



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

LIBRARY
OF THE
UNIVERSITY OF CALIFORNIA.

GIFT OF

Colorado scientific society

Class

LIBRARY
OF THE
UNIVERSITY OF CALIFORNIA.

GIFT OF

Colorado scientific society

Class

THE
PROCEEDINGS
OF THE
COLORADO
SCIENTIFIC SOCIETY

VOL. VII
1901, 1902, 1903, 1904

PUBLISHED BY THE SOCIETY
DENVER, COLORADO

211
243
v. 7

CONTENTS

OFFICIAL PART.

Abstract of Minutes, Reports of Librarian, Secretary and Treasurer	1-xxxvii
--------------------------------------------------------------------------	----------

COMMUNICATIONS.

A Mica-Andesite of West Sugarloaf Mountain, Boulder County, Colorado by John Charles Blake	1-18
Some Relations of Tetrahedral Combinations of Crystalline Form; by John Charles Blake	19-22
Test of the Corliss Engine at the Saratoga Mine, Central City. Some Pumping Data. Description of the Tabor Steam Engine Indicator; by Thomas L. Wilkinson.....	23-40
The Colorado Central Lode, a Paradox of the Mining Law; by Ernest LeNeve Foster	41-56
Notes on Southwestern Utah and Its Iron Mines; by G. C. Hewett	55-66
The Arizpe Meteorite; by A. F. Wuensch	67-68
Abstract of Some Material Presented to the Colorado Scientific Society	69-72
The Commercial Assay of Lead Ores; by A. W. Warwick.....	73-75
The Commercial Assay of Lead Ores. Discussion by Dr. W. A. Johnston	77-78
The Separation of Gold from Copper, with Especial Reference to Pyritic Smelting; by F. R. Carpenter	79-84
Refractometers and Some of Their Uses in Analytical Chemistry; by W. F. Edwards	85-102
Synopsis of Paper on the Development of Pseudomorphs; by Horace B. Patton	103-108
The Commercial Assay of Lead Ores (Discussion).....	109-112
The White Country Granite of West Sugarloaf or Bald Mountain, Boulder County, Colorado; by Garl D. Henry.....	113-116
Notes on the Santa Eulalia Mining District, Chihuahua, Mexico; by Philip Argall	117-126
The Contact, Nevada, Quaquaversal; by Chester Wells Purlington.	127-138

CONTENTS

Notes on an Occurrence of Mica in Boulder County; by T. E. Schwarz	139-140
Mineralogical Notes; by W. P. Headden.....	141-150
Economy in Mill Water; by Jesse Scobey.....	151-162
Gases in Metalliferous Mines; by Harry A. Lee.....	163-188
Death Gulch; by F. W. Traphagen.....	189-192
The Circulation of Underground Aqueous Solutions and the Deposition of Lode Ores; by John W. Finch.....	193-252
The New Geology and Vein Formation; by Franklin R. Carpenter.	253-266
The Progress of Gold Mining in Kalgoorlie, Western Australia, in 1903; by E. Barton-Hack.....	267-288
The New Geology and Vein Formation; by Franklin R. Carpenter	289-296
Some Notes on Vanadium; by W. F. Edwards.....	297-312
Holsting in Deep Shafts; by Charles W. Comstock.....	313-340
The Use of Crude Oil for Fire Assaying; by F. C. Bowman.....	341-346

ILLUSTRATIONS.

Four Half-tone Engravings Accompanying Paper on "Some Relations of Tetrahedral Combinations of Crystalline Form".....	33
Cross Section of Saratoga Mine, Gilpin County, Colorado.....	26
Drawings of Corliss Engine Tests.....	26
Half-tone Map of Colorado Central Lode.....	41
Cross Section Drawing of Colorado Central Lode.....	41
Model of Underground Workings of Colorado Central Lode.....	46
Half-tone Plate of Colorado Central Lode Tunnels and Drifts.....	46
Half-tone Plates of Colorado Central Lode Shafts and Levels.....	46
Utah St. George Sheet of U. S. Geological Survey.....	55
Seven Half-tone Plates Accompanying Paper on "Notes on South-western Utah and Its Iron Ores".....	65
The Arizpe Meteorite.....	67
Large Half-tone Plate of Etched Slice of Arizpe Meteorite.....	68
A Silicified Coral, in a Mass of Flint, from Limestone at Webb City, Mo.	107



ILLUSTRATIONS

A Chambered Nautilus Altered to Pyrite, from the Lias, Near Heidelberg, Germany	107
Pseudomorph of Quartz After Barite, from the Yankee Girl Mine, Ouray, Colorado	107
The Reverse Side of the Same Specimen That is Shown in Fig. 3....	107
Pseudomorph of Quartz After Barite, from the Black Hawk Mine, Rico, Colorado	107
Pseudomorph of Quartz After Barite, from Black Hawk Mines, Rico, Colorado	107
Dolomite and Calcite, from the Camp Bird Extension Mine, Ouray, Colorado	107
Plates 1, 2, 3 and 4, Accompanying Paper on "Notes on the Santa Eulalia Mining District	126
Sketch Maps 1 and 2 of Contact, Nevada, Quaquaversal.....	138
Half-tone Plate in Colors of Limestone Bed, Stained With Copper Carbonates	138
Plan Illustrating Deceptive Blocking Out of Ore.....	138
The Shoshone Falls of the Snake River, Idaho.....	138
Sand Box for Automatically Cleaning Mill Tailings of Coarse Sands	154
Detail of Drag Bracket and Plate for Sand Box.....	154
Slimes Settling or De-watering Tank for Continuous Discharge of Both Slimes and Clear Water	159
Section Map, Showing Arrangement of Connected Spaces Between Sand Grains of the Soil	210
Map of Vertical Section Drawn Along the Devious Course of a Series of Insecting Fissures from Some Central Mountain Point to the Valley and Plains Region on Either Side.....	210
Two Half-tone Plates Accompanying Paper on "Progress of Gold Mining in Kalgoorlie	267
Map "The Golden Mile, Kalgoorlie, W. A.".....	267
Diagram of Ore Treatment, Kalgurli Gold Mines, Ltd.....	267
Two Half-tone Plates Accompanying Paper on Use of Crude Oil for Fire Assaying	341
Cross Section of Furnace	342


OFFICIAL PART.

**ABSTRACT OF MINUTES
FOR THE YEAR 1901.**

THE ONE HUNDRED AND SEVENTY-FOURTH REGULAR MEETING.

February 2d, 1901.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Fourteen persons were present.

The minutes of the preceding meeting were read and approved.

COMMUNICATIONS.—Mr. J. C. Blake read two papers. The first was on a "Mica Andesite of Boulder County, Colorado." Discussed by Messrs. Palmer, Cannon and Hills. The second paper was on "The Structure of Crystallized Matter." This paper proposed a new theory of crystalline structure, and was discussed by every one present.

A vote of thanks to Mr. Blake for his interesting papers was proposed and carried.

It was moved and seconded that the thanks of the Society were due to the University Club for its courtesy in permitting the annual dinner to be held at its club house. Carried.

THE ONE HUNDRED AND SEVENTY-FIFTH REGULAR MEETING.

March 9th, 1901.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Eleven persons were present.

The minutes of the preceding meeting were read and approved.

COMMUNICATIONS.—Mr. Geo. L. Cannon, Jr., read a paper on "The Antiquity of the Human Race." Discussed by Messrs. Argall, Lakes and Comstock.

A vote of thanks to Mr. Cannon was proposed and carried.

THE ONE HUNDRED AND SEVENTY-SIXTH REGULAR MEETING.

April 6th, 1901.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Seven persons were present.

The minutes of the preceding meeting were read and approved.

COMMUNICATIONS.—Mr. T. L. Wilkinson read a paper on "A Test of the Corliss Engine at the Saratoga Mine, Gilpin County, Colorado." This was discussed generally and at some length.

THE ONE HUNDRED AND SEVENTY-SEVENTH REGULAR MEETING.

May 4th, 1901,

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Twelve persons were present.

The minutes of the preceding meeting were read and approved.

The coming visit of the American Association for the Advancement of Science to Denver was discussed by W. S. Ward, G. L. Cannon and others.

It was moved and seconded that this Society express its pleasure and gratification at the selection of Denver for the meeting of the A. A. A. S., and that the Secretary communicate this to the Chamber of Commerce. Carried.

