opinion that such rocks as that of the first massive andesite flow above are rare, if not wanting, in the San Juan fragmental beds of this region. Certainly no extremely basic rock such as basalt, nor the more acid forms such as trachyte or rhyolite, were observed; nor were granular igneous rocks, corresponding to the later stocks, found among the fragments.

The general conclusion as to the origin of the San Juan formation is, that it represents the fragmental ejectamenta of one or more volcanic centers situated at some little distance from the Telluride region, and that these fragmental materials, thus far examined, received their stratified arrangement in the waters of a lake which may have been the same body of water, in which the San Miguel conglomerate was laid down immediately before the volcanic outburst. The irregularity in stratification, and the absence of any distinctly chaotic area of coarse fragmental material, lead me to believe that the rocks are waterlaid. It is, of course, possible that a part of them are waterlaid and that others received their regular arrangement, in large degree, through falling in showers on slopes adjacent to the volcanic vent. This point can only be determined on the basis of further exploration.

The San Juan formation forms the floor of Marshall, Savage, Bridal Veil, and Virginius basins, and in it are the main ore-bodies of the most noted mines of this region. Only the upper portions

of the known veins penetrate the higher and more massive rocks to be described. The same formation appears on both sides of Howard Fork of the San Miguel, about Ophir, where, however, the relations are much complicated by intrusive stocks of diorite. The San Juan beds also appear in Sheep Mountain south of Trout Lake, in the western cliffs of Vermilion Peak, and form the upper part of the mountain called the Twin Sisters at the head of Lime Creek. A thin remnant also appears locally in various parts of the Wilson range of the San Miguel Mountains. From present indications it would appear probable that the San Juan beds form the lower fragmental portion of the San Juan eruptive mass through a large area to the eastward of the Telluride district; but, as will appear from subsequent statements, it is not improbable that their place may be taken in some localities by later fragmental deposits of similar character.

Above the San Juan fragmental beds comes a succession of massive flows and thin, intermediate tuff-beds of two different types of rock. The two massive rocks are augite-andesite and rhyolite, and the tuffs are in some places mixtures of materials of both types, or may be almost entirely of one. There were apparently two centers of volcanic eruption, probably to the eastward of the Telluride area, producing different rock magmas during one general period of eruption.

The augite-andesite sheets are well exposed in the walls surrounding the Marshall Basin. Here their variable thickness is well illustrated, and the thin layers of tuff, which occasionally separate flows, are quite well exposed near the Sheridan mine; and in many other places in the mountains to the westward of Marshall Basin. The first sheet of augite-andesite is exposed almost continuously, resting on San Juan beds, from Marshall Basin to White Mountain, a name which has been given to the peak one mile east of iron mountain, north of the San Miguel River. On White Mountain it has a thickness on the southern ridge of only four feet and is quite vesicular. It is probably not quite continuous in its exposures in the cliff faces, but all that is seen, may be referred to one originally continuous sheet. Above this lower sheet comes a thin layer of tuff containing some rhyolite material, and above that is a thicker sheet of augite-andesite

which forms the principal part of the ridge west of the Sheridan mine, and also forms a bench on the eastern side of the basin. In tracing out the lava flows of this horizon to the southward it was found that there were, in many places, flows of massive augite-andesite separated by rather fine-grained tuff, well stratified and not unlike parts of the San Juan formation except that they seem much more irregular in their bedding, and have a much more homogeneous composition as regards the character of the rock fragments. In almost all places there is at least a thin flow at the base of this augite-andesite complex, serving to mark the termination of the San Juan formation as it has been defined.

Above the augite-andesite series comes the rhyolite series, consisting, first, of a tuff containing also abundant fragments of augite-andesite. This grades upward into a lava-flow containing very many small fragments of augite-andesite, and in many places it is impossible in the field to distinguish between the indurated rhyolitic tuff and the first flow, both containing fragments of andesite. This lower flow varies considerably in thickness but often reaches 100 feet. It is succeeded by a heavier rhyolite flow, comparatively free from included fragments, possessing a very distinct fluidal structure, and forming marked cliff exposures, distinguishing it easily from the andesite outcrops.

On the divide separating Marshall and Virginius basins, a very distinct bench is formed, just above this flow, by a thin sheet of augite-andesite seldom more than fifteen feet in thickness, which can be seen from a distance as forming a thin band separating the lower rhyolite flow from one of identical character above it. Viewing the range north of the San Miguel from a little distance, the two rhyolite flows separated by this distinct band, due to the augite-andesite, form a very distinct feature. Above this upper flow of rhyolite which may be 200 or 300 feet in thickness, there comes a succession of thin flows of rhyolite, often glassy and dark in color, and tuff beds, also variable in texture and in color, usually containing some andesitic material. These tuffs and thin rhyolite sheets break down on weathering much more rapidly and evenly than the more massive rocks below, and form, as a rule, smooth conical points or even sloped ridges on the crest above the most massive rhyolite flow. These charac-

teristics are especially well exhibited in the divides bounding Virginius Basin on the west and south.