COMMUNICATIONS.—Mr. F. R. Carpenter read a paper on "The Smelting of Cripple Creek Ores." This paper was generally discussed.

THE ONE HUNDRED AND SEVENTY-EIGHTH REGULAR MEETING.

September 7th, 1901.

In the Society Rooms, 421 Tabor Opera House Building.

Past President Geo. L. Cannon, Jr., in the Chair.

Eleven persons were present.

The minutes of the preceding meeting were read and approved.

COMMUNICATIONS.—Mr. C. W. Comstock read a paper on "Hoisting in Deep Shafts." This was generally discussed.

ABSTRACT OF MINUTES.

THE ONE HUNDRED AND SEVENTY-NINTH REGULAR MEETING.

October 5th, 1901.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Nine persons were present.

The minutes of the preceding meeting were read and approved.

Mr. A. Lakes presented a specimen said to be a silica replacement of a fungous growth on mine timbers in the lower levels of the Comstock Mines.

Mr. Lakes also called attention to the occurrence of a vein of lignite coal in a granitic fissure vein in Gilpin County, Colorado.

Both of these matters were discussed at some length.

THE ONE HUNDRED AND EIGHTIETH REGULAR MEETING.

November 2d, 1901.

In the Society Rooms, 421 Tabor Opera House Building

The President in the Chair.

Twelve persons were present.

The minutes of the preceding meeting were read and approved.

Mr. T. L. Wilkinson showed a large number of lantern slides of the armor plate plant of the Bethlehem Steel Company, loaned by Mr. F. L. Clerc.

THE ONE HUNDRED AND EIGHTY-FIRST REGULAR MEETING.

December 7th, 1901.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Seven persons were present.

The minutes of the preceding meeting were read and approved.

The following nominations for officers for the year 1902 were made:

President	-	-	-	-	-	Irving Hale.
First Vice-President	-	-	-	-	-	G. C. Hewett.
Second Vice-President	-	-	-	-	-	Harry A. Lee.
Treasurer	-	-	-	-	-	G. L. Cannon.
Secretary	-	-	-	-	-	E. N. Hawkins.
Corresponding Secretary and Librarian	-	-	-	-	-	T. A. Rickard.

For members of the Executive Committee:

G. L. Cannon,	C. W. Comstock,
E. Le Neve Foster,	R. C. Hills,
Richard Pearce.	

The president appointed T. L. Wilkinson and C. W. Comstock a committee to arrange for the annual dinner.

ANNUAL MEETING.

December 21st, 1901.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Seven persons were present.

The minutes of the preceding meeting were read and approved.

Messrs. W. L. Austin and F. L. Clerc were appointed tellers to canvass the ballots for officers.

Upon report of the tellers, the following were declared elected:

President	-	-	-	-	-	Irving Hale.
First Vice-President	-	-	-	-	-	G. C. Hewett.
Second Vice-President	-	-	-	-	-	Harry A. Lee.
Treasurer	-	-	-	-	-	G. L. Cannon.
Secretary	-	-	-	-	-	E. N. Hawkins.
Corresponding Secretary and Librarian	-	-	-	-	-	T. A. Rickard.

Members of Executive Committee:

G. L. Cannon,	C. W. Comstock,
E. Le Neve Foster,	R. C. Hills,
Richard Pearce.	

The Secretary read a letter from Mr. Rickard in which he declined to serve as Corresponding Secretary and Librarian.

Mr. T. L. Wilkinson was, therefore, nominated and elected to this office.

THE ONE HUNDRED AND EIGHTY-SECOND REGULAR MEETING.

February 1st, 1902.

In the Society Rooms, 42, Tabor Opera House Building.

First Vice-President G. C. Hewett in the Chair.

There were ten members present.

On motion the reading of the minutes of the preceding meeting was dispensed with, in order to hasten the reading of a paper by Mr. E. Le Neve Foster.

COMMUNICATIONS.—Mr. E. Le Neve Foster read a paper on “The Colorado Central Lode, a Paradox of the Mining Law”—a very clear exposition of the vein existence upon this property. Discussion of the points presented was variously indulged in, and upon motion a vote of thanks was tendered to Mr. Foster for his elaborate and instructive paper.

Upon motion the Secretary was requested to tender the thanks of the Society to the University Club for the use of its dining hall for the annual dinner of the Society.

The Secretary reported receipt of a tax schedule assessing the Society's property at \$300, and as it has not been customary to pay taxes, the Secretary was requested to lay the views of the Society upon this subject before the County Commissioners for the purpose of having the assessment remitted.

THE ONE HUNDRED AND EIGHTY- THIRD REGULAR MEETING.

March 1, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

First Vice-President G. C. Hewett in the Chair.

Fourteen members were present.

The reading of the minutes of the preceding meeting was dispensed with.

DISCUSSION.—The discussion of the evening was upon the Boulder Oil Field, with particular reference to the proper inter-

pretation of the Hayden maps relating to this field, and the correspondence or similarity between the Eastern oil occurrences and those of the Boulder field. Mr. George L. Cannon pointed out some inaccuracies upon the maps of Hayden, ascribing them chiefly to the general character of the work done and the large territory covered by the report. Professor Cannon spoke of the value in this matter of the Monograph of the U. S. Geological Survey No. 27 upon the Denver Coal Basin, and advised a study of the same in connection with the subject of oil in the northern field.

Messrs. Hewett, Comstock and Hale joined in the discussion, and Mr. Hewett particularly referred to the occurrence of oil rock in the neighborhood of Morrison and Golden, and spoke of the irrelevance of the same to the question of the existence of oil at Boulder.

Mr. Foster suggested that persons engaged in drilling wells be approached for the purpose of collecting information concerning the formations penetrated.

Mr. Hale moved that the chair appoint a committee of three to take this matter in hand, and not only secure such information, but co-operate with Dr. Fenneman of the State University in the collecting of oil well records of the Boulder field for the purpose of getting knowledge of the whole subject of the development in this field—and that such committee shall be authorized to add to itself such other members of the Society whose assistance will be valuable in securing the facts.

The motion was carried and the chair appointed Prof. H. B. Patton of Golden, Prof. Geo. L. Cannon and Edwin N. Hawkins of Denver.

Mr. A. G. Brownlee was elected to membership.

THE ONE HUNDRED AND EIGHTY-FOURTH REGULAR MEETING.

April 5th, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

There were nine members present.

The minutes of the preceding meeting were read, and, there being no objections, they were approved.

The committee on oil was called on to report, but as they had not been able to meet together, no report could be expected.

Mr. A. G. Brownlee and Mr. A. W. Warwick were elected to membership, and the Secretary was instructed to notify them to that effect.

Three new applications for membership were referred to the Executive Committee.

COMMUNICATIONS.—Mr. G. C. Hewett, First Vice-President of the Society, then read a paper on "Southern Utah and Its Iron Ores." The subject of this paper was discussed by Messrs. Comstock, Foster and Clerc.

Mr. Comstock brought up the subject of centrifugal pumps and fans, stating that a French engineer has made some remarkable experiments on the subject. Mr. Clerc spoke of a Swiss centrifugal pump of high efficiency, but the firm making them is not yet prepared to fill orders. The centrifugal pumps were quadrupled.

President Hale spoke of steam turbines built by the General Electric Company, but added that the company was not yet prepared for orders.

A letter was submitted from Dr. Day to Mr. Hewett on the subject of sending our collections to the St. Louis Exposition. General discussion was to the effect that the exhibit would be of no benefit to the Society, and the prevailing opinion was against such action.

THE ONE HUNDRED AND EIGHTY-FIFTH REGULAR MEETING.

May 3d, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

The President in the Chair.

Ten members were present.

The minutes of the previous meeting were read and approved.

The Secretary brought up the subject of the general welfare of the Society with reference to the membership list, and the various members who had resigned or been dropped during the past few years, and with particular reference also to the subject of the Society's permanent quarters and financial status.

In this connection, it was suggested that the possibility of housing the collections and library in the State House, with permanent quarters therein, should be investigated. Discussion upon these questions was general.

The resignation of Dr. S. F. Emmons, presented to the Society, was not accepted, and, on the contrary, it was resolved that in view of Dr. Emmons' eminent services and long connection with the Society, that he should be elected an honorary member. This action was taken, and the Secretary was instructed to so notify Dr. Emmons.

J. W. Finch of Victor and W. G. Moore of Colorado Springs were reported by the Executive Committee as elected to membership, and the Secretary requested to so advise them.

THE ONE HUNDRED AND EIGHTY-SEVENTH REGULAR MEETING.

September 6th, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

Second Vice-President Harry A. Lee, in the Chair.

On motion, and because they were not available, the reading of the minutes of the meeting of June 7th, 1902, was dispensed with.

Applications for membership, properly endorsed, were received from Frank Walter Royer and Thomas Walter Beam, Denver; William Beals, Jr., Boston, and Robert Forrester, Salt Lake City. These were referred to the Executive Committee for proper action.

A communication was read from the Pennsylvania Mines Company, through its president, Ernest Le Neve Foster, announcing that after August 31st it wished to vacate room No. 419, rented to it from the Society. The same communication stated the willingness of Mr. Foster to retain the said office for some months yet upon satisfactory agreement being made, and thus keep the rooms of the Society open daily. The consideration of this communication was left with the Executive Committee.

The Secretary reported the contribution to the Society from R. H. Burrows of Cripple Creek of some mineral and rock specimens. These were added to the mineral collection.

EXECUTIVE COMMITTEE MEETING.

September 10th, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

The communication from Mr. Foster, President of the Penn-

sylvania Mines Company, was read, and the rental indebtedness of this company to the Society of \$200 was promised paid by the Pennsylvania Company at the earliest possible moment, their lease of room 419 expiring August 31st. It was agreed by Mr. Foster that he should have office occupation of this room for an indefinite period, at a rental of \$5.00 per month, and in this way keep the Society's library and collection open.

Applications for membership from Frank Walter Royer and Thomas Walter Beam, Denver, and William Beals, Jr., Boston, Mass., and Robert Forrester, Salt Lake City, Utah, were presented, and upon motion each applicant was elected to membership in the Society.

Upon motion of Mr. Foster, the Librarian was authorized to present to new members back numbers of the Society's proceedings when such were desired, with the limit, however, that at least ten of each shall be retained by the Society for its own collection.

Mr. Lee reported that very favorable progress was being made in the matter of securing permanent quarters for the Society in the State Capitol building, and promised further advice at a later date.

The resignations of F. C. Knight, Robert S. Breed, Anton Eilers and Karl Eilers were presented and accepted.

The Secretary reported the presentation of an assessment schedule upon the Society's property. The Secretary was instructed to endeavor to have taxation remitted by the County Commissioners, as in the case of last year.

GEO. L. CANNON, JR.,

E. LE NEVE FOSTER,

C. W. COMSTOCK,

E. N. HAWKINS,

Executive Committee.

THE ONE HUNDRED AND EIGHTY-EIGHTH REGULAR MEETING.

October 4th, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

Second Vice-President Harry A. Lee in the Chair.

Thirty-two persons were present.

The minutes of the preceding meeting were read and approved.

Dr. N. M. Fenneman of the U. S. Geological Survey and of the chair of Geology at the University of Colorado, delivered an address on the "Arapahoe Glacier," and illustrated his paper by many views displayed with the aid of lantern slides. The lecture was very much appreciated and brought forth an interesting discussion of the physical features developed by Dr. Fenneman.

The thanks of the Society were, by unanimous vote, tendered to Dr. Fenniman for his able and clear paper.

Professor Cannon addressed the Society upon the subject of "Glyptoliths," and exhibited a number of the wind and sand-worn stones which he had collected upon the Cape Cod Coast and elsewhere.

Upon motion, the appreciation of the Society for Professor Cannon's talk was unanimously expressed.

THE ONE HUNDRED AND EIGHTY-NINTH REGULAR MEETING.

November 9th, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

Past President E. Le Neve Foster in the Chair.

There were fourteen persons present.

The minutes of the last meeting were read and approved.

COMMUNICATIONS—Mr. A. W. Warwick presented a paper on "The Chemistry of Roasting." Mr. Warwick read this paper in abstract, and showed the various reactions occurring in furnace practice on the blackboard. All the chemical occurrences have not been followed out, and he brought out the fact that comparatively little had been published, and there was yet much to be brought out by the various furnaces in use. Scientific men of the United States have not gone into this subject as thoroughly as the German and French have. Much improvement in roasting is to be made in this country, and this line of work has a large field. The subject of roasting is not generally well understood. Discussion by Messrs. Comstock, Gouyard and Clerc.

A vote of thanks was unanimously tendered to Mr. Warwick for his interesting and instructive paper.

THE ONE HUNDRED AND NINETIETH REGULAR MEETING.

December 6th, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

Past President E. Le Neve Foster in the Chair.

The minutes of the last meeting were read and approved.

The Executive Committee reported the election of E. H. Platt to active membership in the Society.

On Motion of Mr. Wilkinson, seconded by Mr. Hawkins, the Chairman appointed a committee to draft resolutions upon the subject of the assault upon Arthur L. Collins at Telluride, on

November 19th, which resulted in his death two days later. The chair appointed Messrs Comstock, Hawkins and Wilkinson as such committee.

The following were nominated for officers for the ensuing year:

President	-	-	-	-	-	G. C. Hewett.
First Vice-President						H. A. Lee.
Second Vice-President						A. G. Brownlee.
Treasurer	-	-	-	-	-	Geo. L. Cannon.
Secretary	-	-	-	-	-	E. N. Hawkins.
Corresponding Secretary and Librarian	-					A. W. Warwick

For members of the Executive Committee:

Geo. L. Cannon,	C. W. Comstock,
F. L. Clerc,	T. L. Wilkinson,
A. W. Warwick.	

Messrs. Wilkinson, Comstock and Hawkins were appointed a committee to arrange for the annual dinner.

ANNUAL MEETING.

December 20th, 1902.

In the Society Rooms, 421 Tabor Opera House Building.

President Irving Hale in the Chair.

There were seven members present.

The minutes of the last meeting were read and approved.

The President appointed Messrs. Comstock and Royer tellers to count the ballots for officers. The report showed the following

officers as receiving the highest number of votes, and they were declared elected:

President	-	-	-	-	G. C. Hewett.
First Vice-President	-	-	-	-	H. A. Lee.
Second Vice-President	-	-	-	-	A. G. Brownlee.
Treasurer	-	-	-	-	Geo. L. Cannon.
Secretary	-	-	-	-	E. N. Hawkins.
Corresponding Secretary and Librarian	-	-	-	-	A. W. Warwick.

Members of the Executive Committee:

Geo. L. Cannon,	C. W. Comstock,
F. L. Clerc,	T. L. Wilkinson,
A. W. Warwick.	

The Corresponding Secretary and Librarian read his annual report, which, upon motion, was ordered printed and to be distributed to the members.

At a meeting of the Committee of the Colorado Scientific Society appointed for the purpose of taking action upon the assassination of Mr. Arthur L. Collins at Telluride, it was unanimously resolved—

That in the death of Mr. Collins the Society has lost a pleasant companion, an able and valued member, and a brave and upright man;

That the Colorado Scientific Society, by its officers and proper committee, and through its members, wishes to express its abhorrence of, and opposition to, such practices of lawlessness as have led directly to the assassination of our friend and associate in this body;

That, it was further resolved, that the Colorado Scientific Society express to the widow and children of Mr. Collins its sincere sympathy with her and them in the loss of a kind husband and father and a courageous man, and that a copy of these resolutions be incorporated in the records and proceedings of the Society.

COMMITTEE.

REPORT OF THE CORRESPONDING SECRETARY
AND LIBRARIAN.

1899-1902.

In the years gone by it has been customary for the various officers of the Society to make a report at the annual meeting in December, and to that end I beg leave to give an account of that part of the Society's work which, by election, has fallen to my lot.

I will say, in the beginning, that heretofore I have not made a report at the annual meetings, and therefore I will extend this report to cover the three years during which I have been the Corresponding Secretary and Librarian of this Society.

I think I may be pardoned if I now and then overstep my bounds, for there are some things, not within my office, about which I wish to speak, and for that reason I do not wish it to appear that I have usurped any of the prerogatives of any of the other officers.

The Colorado Scientific Society was organized, informally, in the rooms of the U. S. Geological Survey, on December 8, 1882—twenty years ago—and Mr. S. F. Emmons was chosen President. There were twelve gentlemen present, and they became the charter members of the Society, and it may be of interest to the present members of the Society to know who the twelve original members were. They were—

Herman Beeger,

P. H. van Diest,

S. F. Emmons,

Whitman Cross,

Anton Eilers,

J. B. Grant,

Rev. H. Martyn-Hart,

W. F. Hillebrand,

Richard Pearce,

N. P. Hill,

A. H. Low,

A. von Schulz.

Of these, four have been elected to honorary membership:

Dr. Whitman Cross and W. F. Hillebrand, on April 6, 1896.