The two flows of massive, banded rhyolite form the crest of the ridge from Silver Mountain near Ophir eastward, and that separating the drainage of the San Miguel from that of Mineral Creek. The same rock also forms the very sharp summits of Vermilion Peak, Castle Point, and U. S. Grant Peak, to the east of Trout Lake. Very small remnants of the lower rhyolite flow are also seen in some of the sharp points east of Sheep Mountain, and it is clear that this complex of rocks once covered the entire region.

Diorite Stocks.

Several of the highest peaks of the western San Juan are made up of a granular rock, usually a quartz-bearing augite-diorite, grading in certain places into a quartz-bearing gabbro. The principal masses of this diorite are those of Grizzly Peak and Rolling Mountain, Silver Mountain, Stony Mountain, Mt. Sneffels, and Mt. Wilson. In all cases these masses are irregular in outline, showing contacts which cut directly across the bedding of sedimentary rocks and the volcanic series alike; with branching arms which occasionally run out parallel to the bedding or cut across it at various angles. The horizontal plan of one of these stocks presents numerous projecting points and re-entrant angles, and dikes which run out for short distances from many of the projections. In one case, west of Ophir Loop, a sheet from the Silver Mountain mass is intruded for some distance just below the Dakota Cretaceous sandstone, and forms a vertical cliff of nearly 1,000 feet directly opposite the old postoffice at Ames.

The largest stock is that reaching from near Pandora, on the south fork of Mineral Creek, for four miles to the southwest. The summits of Grizzly Peak, Rolling Mountain and several other points to the south of Vermilion Peak, are made up of this mass of augite-diorite. In this case the rock is rather fine-grained and very uniform in appearance throughout the mass as far as observed.

The Mt. Wilson stock is nearly three miles in greatest diameter and cuts up through the Cretaceous shales, the San

Miguel conglomerate, and a thin remnant of the San Juan formation. This rock also is quite homogeneous through the entire mass seen.

The two stocks of Mt. Sneffels and Stony Mountain are so connected by numerous arms that they may be regarded as practically one. The enormous talus-slopes at the head of Canyon Creek prevent accurate mapping of the connection between the two. This stock stands in contrast to the ones previously mentioned in being much smaller, and exhibiting a very considerable variation in the character of the rock. As the material collected has not yet been studied in detail I will only say at this time that almost all of the modifications are still quartz and orthoclase-bearing varieties, but augite, hypersthene, and a plagioclase very rich in lime, are so strongly predominant that it seems no longer possible to consider the rock as an augite-diorite. From the coarse-grained phases of the latter composition there are gradual gradations to fine-grained augite-diorite exactly corresponding to the other rocks mentioned. In Mt. Sneffels, the main mass of which is beyond the area of the Telluride sheet and could not, therefore, be examined in detail, there are many dikes of porphyritic facies cutting the granular rocks. The study of this mass must be left for some future season.

The last stock to be especially mentioned is that extending from Silver Mountain to Yellow Mountain, and sending off a sheet to the westward as already mentioned. This mass also varies considerably in character, but the principal part is an augite-diorite containing a large amount of orthoclase and quartz, and passing, in some places, even into granitic facies through the preponderance of orthoclase over plagioclase. It grades on the other hand into a gabbro facies.

Besides these larger stocks there are numerous small ones scattered throughout the eastern part of the Telluride district. Where these penetrate the Cretaceous shales, as in the drainage of Deep Creek, they have metamorphosed the sediments, producing zones of hornfels and other less pronounced products.

Other stocks of similar augite-diorite are known to the writer in more distant parts of the San Juan, as, for example, in Sultan Mountain south of Silverton. The interesting problems of petro-

graphy and geology which they bring to notice, cannot be adequately treated at the present time. As these rather coarsely granular stock-rocks reach an elevation of over 14,000 feet in Mt. Sneffels and Mt. Wilson, it is clear that at the time of their intrusion the volcanic complex of the San Juan was much thicker than at the present time, and this implies a mass of volcanic accumulations at the period of diorite intrusion which is vast indeed.

Intrusive Rocks in the Cretaceous Sediments.