Prof. P. H. van Diest, on September 11, 1897, and S. F. Emmons, on May 3, 1902.

We are fortunate in having such a list of honorary members. By their attainments in scientific pursuits, and their long and ardent devotion to the best interests of this Society, they have well earned their title to such distinction, and they have, and are, still reflecting great honor on the Society.

J. B. Grant and Richard Pearce are still active members of twenty years' standing.

Rev. H. Martyn-Hart, A. H. Low, A. von Schulz and Anton Eilers are no longer members.

Death has claimed Herman Beeger and N. P. Hill.

The first regular meeting was held on January 2, 1893, at which seven new members were elected, and of these gentlemen, E. Le Neve Foster, Dr. Milton Moss and R. C. Hills still retain their active interest and membership in the Society.

The membership increased steadily until 1897, when it was at the highest figure—about 150.

In the last few years the Society has suffered by reason of a large number of resignations. Some members were dropped for non-payment of dues. Hence, our membership—active, associate and honorary—is, at the present time; 122.

The object of the Society, when organized, was the promoting of scientific intercourse, observation and record in the State of Colorado, and as a means for obtaining this end, besides the meetings, the reading and discussion of papers on scientific subjects and the publication of the same, there was to be a collection of scientific books and periodicals, which was to be the library of the Society.

This library has grown from a very small beginning until now it contains between 2,000 and 2,500 volumes and pamphlets. I may say, with perfect frankness, this library is not appreciated by the members of this Society. It is true that we, unfortunately, do not possess many of the latest scientific books, but on the shelves of this library are to be found the reports and proceedings of the most noted scientific institutions and societies of the world. We

have them from England, France, Russia, Germany, Canada, Mexico, Austria, Australia, Sweden, Belgium, Switzerland, Italy, Argentine Republic and Japan, besides a great many in our own country.

The first report of the Librarian was for the year 1887, and the library then contained 257 volumes and 137 pamphlets, or a total of 394. The number of exchanges then on the list was 37.

It is the pleasure and privilege of the Society now to exchange publications with 128 scientific institutions and societies, of which 40 are foreign, 2 in Mexico, 9 in Canada and 77 in the United States. During the past year a number of additional applications to be placed on our exchange list from foreign and domestic societies, have been received.

Many of the best books of reference, up to the last year, have been of but little use, for the reason that they lay on the shelves unbound. One finds it difficult and unpleasant to gather information or data from books in such condition. As a remedy for this, and also as a means of preserving valuable scientific periodicals, the library had some binding done. There is much binding yet to be done, and this should be kept up as the financial condition will permit. But a start has been made. We now have "The Bulletin of the Geological Society of America," volumes 1 to 11, inclusive, bound and volume 12 is in the bindery.

"Journal of Geology," volumes 2 to 8, inclusive, and volumes 1 and 9 being bound. Volume 1 was not bound, from the reason that No. 1 of volume 1 was missing, but within the past week No. 1 of volume 1 has been received, and volume 1 is now in the binder's hands.

"The Quarterly Journal of the Geological Society of London," with index; volume 30 (1874) to volume 55 (excepting volume 29, which is not in the library, and volume 28, unbound. Volume 56 is now being bound. Most of these periodicals were presented to the library by Mr. E. Le Neve Foster.

"The American Geologist," volumes 15 to 26, and volume 27 being bound.

Also, two volumes of the International Congress of Mines and Metallurgy, which was held in Paris in 1900, during the Exposition.

From this beginning it is to be hoped that some money will be set aside annually to go towards binding more of these valuable periodicals, now lying unbound in the library.

The Reports and Monographs of the U. S. Geological Survey are consulted a great deal. Of these annual reports we have 66 volumes, beginning with volume 1, in 1880. There are two volumes missing—volume 11, part 1, and volume 17, part 2. Of the Monographs, the list of 39 volumes is complete, excepting volumes 13, 14, 15 and 16. These, I believe, may be supplied. There are, also, in the library, a great number of the Geological Survey Bulletins. These are not bound.

The library has also added, during the past year, forty (40) boxes for the filing of the copies of papers which have been read before this Society, and also for filing our increased number of exchanges.

A few words about our own Proceedings: For the use of the library there are four volumes of volume 1, bound; all the unbound copies of volume 1 are gone. At some future time it may be advisable to get out a second edition of volume 1.

Volume 2 is in three parts, and there are only a few left.

Volume 3 is in three parts.

Volume 4 is in one volume.

Volume 5 is in one volume. Of the three last we have quite a number.

Volume 6 is in one volume, and has recently been distributed.

I have had a considerable number of inquiries for our Proceedings, both for exchange and sale. The volumes of the Proceedings have been sold to members at cost, and to non-members—as a protection to members—at double cost. I do not

believe that as an inducement for new members to enter the Society, that presenting them with a set of the Proceedings is right. They are obtaining for nothing that which they did not help create or maintain. I do not know of a single eastern engineering society—or, in fact, any such institution as ours—in which such practice prevails. A new member is entitled to the Proceedings from the date of his admission. Our Proceedings are valuable and are in demand, and from the sale of them a good sum will be derived besides valuable exchanges.

In the future the manner of issuing the Proceedings will show a saving to the Society. Formerly papers and discussions were printed directly after such papers had been read before the Society, and sent to each member and exchange. When two or three years had elapsed, and there were enough papers to make a volume, all these papers were reprinted and gathered into a volume. This proved to be a heavy burden for the Society, and an unnecessary one. To avoid this double expense, the papers are now printed but once. They are paged, and on the cover the number of the volume, part and pages are indicated. At the end of the year the abstracts of the meetings will be printed and distributed. In this way the members will have the abstracts of meetings and papers complete, and may bind them at their pleasure. A large number of our exchanges use this scheme, and it is a success. It is important, however, that the members should preserve the papers and bulletins if they wish later to have them bound.

The Society has on the reading table the following periodicals:

The Engineering and Mining Journal,
The Journal of Geology,
The Bulletin of the Geological Society of America,
The Quarterly Journal of the Geological Society of London,
The American Geologist,
The Journal of the Franklin Institute,
The Anglo-Colorado Mining and Milling Guide,
The Mining Reporter,

*The Australian Mining Standard,
The Electrical World and Engineer,
Mines and Minerals,
Science.*

For the kind, courteous and valuable assistance and advice in the management and work of the library of the Society, I wish to express my sincere thanks to Mr. E. Le Neve Foster, Mr. Charles W. Comstock and Mr. Willaim Mitchell.

The Society has had several temporary homes since its organization—the County Court House, the East Denver High School, the Boston Building, and these rooms we now have in the Tabor Opera House Building. Many of the out-of-town members have never seen our present quarters. We have here more space, and it is better adapted to our needs, I believe, than any rooms we have had. Our mineral cases were arranged to economize space, and so do not show to advantage. It is to be hoped that, in the near future, the Society may have a permanent home.

There has been more or less discussion as to the advisability of the several societies in Denver uniting to form one large association, but up to the present time nothing has been accomplished, nor is there much of a prospect for such union, as no one of the societies seems to relish the idea of losing its identity. The idea of this merger began in 1885, and has been revived from time to time.

During the summer of 1902, the annual meeting of the American Association for the Advancement of Science was held in Denver. Our Society, as a body, for financial reasons, did nothing for the entertainment of the members of this Association, but a number of the members of our Society, who are also members of this Association, took prominent parts in the various meetings.

In 1900 the Society permitted its valuable gold specimen to

be shown at the Paris Exposition. Some time after the Exposition closed, the Society received notice that it had been awarded a bronze medal and diploma, which arrived in due course.

This valuable gold specimen was presented to the Society by Mr. J. A. Porter, and was taken from the Smuggler-Union Mine at Telluride. It is in two large pieces, having been cut in two, to show the interior formation. While it was at the Paris Exposition it was insured for \$1,200.

Through the courtesy of Prof. P. H. van Diest, who visited the Paris Exposition, a number of interesting and valuable papers and pamphlets pertaining to the Exposition were presented to the Society.

During the year, prompted by the boom in oil at Boulder, a committee on the "Oil Industry in Colorado" was appointed to gather statistics for record for the Society. Difficulty in the matter of obtaining such data as would be of importance to the Society have been met with, but the committee will no doubt be able to present some valuable matter at a later date.

In 1900, after some discussion as to the feasibility of organizing different sections of the Society, a trial of a mechanical section was made. Four meetings were held. It was, unfortunately, found that the attendance was too small to justify the continuance of this section.

With this meeting—December 20th, 1902—there have been held, since January 2d, 1882, 190 regular meetings.

Since 1897, the record of meetings, attendance, papers, etc., is as follows:

<i>Year.</i>	<i>Meetings.</i>	<i>Av. Attendance.</i>	
1886.....	9.....	12	
1899.....	6.....	8	
1900.....	8 (*12)	11	*4 meetings in the Mechanical Section
1901.....	10.....	10	
1902.....	8.....	12	

<i>Year.</i>	<i>Members Elected.</i>	<i>Members Resigned.</i>
1898.....	5.....	Since 1899....18
1899.....	4	
1900.....	2	
1901.....	2	
1902.....	7	
	<hr/>	
Total.....	20	

<i>Year.</i>	<i>Papers.</i>
1898.....	10
1899.....	6 and two discussions.
1900.....	6 and one discussion in Mechanical Sec.
1901.....	9
1902.....	5 and two discussions.

NECROLOGY.

C. A. MARTINE,
Died June 24, 1900.

NATHANIEL P. HILL,
Died May 23, 1900.

CHARLES H. TOLL,
Died December 4, 1901.

HENRY FULTON,
Died December 6, 1901.

H. VAN F. FURMAN
Died April 28, 1902.

HENRY WILLIAMS,
Died July 8, 1902.

ARTHUR L. COLLINS,
Died November 21, 1902.

PETER H. VAN DEIST,
Died December 25, 1902.

HENRY A. VEZIN,
Died December 27, 1902.

Of the 122 members of the Society, there reside in Denver 58; in the State, but outside of Denver, 33; outside of Colorado,

25, and outside of the United States, 6. It will be noted that the average attendance at the meetings since 1897 is about 11—or nearly 20 per cent. of the Denver membership. Since 1898 we have elected 20 new members, and the resignations since 1899 have been 18. We have now, on account of death, resignations and those dropped for the non-payment of dues, a membership of 122.

In looking over the Proceedings of the Society for a number of years back, I could not help observing that the attendance at the meetings was much larger. In the early '90's the Secretary's minutes show the average attendance to have been between 25 and 30. The minutes show that the interest of the members in the welfare and prestige of the Society was keen; that possibly the position of the Society was stronger than now. Have conditions changed so much? Do the papers of volume 6 suffer in comparison with those of volumes 3, 4 or 5? Is it the fault of the officers, or is it that a spirit of general indifference prevails? Granting that one or several of these conditions exists, I believe that, for the vital interests of the Society, they should be met and overcome. The members, especially those outside of Denver, want something for the amount of their dues. A society whose average attendance is no more than ours, to say the least, is not inspiring.

There can be but one remedy for this general apathy which seems to have settled over the Society, and that is for each member to put his shoulder to the wheel; that each member, be he officer or not, attend the meetings and perform his duty as a member in all that the word implies.

THOMAS L. WILKINSON.

TREASURER'S REPORT FOR 1902.

RECEIPTS.

From Annual Dues	-	-	-	-	-	-	\$ 874.15
" Rent of Rooms	-	-	-	-	-	-	210.00
" H. A. Vezin, former Treasurer	-	-	-	-	-	-	301.17
" Sale of Publications	-	-	-	-	-	-	3.25
" Dinner Fees (1902)	-	-	-	-	-	-	100.00
							<u>\$1,488.57</u>

EXPENDITURES.

For Rent of Rooms	-	-	-	-	-	-	\$ 720.00
" Dinner (1902)	-	-	-	-	-	-	102.68
" Postage	-	-	-	-	-	-	40.00
" Stereopticon Work	-	-	-	-	-	-	5.00
" Boxes for Library	-	-	-	-	-	-	14.00
" Flowers	-	-	-	-	-	-	10.00
" Expressage	-	-	-	-	-	-	1.90
" Printing	-	-	-	-	-	-	610.42
" Sundries	-	-	-	-	-	-	9.03
							<u>\$1,513.03</u>
							1,488.57
Amount Due Treasurer	-	-	-	-	-	-	<u>\$24.46</u>

G. L. CANNON, *Treasurer.*

NECROLOGY.

NATHANIEL PETER HILL.

Nathaniel Peter Hill was one of the charter members of this Society. He was 68 years old at the time of his death—May 22, 1900. He was born in Orange County, New York, and spent his boyhood on a farm. He graduated from Brown University, and became an instructor in chemistry. Mr. Hill was one of the pioneers of Colorado. He took up mining at Black Hawk. Later he made his residence in Denver and was for years the head of the Boston and Colorado Smelting Company at Argo. He was also interested in other lines of business. Mr. Hill served one term in Congress as United States Senator from Colorado.

He was in active business up to his last illness, and was eminently successful in his mining and smelting ventures. He was a gentleman of wealth, refinement and culture.

HOWARD VAN FLEET FURMAN.

Howard van Fleet Furman, one of the Society's best known and respected members, and a mining engineer and metallurgist of national reputation, died on April 28, 1902, of pneumonia, at Mapimi, State of Durango, Mexico. He graduated from the Columbia School of Mines with honor in the class of '81, and at the time of his death was about 45 years of age. He came West in 1882, and entered the employ of the Globe Smelting and Re-

fining Company at Denver. He was later with the Germania Lead Works, in Utah, the Billings Smelter, Socorro, New Mexico, and the Bailey Smelter, Denver, all in an executive and metallurgical capacity.

From 1888 to 1894 he was the consulting engineer and metallurgist for several large concerns in the West and Southwest. In 1894 he became the chief assayer of the United States Mint at Denver, resigning in 1895 to accept the chair of Metallurgy in the Colorado State School of Mines at Golden. He resigned this position in 1897 to take up professional work again. He accompanied an expedition, which started from London in 1897, whose object was to obtain mining concessions from King Menelik of Abyssinia. This commission did not prove successful for many reasons. After returning to America he made a number of trips to Alaska and old Mexico in a professional capacity. In January, 1902, he accepted a flattering offer to go to Mexico and assume charge, as superintendent, of the smelting plant of the Compania Minera de Penoles, at Mapimi.

Previous to this appointment he had succeeded in treating the ores of this mine—a complex copper and gold ore—and, naturally, his services were appreciated and sought for.

His future appeared indeed bright, his work was congenial and to his liking, and his success at this mine was assured when, after only four months at Mapimi, he fell sick and died. He lies buried at Mapimi, far from wife, son and friends.

In his life he found time for literary work in his profession, his papers before this Society are several and are able and important. His "Manual of Assaying" is perhaps the best known of all the books on this subject.

Professor Furman was a genial, wholesouled gentleman. He was a worker, a constant student, a popular instructor and a good friend. By his death the Society has lost a valuable member. Besides many friends, his wife and son remain to mourn his death.

HENRY WILLIAMS.

Henry Williams was born in Cornwall, England, 62 years ago. He was educated at Probus, near Truro, Cornwall. At an early age he showed a strong inclination to study metallurgy. He took a course in chemistry at the mining school in Cornwall. Later on, with a view of obtaining a more advanced course in metallurgy, he went to Germany and took a course of instruction at Clausthal, under Kerl. After finishing his studies in Germany, he returned to England, and was appointed assayer at the well-known establishment of Henry Vivian & Sons, of Swansea, Wales. From the position of assayer, which he filled for some time with credit to himself and his employers, he was promoted to the management of a branch works of the company at Taibach, near Swansea. About the year 1866 he was sent by the firm of Vivian & Sons to Mexico, with headquarters at Mazatlan, as a representative of the firm, for the purchase of gold, silver and copper ores, for shipment to Swansea.

In 1872 he came to Colorado to take charge of a smelting plant that was started at what was then known as the Whale Mill, at Spanish Bar, near Idaho Springs. In 1875 he was appointed superintendent of the branch works of the Boston and Colorado Smelting Company, at Alma, in Park County, Colorado, which position he filled with satisfaction to the company until the plant closed, in 1878.