It is an interesting fact that, within this same Telluride district, there are three very distinct laccoliths of augite-diorite in the Cretaceous shales below the horizon of the San Miguel conglomerate. In the northwestern corner of the area, either side of Summit Creek, are two laccoliths intruded in the Cretaceous shales not far above the horizon of the Dakota. The westermost which is opposite the mouth of Big Bear Creek, and just above the ore deposits of Sawpit Gulch, has a thickness of about 1,900 feet, of fine and even-grained augite-diorite, resting almost directly on the Dakota on the western slope of the mountain, while, on the eastern side, Colorado shales rise to the very summit, resting upon the diorite with a steep easterly dip. Between Summit Creek and Deep Creek is another laccolith of the same rock, forming two summits, between which is a basin at the head of Willow Creek. The maximum thickness of this mass of diorite is somewhat more than 2,000 feet, and, on the northwestern summit, Colorado shales rest in almost horizontal position upon the diorite, and then dip north, and connect with the shales on the eastern and western sides of the mountain. The debris-slopes prevent an examination of the lower contact at any point, but there is no reason to suppose that this mass is a stock. Between these two larger laccoliths in the bed of Summit Creek is a small intrusive sheet, 200 or 300 feet in maximum thickness, intruded directly on the upper surface of the Dakota. In the extreme southern portion of the area is an almost exactly corresponding mass of diorite, also resting directly upon the Dakota in the bend of the East Dolores. In this case the lower contact with Dakota can be traced almost continuously for several miles. This mass is about 1,400 feet in thickness, and is capped by a remnant of Colo-

rado shales lying in almost horizontal position. The laccolithic form of this body is very clearly illustrated by the fact that to the northeast, across the narrow valley of the Dolores, this intrusive body has thinned out to a thickness of only 100 feet, appearing as a thin sheet along the slope of the valley. That is to say, the river is eroded directly on the rapidly arching line of the laccolithic dome.

The larger laccoliths mentioned are granular in structure, somewhat finer-grained than the stock diorites which have been mentioned, but are probably of identical composition. Near contacts they become slightly porphyritic, and the small intrusive sheets which may be seen in the vicinity of the greater masses, are distinctly porphyritic modifications of this diorite. In the Wilson Range there are numerous intrusive sheets of diorite-porphyry in the Cretaceous and later sedimentary rocks, which are cut through by the diorite stocks. It is my impresson that these intrusions are of a slightly earlier date than the stock intrusions of the same magma.

The rocks which form these stocks and intrusive sheets, or laccoliths, in the sedimentary formations of the Telluride area, are exactly similar to those which have a considerable distribution to the southwest in the La Plata Mountains and in the intermediate area about Rico. From a reconnaissance in the La Plata Mountains in the summer of 1893, I am able to say that the intrusive sheets of diorite-porphyry do not have so great a development as is represented upon the Hayden map. There are in fact many regular intrusive sheets, but there are also four or more diorite stocks exactly analogous to those of the Telluride area, which for the most part cut across the diorite-porphyry sheets, although occasionally sending out arms which are more or less regular, though limited, lateral intrusions. As the La Plata and Rico areas will be surveyed in detail during the season of 1896 I do not wish to make positive statements concerning the relations of the regular intrusions and the irregular stocks, but it seems most probable that within the same general eruptive period there were two forms of eruption; one more sudden and violent in the eruptive acts and producing the stocks, while the other, under a

more slowly exerted force, produced laccoliths and intrusive sheets which are presumably more regular in the lower series of sandstones and conglomerates below the Dakota than in the large mass of friable shales above that horizon.

THE SAN MIGUEL FORMATION.*

By Whitman Cross.

Meeting of September 7, 1896.

In the course of the survey of the district embraced in the Telluride quarter degree sheet of the Geological Atlas of the United States, during the summer of 1895, I had opportunity to examine and trace out in detail a sedimentary formation which has previously been described only in a very general way. In his presidential address delivered before this Society on December 17, 1888,† Mr. R. C. Hills referred briefly to the formation in question, while pointing out interesting problems for investigation in Colorado, describing it as

"a considerable thickness of coarse conglomerate outcropping around the base of Mt. Sneffels, on Canyon Creek above Ouray, and on Marshall Creek above Telluride. It rests unconformably upon Mesozoic strata, and consists wholly of conglomerate composed largely of metamorphic debris. Apparently it is a shore deposit in course of formation at the beginning of the eruption of the San Juan breccia immediately overlying it, in which case it probably belongs in the Tertiary."

Two years later, on a similar occasion, before this Society, in his most valuable address: "Orographic and Structural Features of Rocky Mountain Geology,‡" Mr. Hills once more refers to this formation, and concludes, as to its age, that it is "presumably post-Laramie or early Eocene." Before taking the field my attention was again called to the conglomerate in question, by Mr. Hills in person, and my own observations indicate the general correctness of his views in regard to it. I am not aware of any other definite reference to, or recognition of this formation.

*Published with the permission of the Director of the U. S. Geological Survey.
†Published in Proc. Colo. Sci. Soc., Vol. III, p. 174.
‡Proc. Colo. Sci. Soc., Vol. III, p. 407.

One of the principal localities in which the conglomerate was observed by Mr. Hills, is on the north side of the San Miguel River, from Marshall Creek westward for several miles, and it so chanced that, in the survey of the Telluride region, I first came upon the beds to be described in these same exposures. The formation was afterwards traced in all directions beyond the limits of the Telluride sheet, and as it cannot on present evidence be correlated with any other known deposit, it is proposed to designate it the San Miguel Formation, from its typical exposures above referred to, and many others in the drainage area of the same river.

General Character and Relationship.

The San Miguel formation is characteristically a coarse conglomerate in which pebbles of many kinds are easily recognizable at a glance. Granite, schists of various kinds, hard bluish quartzites, limestones, red sandstones, and some dense porphyritic eruptive rocks are the commoner constituents. The pebbles vary greatly in size in different places, being boulders of more than a foot in diameter at some points, and often measuring several inches. The beds grade, on the other hand, into finer-grained sandstones or grits, and, in one extreme locality, many strata are shales. The thickness of the complex varies from 200 feet to nearly 1,000 feet, the latter thickness being reached where the beds are of the finest grain at their western observed occurrence in the Mt. Wilson group.

A great unconformity occurs at the base of the formation. Its base is first found resting on the Colorado Cretaceous shales, and from that horizon, gradually descends, transgressing the edges of the Colorado and Dakota Cretaceous, the entire thickness of the Jura, and is seen in contact with the Trias. In the district south of Silverton it is believed that the San Miguel conglomerate passes over the entire Paleozoic section and may come to a contact with the Algonkian quartzite of the Needle Mountain area.

Above the San Miguel conglomerate occurs the bedded volcanic series which makes up so large a part of the San Juan Mountains. The lower part of this volcanic series consists of apparently water-laid strata in which andesitic debris is at first mingled with material such as that of the San Miguel conglomerate,

and for this bedded, clastic formation above the San Miguel I propose the name San Juan Formation. It is conformable with the San Miguel throughout the district studied, and possesses a thickness varying between 1,500 and 2,500 feet. It has been described in some detail in the preceding article.

Details of Distribution and Unconformity.

On the northern side of San Miguel River, about four miles northwest of Telluride, the San Miguel conglomerate rests on dark Colorado Cretaceous shales, at nearly 2,000 feet above the Dakota. This contact is well shown on the head of Deep Creek. Between this point and the head of the San Miguel Valley, just above Telluride, the full extent of the observed unconformity is well shown, and can, in fact, be taken in at a glance by an observer stationed on any high point on the south side of the river.

The San Miguel conglomerate dips quite uniformly at a low angle eastward in this vicinity, while the underlying Mesozoic beds either lie nearly horizontal or assume a westerly dip in the vicinity of Telluride.

At this head of the San Miguel Valley the conglomerate is 200 to 400 feet in thickness, has a variable light-reddish color, and forms a very marked band below the dark, dense andesitic sandstones of the San Juan formation, which are especially dark and uniform in texture for several hundred feet above the San Miguel. Where the trail to Marshall Basin crosses the outcrop of the San Miguel conglomerate, just above the Pandora mill, there is but a thin remnant of the white Jurassic sandstone between the San Miguel and the Triassic sandstone and conglomerate, so that it is not wonderful that the whole of the reddish conglomerate has been referred to as one formation by most of those who have noticed it only on this thoroughfare and who have not traced the divergence of the two formations westward.

In the cliff wall below Ingram Basin and under the Bridal Veil Fall the contrast between the San Miguel conglomerate and the dark band of the San Juan above it may be followed with ease. In Bear Creek Canyon, south of Telluride, one may place his finger on the line where the descending base of the San Miguel cuts out

the last layer of the white sandstone referred to, and the Jura and rests on the upper surface of the red Trias.

From the vicinity of Telluride the San Miguel conglomerate may be traced across to Silver Mountain, where, just above Ophir Loop, the diorite-gabbro stock cuts across it. The conglomerate is present in the valley of Howard Fork about the town of Ophir, crossing the valley above the mouth of Swamp Creek. It is well exposed in the canyon of the latter and in Waterfall Gulch, but is again cut by the diorite stock in Yellow Mountain.

The San Miguel conglomerate was traced from Yellow Mountain along the base of Vermilion Peak and around Sheep Mountain to the west side of Grizzly Peak, where it is cut by another great diorite stock, that of Grizzly Peak and Rolling Mountain. It appears, in short, as a constant factor under the San Juan formation, in all the area studied. At the head of the west fork of Mineral Creek about Pandora, and in the mass of the Twin Sisters, it is always clearly distinguishable. At the head of Cascade Creek and on the north side of the head or Lime Creek it is a very prominent horizon. From a high butte of dark Jurassic limestone situated north of Engineer Mountain one can see the characteristic cliff of the San Miguel conglomerate running nearly on a level eastward toward the south base of Sultan Mountain, and clearly transgressing the edges of the westward-dipping Paleozoic red beds. It would seem probable that, unless removed by erosion or interrupted at a critical point by the augite-diorite stock of Sultan Mountain, the San Miguel must come to contact with the lower Paleozoic limestones before reaching the canyon of the Animas.