In the fall of 1878 he was sent to Montana to determine how far it was desirable to establish smelting works in that State, and after spending about two months in looking over the most promising fields, he decided to recommend the erection of a smelting plant at Butte. A company was at once organized, and in the spring of 1879 he went to Montana, secured a site for the smelter, and in the fall of that year the works were in operation, and con-

tinued under his management until they were sold to the Amalgamated Copper Company in 1899, when he retired.

Mr. Williams had shown signs of failing health for some years, hastened, perhaps, by too close application to business. The end came rather suddenly and was a shock to his intimate friends. He was a man of sterling honesty, and his career may be said to have been uniformly successful.

RICHARD PEARCE.

ARTHUR L. COLLINS.

Arthur L. Collins, general manager of the Smuggler-Union Mine at Telluride, was fatally shot by an unknown assassin on the night of November 19, 1902, and died two days later. The news of his death came as a great shock to his relatives and friends and to those who had watched the course of events at Telluride.

Mr. Collins was born July 8, 1868, at Truro, County of Cornwall, England. His father, Mr. J. H. Collins, is one of the prominent mining engineers of England, and his son's early education and training were guided by him.

Mr. Collins started out as a mining engineer quite young, and he had a large experience in many countries. He went to Spain, Norway, Asia, Africa and Australia before coming to the United States. He came to Colorado some ten years ago and took charge of the California Mining and Milling Company for the English owners. Besides this he had charge of various other mining interests. He became general manager of the Smuggler-Union properties in 1899. The sad manner of his death arouses feelings of sincere sympathy. He was a rising man in his profession, a man of much experience and travel, and, as he has

shown himself under the most trying circumstances, a brave, upright man, and the pity is that he should have been sacrificed to the conditions which prevailed.

PETER H. VAN DIEST.

One of the most distinguished members of the Colorado Scientific Society, and one of its charter members, has passed away since the last publication. Professor Peter H. van Diest, long regarded as the "father" of the Society, died very suddenly on Christmas morning, at the residence of his son; Edmond C. van Diest, at San Luis, Colorado.

Professor van Diest was born in Holland, in 1835, and was in his sixty-eighth year at the time of his death. He graduated in technical lines at the early age of nineteen, and four years later was sent to Java, in the employ of the Dutch government, in which he remained in several capacities for over fourteen years.

During a portion of this time he lived at Batavia, returning once to Holland, where he married. Appointed by the government to inspect the valuable tin mines of the island of Banca, off the coast of Sumatra, he remained there for a number of years, making a thorough geological and economic survey of the whole territory, and afterward publishing the results of his work in a volume which has received the honor of a translation into English. In this country all of the children surviving him were born.

As the result, however, of arduous work in the treacherous climate of the East Indies, his health at last gave way, and in 1872 he returned to Holland. It appears to have been so dangerous an attack that special permission had to be obtained for him to embark, as it was feared that he could not survive the voyage. At

this time he received the award of a life pension from the Dutch government. Had he been able to remain but two months longer in the East Indies he would have been entitled to the highest pension allowed under the regulations of Holland. As it was, he remained for life in receipt of this pension, which sufficiently marks the value and distinction of his scientific and technical career while in the Dutch colonies.

In 1872, after vainly seeking perfect restoration to his health by European travel, he came to the United States, Colorado being his first home here. Having secured a position in mining lines, he returned to Holland for his family, and for some time resided in Boulder, afterward in Custer County, in charge of various mining enterprises. His talent as a draughtsman and topographer secured him a position in the office of the U. S. Surveyor General, which he held for many years. During this period he lost his wife, a lady justly endeared to a large circle in Denver.

Although surviving, in his office, several changes of administration, Professor van Diest was at last replaced, under the system—a disgrace to our country—which sets at naught any talent or service not in the line of “politics.” During this period, however, his children had grown up and married, and he now took up his residence with his only living son, in San Luis. He was emphatically a domestic man, and was never so happy as when surrounded by his children and grandchildren. During the latter period of his life he twice visited Europe, and at the time of his death had just returned from a trip of several months’ duration, in Holland and France. Visiting in turn each and every one of his children, East and West, on his return, and just previous to his return to San Luis, once more attending a meeting of the Scientific Society which he had helped to establish so many years before, it seemed as though he were making a farewell visit to all that he loved, before taking the longer journey.

Few of the scientific men who have been members of the Colorado Scientific Society will be longer remembered than Pro-

fessor van Diest. Not only were his varied talents held in esteem, but he was perhaps the best known and the most universally liked of any of its members. Always genial, and with a never-failing fund of anecdote and reminiscence, he was welcomed alike in the Society and in the home. Not a member of the body of which he was so long, by common consent, considered as the father, that does not feel that a gap not to be filled has been made in its ranks.

Five of Professor van Diest's children survive him. Edmond C., a graduate of the Colorado School of Mines, was the only son, except one, who died in infancy in Boulder. The four daughters, all married, live, three in Colorado and one in Massachusetts. He was buried in Denver on the 28th of December, from the house of his daughter, Mrs. G. J. Rollandet.

HENRY A. VEZIN.

The dying year of 1902 records the death of another of the Society's well known and distinguished members—Henry A. Vezin—who died at Denver, December 27th, 1902.

Mr. Vezin was born in Philadelphia, Pennsylvania, 67 years ago, and at an early age went to Germany for his education. Mechanical and mining engineering, his profession, took him to various places on the Continent. He was considering a second trip to Russia to take a permanent position when he decided to come back to the United States. At the commencement of the civil war he joined the engineer corps and served throughout the war. He was mustered out with the rank of Captain and was breveted Lieutenant-Colonel. After the war he came west and located at Central City, Colorado, and engaged in mining engineering. He later was in Empire and Leadville, Colorado. In the late 80's he

came to Denver, where he opened an office and practiced his profession almost to the hour of his death.

His ability as an engineer was marked. The Vezin sampler, though never patented, will long remain a monument to his genius. He was a man of great resources. From the fact that he was a pioneer in the West, he had many difficult problems to solve in engineering, and this made him the careful, cautious, painstaking man he was. He was distinguished for his breadth of knowledge of his profession. He was tenacious; he would override all obstacles; all details were thoroughly cared for, and a subject once ended—was complete.

Mr. Vezin was a many-sided man. He was loyal to his friends and always a fair antagonist. He was a man of rather more than the average even temper. His generosity was one of his strongest traits; anything he possessed was at his friends' disposal; he was generous to a fault.

His long and eventful career in Colorado, his ability, sound judgment and experience in his profession, his generosity, straightforwardness and honesty endeared him to his friends and made him respected by those who did not have the pleasure of his acquaintance.

Mr. Vezin was for many years a member of this Society and for several years an officer. He gave up the office of Treasurer last year. Though not a frequent contributor, he was a constant attendant, and took a prominent part in discussion and in the policy of the Society.

He was also a member of several societies—the Engineers' Club of Philadelphia; the American Institute of Mining Engineers, and the North of England Institute of Mining Engineers. He was also a member of the Loyal Legion.

The places of such men as Mr. Vezin are hard to fill, and many never can be filled.

Mr. Vezin never married. He has no relative in the West,

but leaves a sister in Philadelphia and a brother in London. He was buried in Philadelphia.

Mr. Vezin was a gentleman, refined and upright; a credit to this Society, his friends and his country.

LIST OF MEMBERS.