On the southern slope of Mt. Wilson the formation again rests on Cretaceous shales, and is developed in its greatest thickness, reaching nearly 1,000 feet. The strata are here much finer-grained than in the mountains to the eastward, and as they have also been much indurated and bleached through agencies accompanying the great diorite intrusion of the central peaks of the group, one might not at first recognize the formation, were it not for the occasional fine-grained conglomerate and the relation to the overlying San Juan beds. In Sheep Mountain, south of Trout Lake, is found a transition in character and thickness from the coarse conglomerate

on the east to the sandstone and shale series of Mt. Wilson on the west.

As viewed from Mt. Wilson it would appear probable that the San Miguel formation is present in Dolores Peak, but there are certainly intrusive sheets of diorite-porphyry in the Cretaceous shales of that peak, as stated by Holmes, and it may be that the bedded appearance of the upper slopes is wholly due to the same formations.

Constitution of the San Miguel Conglomerate.

The angular unconformity known or supposed to exist below the San Miguel conglomerate, is of the same degree as the stratigraphic break shown by the pebbles in that formation. The composition of the conglomerate varies somewhat from place to place, but all along the eastern part of the district of the Telluride sheet it may be noticed that limestone and red sandstone pebbles are much more abundant in the lower half of the conglomerate, while the proportion of bluish quartzites and dense greenish schists increases upward. This relation is perhaps most distinctly seen in the cliff of the San Miguel facing southward at the head of Lime Creek, and from this position the full significance of the variation in question is very clear. The observer can here see the towering pinnacles of the Needle or Quartzite Mountains, twelve miles to the eastward, beyond the Animas, formed of just such hard Algonkian quartzites as those of the pebbles, while on the western side of the Animas canyon, resting on the granites and quartzites, are the limestones of the Lower Carboniferous and Silurian.

The materials of the San Miguel conglomerate are those known in the Quartzite Mountains or in the strata dipping away from those peaks on the west and south. To this statement the igneous rocks found in the conglomerate, are as yet an exception. When the districts to the eastward of that from which the formation has been described, are better known it is quite probable that the source of the igneous rocks will be determined. The fact that real volcanic rocks, such as the andesites of the San Juan series, do not appear except in the upper beds of the San Miguel, has an importance to be brought out in the following section.

Age of the Formation.

Although careful search was made for fossils in the finer-grained strata of Mt. Wilson and of several other localities, no identifiable remains of any kind were found. Only a few carbonized plant stems and some curious trail-like markings in mud layers were seen. The only direct evidence as to the age of the San Miguel formation lies in the fact that it is older than, and that it apparently, immediately preceded, the first of the great volcanic eruptions which built up the San Juan mountains; and, further, that the floor on which it was laid down, was a base-level of erosion formed after great orographic movements affecting all formations from the Silurian to the Cretaceous and, presumable, to the top of the Laramie.

In his second address above referred to, Mr. Hills suggests that the San Miguel is "post-Laramie or early Eocene." Mr. Hills uses the term "post-Laramie," as I have done,* for the formations such as the Arapahoe, Denver, and Middle Park formations in Colorado, and the Livingstone† formation in Montana, which, while containing fossils of Mesozoic types, as viewed by the paleontologists, are later than great orographic movements terminating the regular succession of Cretaceous deposits. To support his view Mr. Hills points out that, on the eastern border of the San Juan volcanic district, the upper members of the series of lavas are "involved in the disturbances which produced the San Louis Park depression, and the final upheaval of the Sangre de Cristo Range." This movement he believes to have been of the post-Bridger Eocene.

To make the San Miguel conglomerate the equivalent of the Arapahoe formation brings the suggestion that the bedded San Juan series of tuffs and braccias corresponds to the Denver beds. In fact, the actual unconformity seen below the San Miguel, and so clearly indicated in its sediments, is of the same order as that stratigraphic break between the Laramie and the Arapahoe, proven by the pebbles in the latter conglomerate. And the great volcanic

*Post-Laramie Deposits of Colorado. Amer. Jour. Sci., Vol. XLIV. 1892, p. 19. The Post-Laramie Beds of Middle Park, Colo.. Proc. Colo. Sci. Soc.

†Bulletin 105 U. S. Geological Survey. "The Laramie and the Overlying Livingstone Formation in Montana," by W. H. Weed.

floods of the San Juan are comparable to those which I have thought were probably poured out over the Front Range, from the testimony of the Denver and Middle Park formations.

In this connection the post-Laramie beds of the Animas River section below Durango, which are mainly made up of just such andesitic debris as is found in the San Juan complex of tuffs and breccias, become of much significance. The Animas beds now appear in apparent conformity upon the Laramie in the only region where I have seen them in contact, and no possible equivalent of the San Miguel has been found. The Animas beds near Durango are, however, several miles south of the southern edge of the San Juan volcanic series, as shown by the Hayden map, and the relation of the two formations is not yet known.

In view of the fact that the work of the next few years in this region will undoubtedly bring to light much evidence bearing on the problems here suggested, further speculation seems undesirable. But the view entertained by Mr. Hills concerning the age of the San Miguel formation, and, in general, of the whole San Juan series of eruptions, makes the possible correlation of the San Miguel and Arapahoe formations an important feature to be brought out in describing the former.