- | | |
|------------------------------------------------------------------|------------------------------------------------------------------|
| Amy, E. J. H.,
care Amy & Co.,
44 Wall St., New York City. | Blake, J. C.,
University of Colorado,
Boulder, Colo. |
| Austin, W. L.,
P. O. Box 941,
Denver, Colo. | Brownlee, A. G.,
830 Penn. Ave.,
Denver, Colo. |
| Argall, Philip,
730 Majestic Bldg.,
Denver, Colo. | Campbell, Frank J.,
807 Penn. Ave.,
Denver, Colo. |
| Beals, William, Jr.,
20 Central St.,
Boston, Mass. | Carnahan, Chas. T.,
202 Equitable Bldg.,
Denver, Colo. |
| Beam, Thomas W.,
107 Boston Bldg.,
Denver, Colo. | Carpenter, Franklin R.,
918 Equitable Bldg.,
Denver, Colo. |
| Bellinger, H. P.,
care Solvay Process Co.,
Geddes, N. Y. | Cross, Whitman,
U. S. Geol. Survey,
Washington, D. C. |
| Bunce, Walter H.,
Room 10 Hess Block,
Ouray, Colo. | Cannon, Geo. L.,
East Denver High School,
Denver, Colo. |
| Ballou, Franklin,
Box 940
Denver, Colo. | Chauvenet, Regis,
1450 High St.,
Denver, Colo. |
| Brunton, D. W.,
Boston Bldg.,
Denver, Colo. | Coleman, Seymour,
700 Old Colony Bldg.,
Chicago, Illinois. |
| Baker, James H.,
University of Colorado,
Boulder, Colo. | Cress, Benjamin L.,
Red Cliff, Colo. |

- Comstock, Chas. W.,
76 Grant Ave.,
Denver, Colo.
- Callow, John M.,
Boston Cons. M. Co.,
808 Dooly Bldg.,
P. O. Box 57,
Salt Lake City, Utah.
- Carr, Louis B.,
Ouray, Colo.
- Clerc, F. L.,
Hotel Metropole,
Denver, Colo.
- Dickerman, Alton L.,
Colorado Springs, Colo.
- Daily, W. H.,
222 Sansome St.,
San Francisco, Cal.
- Davis, Wm. C.,
care F. M. Davis Iron Works Co.,
Denver, Colo.
- Dusedau, Wm.,
1732 Blake St.,
Denver, Colo.
- Dane, Edwin O.,
Hotel Broadway,
Denver, Colo.
- Edwards, J. W.,
P. O. Box 148,
Goldfield, Colo.
- Eakins, L. G.,
care American S. & R. Co.,
Pueblo, Colo.
- Foster, E. Le Neve,
2105 Lafayette St.,
Denver, Colo.
- Forrester, Robert,
Dooly Bldg.,
Salt Lake City, Utah.
- Farish John B.,
517 Cooper Bldg.,
Denver, Colo.
- Finch, John W.,
State Geologist,
Denver, Colo.
- Frost, O. J.,
Room 24 Jacobson Bldg.,
Denver, Colo.
- Freeland, Francis T.,
P. O. Box 1013,
Denver, Colo.
- Franklin, Nelson,
Victor, Colo.
- Frenzel, A. B.,
1540 Sherman Ave.,
Denver, Colo.
- Grant, J. B.,
8th and Penn. Ave.,
Denver, Colo.
- Goodale, C. W.,
Butte, Montana.
- Guggenheim, S.,
71 Broadway,
New York City.
- Garvin, C. J.,
223 20th Ave.,
Denver, Colo.

Gebhardt, Eugene W.,
School of Mines,
Golden, Colo.

Hack, E. Burton,
121 Boston Bldg.,
Denver, Colo.

Hardinge, Hal. W.,
1752 Curtis St.,
Denver, Colo.

Hillebrand, Dr. W. F.,
U. S. Geol. Survey,
Washington, D. C.

Hills, R. C.,
408 Boston Bldg.,
Denver, Colo.

Headden, Dr. Wm. P.,
Agricultural College,
Ft. Collins, Colo.

Hawkins, E. N.,
212 213 Colorado Bldg.,
Denver, Colo.

Hale, Irving,
1263 Columbine St.,
Denver, Colo.

Hanington, C. H.,
1080 Grant Ave.,
Denver, Colo.

Hill, Prof. L. C.,
State School of Mines,
Golden, Colo.

Holt, M. B.,
Silverton, Colo.

Harsh, Samuel A.,
Box 1057,
Helena, Montana.

Hurlburt, Geo. R.,
Ouray, Colo.

Hover, Wm. A.,
14th and Lawrence St.,
Denver, Colo.

Hallet, Hon. Moses,
P. O. Box 626,
Denver, Colo.

Hills, Victor G.,
423 E. Carr Ave.,
Cripple Creek, Colo.

Hall, Chas. B.,
Mexican Ore Co.,
Pachucha,
Estado Hidalgo, Mexico.
Apartado 94.

Harman, Jacob,
54 Locust Ave.,
New Rochelle, N. Y.

Hogarty, Barry,
Greeley, Colo.

Hewett, G. C.,
Colorado Springs, Colo.

Haldane, Wm. G.,
School of Mines,
Golden, Colo.

Jerome, John L.,
Boston, Bldg.,
Denver, Colo.

Johnston, Dr. Wm. A.,
2135 Downing Ave.,
Denver, Colo.

Kirby, E. B.,
Rossland, B. C.

Kountze, C. B.,
Colorado National Bank,
Denver, Colo.

Lawrence, B. B.,
56 Wall St.,
New York City, N. Y.

Livingstone, Chas. H.,
1234 Humboldt St.,
Denver, Colo.

Leffingwell, W. H.,
Lake City, Colo.

Lee, Harry A.,
Denver, Colo.

Lay, Henry C.,
Telluride, Colo.

Morse, Willard S.,
Agua Calientes, Mexico.
Apartado A.

Mentzel, Frederick,
Box 353.
Durango, Colo.

Moore, Chas. J.,
P. O. Box 548,
Cripple Creek, Colo.

Moss, Dr. Milton,
Huntsville, Alabama.

Macnutt, C. H.,
Pulacayo, Bolivia,
via Antofogusta, Chili.

Miller, D. A.,
Room 83 Equitable Bldg.,
Denver, Colo.

Minard, F. H.,
Equitable Bldg.,
Denver, Colo.

Mills, Wm. F. R.,
P. O. Box 1711,
Denver, Colo.

McClurg, James A.,
Majestic Bldg.,
Denver, Colo.

Moore, Willis G.,
1034 E. Platte Ave.,
Colorado Springs, Colo.

McNeill, John L.,
930 Logan Ave.,
Denver, Colo.

Newhouse, Edgar L.,
American S. & R. Co.,
71 Broadway
New York City.

Nesmith, John W.,
12th and Penn. Aves.,
Denver, Colo.

Olcott, Eben E.,
36 Wall St.,
New York City.

Porter, J. A.,
Denver Club,
Denver, Colo.

Palmer, Chas. S.,
School of Mines,
Golden, Colo.

Pearce, Richard,
1712 Sherman Ave.,
Denver, Colo.

Pearce, H. Vyvyan,
B. & C. Smelting Co.,
Denver, Colo.

Page, Wm. Byrd,
932 Equitabls Bldg.,
Denver, Colo.

Patton, H. B.,
State School of Mines,
Golden, Colo.

Penrose, Prof. R. A. F.,
400 Bullitt Bldg.,
Philadelphia, Pa.

Platt, E. H.,
1044 Grant Ave.,
Denver, Colo.

Pierce, Geo. W.,
McPhee Bldg.,
Denver, Colo.

Ricketts, L. D.,
Bisbee, Arizona.

Raht, August,
American S. & R. Co.,
Salt Lake City, Utah.

Royer, Frank W.,
4001 West 35th Ave.,
Denver, Colo.

Raymer, Geo. S.,
Rotch Bldg, Harvard University,
Cambridge, Mass.

Rickard, T. A.,
261 Broadway,
New York City.

Roeser, Fred.,
American S. & R. Co.,
Pueblo, Colo.

Rogers, Ed. M.,
Guggenheim Exploration Co.,
71 Broadway,
New York City.

Rogers, Henry T.,
Boston Bldg.,
Denver, Colo.

Sigel, Fred. L.,
2363 Stout St.,
Denver, Colo.

Sticht, Robert,
Mt. Lyell Mng. & Rail Co., Ltd.,
Queenstown, Tasmania.

Schwarz, T. E.,
Room 4 Bank Bldg.,
Denver, Colo.

Smith, Frank M.,
East Helena Smelter,
Helena, Montana.

Smith, Frank C.,
159 La Salle St.,
Chicago, Illinois.

Stockton, Robert S.,
State School of Mines,
Golden, Colo.

Stoddard, W. B.,
Boulder, Colo.

Stahl, J. H.,
1717 Pearl St.,
Boulder, Colo.

Tyler, S. W.,
1625 Franklin St.,
Denver, Colo.

Titsworth, Fred. S.,
202 Boston Bldg.,
Denver, Colo.

Tindall, Wm. F.,
1727 Stout St.,
Denver, Colo.

Underhill, James,
Box 67,
Idaho Springs, Colo.

van Diest, E. C.,
San Luis, Costilla Co., Colo.

Wittle, Wm.,
Rico, Colo.

Wolcott, Henry R.,
Boston Bldg.,
Denver, Colo.

Ward, Wm., S.,
Boston Bldg.,
Denver, Colo.

Wood, Henry E.,
1734 Arapahoe St.,
Denver, Colo.