NOTES ON THE OCCURRENCE OF A RICH SILVER AND GOLD MINERAL CONTAINING TELLURIUM, IN THE GRIFFITH LODE NEAR GEORGETOWN, CLEAR CREEK COUNTY, COLORADO.

By Dr. Richard Pearce.

Meeting of October 5, 1896.

A member of this Society, Mr. C. A. Martine of Georgetown, has sent me for investigation a mineral which he has recently discovered in the Griffith mine, and which promises to be a material of some mineralogical interest. Mr. Martine discovered that it contained tellurium, and was lead to believe that it might prove to be a telluride of silver and gold, of an entirely new species.

The mineral occurs only in small quantities associated with pyrite, galenite and chalcopyrite, in a felspathic matrix containing small quantities of magnesite.

The color is dark-gray with a bright metallic lustre; hardness about 3.

An analysis was made by Mr. F. C. Knight on carefully selected material, but, owing to its intimate association with the minerals named above, it was impossible to obtain the mineral in a pure form.

The result of the analysis is as follows:

Ag	50·65
Te	18·80
Pb	9·34
Cu	4·65
Fe	4·00
Bi	1·16
S	8·06
$MgCO_3$	1·95
Alloy of Au and Ag	0·48
Insoluble residue	1·07
	100·16

It was supposed by Mr. Martine that the gold present in the mineral, was combined with tellurium ; the results of my investigations show, however, that the gold exists in the form of a rich alloy of Au and Ag. One small piece of the mineral showed distinctly a coating of gold and silver alloy on its cleavage plane. On treating the powdered mineral with nitric acid the residue showed no indication whatever of brown sponge gold, which would have been the case if this metal was combined with tellurium. On the other hand the residue contained the gold only in the form of a bright pale yellow alloy which proved to be 725 fine, the rest being silver.

The mineral, judging from the above analysis, may be said to consist of a mixture of hessite and argentite. Ag_2Te and Ag_2S, associated with other minerals in the following proportions :

Hessite	51·22
Argentite	20·93
Cu_2S } Chalcopyrite	5·82
FeS } probably	6·28
PbS (galenite)	10·78
Bi_2S_3	1·42
Au and Ag alloy	0·48
$MgCO_3$	1·95
Insoluble residue	1·07
	99·95

It is interesting to note that the relation between the hessite and the argentite corresponds closely to the formula: $2\ (Ag_2Te) + Ag_2S$.

NOTES ON THE OCCURRENCE OF TELLURIUM IN AN OXIDIZED FORM IN MONTANA.

By Dr. Richard Pearce.

Meeting of November 2, 1896.

On a recent visit to Montana I came across some rich gold ore from the Mayflower Mine, owned by Mr. W. A. Clark of Butte. I am not at this time in the possession of any particulars giving the locality or the geological conditions under which the ore occurs.

There is nothing in the general appearance of the ore which would lead one, for a moment, to expect that it might contain gold. The specimen which I present to this Society, may certainly be claimed to have no special features indicating richness, but assays which I have obtained from clippings, show 21·33 ounces Au, and 93·67 ounces Ag per ton, and I learn that the mine yields ore by the car load, which contains from 10 to 20 ounces Au per ton.

The richness of the material induced me to make some investigations for the presence of tellurium in an oxidized form, similar to the occurrences in Cripple Creek and South Dakota, which have formed the subject of some three papers which I have presented to this Society.

I found, on treating the finely powdered ore with hydrochloric acid, that the whole of the ferric oxide present in the ore, was soluble, and a residue of white silicious material was left undissolved. The soluble portion, on treating with an excess of a solution of stannous chloride, gave an abundant flocculent precipitate of metallic tellurium, which, after weighing, indicated a quantity equal to 87·49 ounces per ton. The insoluble portion, after treating with hydrochloric acid, was carefully concentrated by vanning to get rid of the silicious material as far as possible ; a concentrated product being by this means obtained, which showed a quantity of

fine gold, together with some very brilliant white crystals of what appeared to be sylvanite, as they were certainly possessed of all the habits of that mineral.

The results of these investigations would lead one to infer that below the zone of oxidation tellurides of gold and silver may be expected to occur. This particular specimen which I believe was mined near the surface, indicates that the tellurides originally present in the rock, were not completely oxidized by the action of surface waters circulating through the vein.

The presence of so much silver (unlike the occurrence of Cripple Creek) would tend to prove the existence at depths, below the zone of oxidation, of such minerals as hessite or petzite, associated with sylvanite. It may, however, be found that the latter mineral is the only representative of the telluride group present, associated perhaps with rich silver minerals, as previously referred to in my few notes on the Dakota occurrence of tellurium.

Mr. Clark has promised to give me every opportunity to study the character of the minerals which may be found at greater depth. These results I hope to present to the Society at some future day, together with any points of interest I may be able to procure bearing on the geological features of the deposit.

AN AUTOMATIC WATER RECORDING GAUGE.

By Ernest Le Neve Foster, Denver, Colorado.

Meeting of December 7, 1896.

It is seldom that the water pumped or raised in mining operations is determined with any degree of accuracy, although such information is data of importance which the mine manager should secure. It enables him to ascertain the efficiency and economy with which this branch of his work is proceeding, and also furnishes much other interesting information.

Heretofore, in most cases, it has only been customary to make estimates in a crude way. These are almost invariably far in excess of the actual amounts, giving a much greater efficiency to the fuel used than is due it. Nothing but a systematic and continuous measurement will give reliable results. The old and common way of counting the strokes of the pump, and, from the size of the plungers, determining the discharge of water, is imperfect, unsatisfactory, and subject to numerous errors. The stroke of the pump, especially with steam pumps, may from sundry causes be short of its original design, the speed also will vary throughout the day, since it is almost impossible in mine work, where the hoisting engines and pumps are often supplied from the same boilers, to maintain an even pressure. Again, unless all valves are in perfect order, the leakage from that source is very great, more particularly under high heads; hence, almost withuot exception, calculations based on this kind of data are very erroneous.

Having had occasion during the past year to obtain reliable data of the amount of water discharged from a mine under my supervision, I set about to devise a plan which would give me the correct information, and, presuming that it might be of interest to others, I here give a brief account of the plan adopted.

In the first instance the water was hoisted by means of an automatic self-discharging bucket containing 400 gallons, but subsequently was changed to an 8-inch Cornish pump. However, in both cases, a very similar device was used. In the first instance it acted as a counter, and, in the second place, traced a line on a diagram showing the number of inches of water flowing over a dam.

Selecting for my purpose the clock and dial of a large Bristol recording pressure gauge I substituted for the arrangement for moving the pen-arm a long lever attached nearly at right angles to the pen-arm, and working on a pivot at the angle, having the end of the long lever stretched beyond the instrument, and over a tank. This was then attached, by a parallel motion, to a rod working in guides, and fastened to a six-inch copper float, the lever being further balanced by a counterpoise. The rise or fall of the water caused the float to move correspondingly, and thus operated the pen-arm.

The water from the bucket was discharged into the tank containing the float. This tank was of sufficient capacity to contain the full amount in the bucket, and, being filled rapidly, the pen moved quickly across the dial. As the tank emptied slowly through a discharge pipe at the bottom of the tank, the pen, in returning, traced a line across the dial. These, when counted, gave the number of buckets raised, so that by simple computation a very close approximation of the amount of water raised was arrived at. The outlet from the tank was so arranged that the tank would have time to empty between buckets.

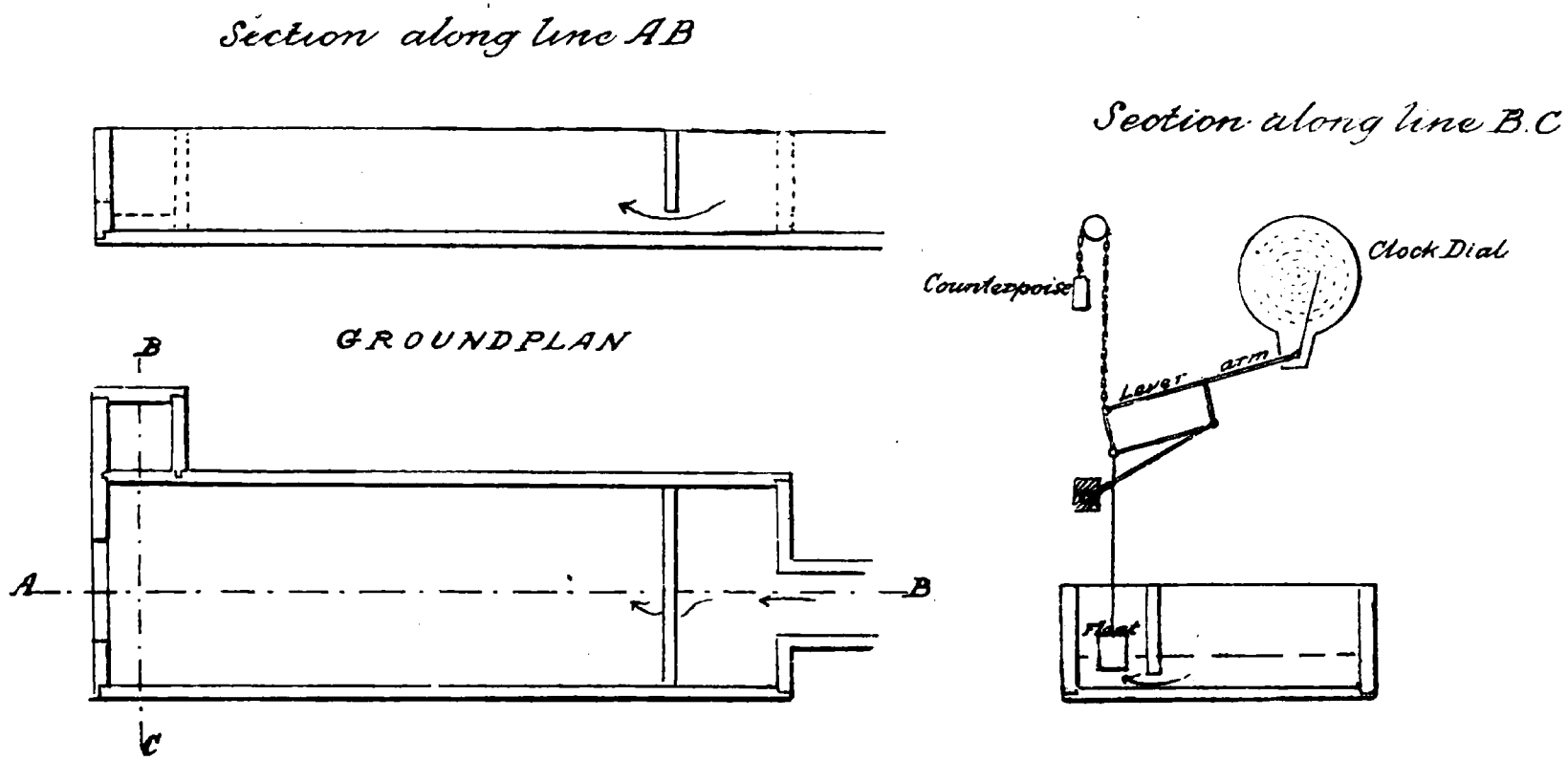
In addition to the information regarding the quantity of water, the system had an additional advantage, that it showed exactly the hour and minute each bucket was raised, and consequently the regularity with which the engineer attended to his work, whether by day or night. The superintendent or foreman being thus informed of all stoppages, could inquire into the reasons. In my case I found a notable difference in the amount of work performed before and after placing this device. Prior to its installation the average amount hoisted was 18 to 20 buckets per hour, but afterward it increased to 25 to 30 buckets per hour.

After the installation of the pumping plant I decided to con-

tinue my system of recording the water raised, in order that I might have data regarding the quantity of water in the mine at the different seasons of the year, and for the further purpose of determining the efficiency of the pumping machinery, when it worked, when stoppages occurred, and any other particulars obtainable. This affords a valuable record, and by requiring the engineers to report the cause of all stoppages I am placed in possession of information I should not otherwise have.

To carry out this plan I used the same arrangement as before, except that the tank was done away with, and a V-weir placed in an enlarged part of the discharge launder, so as to quiet the flow as much as possible, as shown in the annexed diagram. By the side of this dam, but freely connected with the enlarged part of the launder was a smaller box or compartment for the float to work in, so that it might be free from any disturbance caused by the flow of water, and yet readily indicate the rise or fall in the height of the water. As rise or fall occurs the pen traces a line on the dial, which, being divided to represent inches and tenths of actual rise or fall, makes a record of the depth of water flowing over the dam at every minute of the day and night. This being obtained, the calculation into gallons is easily made, and the amount pumped each twenty hours obtained. This can then be transferred to a horizontal chart, and a line of different color for each month affords a most interesting diagram.

There is no reason why this apparatus could not be used for gauging streams or large bodies of water flowing over ordinary weir dams, thus obtaining information from day to day with equally satisfactory results. The adjustment of the parts can be made as fine as it is deemed necessary for the accuracy of the results desired.



Scale 3 Feet to 1 Inch

NECROLOGY.

C. O. Shields.

It is our painful duty to record the death of Mr. C. O. Shields, late a member of the Society. He was born January 30, 1859, in Adams County, Illinois, but coming to Colorado as a child, received his education entirely in this State, first at Colorado Springs, and finally at the State School of Mines, at which institution he was one of the first students. His first position was that of assayer at the works of the Pueblo Smelting and Refining Co.; leaving which in 1885, he went to Denver as assayer to the Denver Public Sampling Works. In 1887 he went to Morenci to take charge of a copper plant, but, at the end of a year, accepted the position of chemist to the Serra Mojada Smelting Co., Mexico, of which plant he subsequently became superintendent. Becoming badly "leaded," he took a trip to the Sandwich Islands, where he recovered his health. Upon his return he again took up active work, first in Denver, as a member of the firm of Shields & Jones, and afterwards in Cripple Creek, under the firm name of Middleton & Shields. Finally, becoming Vice-President of a New York Development Company, he went to Bolivia to take charge of the Company's operations in that country. A few days after landing, and probably owing to his too great impatience to reach the mines which were at a high altitude, he contracted congestion of the brain and lungs, and after a sickness of only four days, he died at Uyuni, where he was buried.

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