Wuensch, A. F.,
1234 Corona St.,
Denver, Colo.

Wilson, J. H.,
Sheffield Sm. Co., Ltd.,
Sheffield, England.

Wilfley, A. R.,
2805 Humboldt St.,
Denver, Colo.

Woodward, E. C.,
28 E. Kiowa St.,
Colorado Springs, Colo.

Wilkinson, Thos. Lee,
Boston Bldg.,
Denver, Colo.

Wood, F. P.,
504 Charles Bldg.,
Denver, Colo.

Warwick, A. W.,
1919 Penn. Ave.,
Denver, Colo.

White, E. Lyman,
Bureau of Mines, State House,
Denver, Colo.

LIST OF EXCHANGES.

Academy of Natural Sciences of Philadelphia, Philadelphia, Pa.	Boston Society of Natural History, Berkeley St., Boston, Mass.
Academy of Science of St. Louis, St. Louis, Mo.	Buffalo Society of Natural Sciences, Buffalo, N. Y.
American Academy of Arts & Sciences, 1154 Boylston St., Boston, Mass.	British Museum (Natural History), London, England,
American Chemical Journal, Baltimore. Md.	Brookville Society of Natural History, Brookville, Ind.
American Geographical Society, 15 West 81st St., New York City, N. Y.	Bridgeport Scientific Society, Bridgeport, Conn.
American Philosophical Society, 104 South 5th St., Philadelphia, Pa.	Bibliotheque de L'Universite de Toulouse, Toulouse, France.
Akademie der Wissenschaften, Wien, Austria.	Canadian Institute, 58 Richmond St., East, Toronto, Ontario, Canada.
American Museum of Natural History, 77th St. and Central Park, west, New York City, N. Y.	California Academy of Sciences, San Francisco, Cal.
Australian Mining Standard, Broken Hill Chambers, 31 Queen St., Melbourne, Victoria, Australia.	Chemical Society, Burlington House, Piccadilly, W. London, England.
Australasian Institute of Mining Engineers, Colonial Mutual Chambers, Market St., Melbourne, Victoria, Australia.	Cincinnati Society of Natural History, 312 Broadway, Cincinnati, Ohio.
Australasian Association for the Advancement of Science, Sydney, N. S. W., Australia.	Colorado College Scientific Ass'n, Colorado Springs, Colo.
	California State Mining Bureau, 24 Fourth St., San Francisco, Cal.

- Chicago Academy of Sciences,
Chicago, Illinois.
- Carnegie Museum,
Pittsburg, Pa.
- Chemical and Metallurgical Society
of South Africa,
Box 4875, Johannesburg,
South Africa.
- Chicago Entomological Society,
701 Larrabee St.,
Chicago, Ill.
- Centro Nacional de Ingenieros,
Buenos Aires,
Argentine Republic, South America.
- Davenport Academy of Natural
Sciences,
Davenport, Iowa.
- Department of Mines of Nova Scotia,
Halifax, N. S.
- Department of Mines of New South
Wales. The Honorable the Minister
of Mines, Dept. of Mines,
Sydney, N. S. Wales,
Australia.
- Dr. R. W. Raymond, Sec'y A. I. M. E.,
16 Burling Slip,
New York City, N. Y.
- Elisha Mitchell Scientific Society,
Chapel Hill, N. C.
- Engineering and Mining Journal,
261 Broadway,
New York City, N. Y.
- Engineers' Society of Western Penna.,
410 Penn. Ave.,
Pittsburg, Pa.
- Entomologisk, Tids krift fran
Entomologiska Foreningen,
Stockholm, Sweden.
- Field Columbian Museum,
Chicago, Illinois.
- Franklin Institute,
Philadelphia, Pa.
- Geographical Society of California,
Academy of Science Bld.,
San Francisco, Cal.
- Geological Society of America,
Rochester, N. Y.
- Geological Survey of Canada,
Ottawa, Canada.
- Geological Society of Glasgow,
Glasgow, Scotland.
- Geological and Natural History
Survey of Minnesota,
care State University,
Minneapolis, Minn.
- Geological Survey of Illinois,
Springfield, Illinois.
- Geological Survey of Ohio,
Columbus, Ohio.
- Geological Survey of Louisiana,
Baton Rouge, La.
- Geographical Society of Philadelphia,
Philadelphia Pa.
- Hamilton Scientific Association,
Hamilton,
Ontario Canada.

Iowa Geological Survey, H. F. Bain, Asst. Geologist, Des Moines, Iowa.	Library, Bureau of Ethnology, Washington, D. C.
Iowa Academy of Science, Des Moines, Iowa.	Library of the Missouri Botanical Gardens, St. Louis, Mo.
Indiana Academy of Science, Brookville, Indiana.	Liverpool Geological Society, Liverpool, England.
Instituto Geologico de Mexico, Mexico, D. F.	Manchester Geological Society, Queen's Chambers, 5 John Dalton St., Manchester, England.
John Eyerman, Easton, Pa.	Manitoba Historical and Scientific Society, Winnipeg, Manitoba.
Kansas Academy of Science, Topeka, Kansas.	Massachusetts Inst. of Technology, Boston, Mass.
Kansas City Academy of Science, Kansas City, Mo.	Mining Reporter, Denver, Colo.
Kansas State Historical Society, Topeka, Kansas.	Minneapolis Academy of Natural Sciences, Minneapolis, Minn.
Kansas University, Lawrence, Kansas.	Museo Nacional, Montevideo, Uruguay, South America.
K.K. Naturhistorischen Hofmuseums, Wien, Austria	Museo Nacional, Rio de Janeiro, Brazil, South America.
Konigl, Bayer, Akademie der Wissenschaften, Munchen, Bavaria, Germany.	Museum of Comparative Zoology, Harvard College, Cambridge, Mass.
der Konigl, Bohm, Gesellschaft, Prag, Bohemia, Austro Hungary.	Maryland Geological Survey, care State Geologist, Johns Hopkins University, Baltimore, Md.
L'Academie Imperial des Sciences de St. Petersbourg, St. Petersbourg, Russia.	

Museo Nacional de Buenos Aires, Buenos Aires, Argentine Republic, S. A.	Ottawa Literary & Scientific Society, Ottawa, Canada.
Museum of Natural History, Springfield, Mass.	Philosophical Society of Glasgow, Glasgow, Scotland.
National Geographical Society, Washington, D. C.	Patent Office Library, 25 South Hampton Buildings, Chancery Lane, London, W. C., England.
Naturwissenschaftlichen Vereines fur Steiermark, Graz, Steiermark, Austro-Hungary.	Peabody Museum of American Archaeology and Ethnology, Cambridge, Mass.
Naturwissenschaftlichen Verein, fur Schwaben u Newburg, (A. V.) Augsburg, Germany.	Rassegna Della Scienze Geologiche in Italia. Rome, Italy.
New York Public Libraries, New York City, N. Y.	Rochester Academy of Science, Rochester, N. Y.
Naturwissenschaftlichen Vereins des Trencsiner Comitatos, Trencsen, Hungary.	Royal Geological Society, Cornwall, Penzance, England.
Naturforschenden Gesellschaft, Friburg im Baden, Germany.	Royal Geographical Society of Australasia, Brisbane, Queensland, Australia.
New York Academy of Sciences, New York City.	Royal Institution of Cornwall, Truro, Cornwall, England.
New York Microscopical Society, J. L. Zabriskie, Waverly Ave., Flatbush, L. I., N. Y.	Royal Society of New South Wales, 5 Elizabeth St., Sydney, N. S. Wales.
Nova Scotia Institute of Natural Sciences, Halifax, N. S.	Royal Society of Edinburgh, Edinburgh, Scotland.
Natural Association of Staten Island, New Brighton, S. I., N. Y.	R. University Library, for the Geological Institution, Upsala, Sweden.
Ohio State Archaeological and His- torical Society, Orton Hall, O. S. U., Columbus, Ohio.	State Library, State House, Denver, Colo.

- | | |
|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Santa Barbara Society of Natural History, Santa Barbara, Cal. | School of Mines,
Columbia University,
New York. |
| St. Gallischen Naturwissenschaftlichen Gesellschaft,
St. Gallen, Switzerland. | Smithsonian Institution,
Washington, D. C. |
| Seismological Institute, Imperial University, Tokyo, Japan. | State Experiment Station,
Baton Rouge, La. |
| Society of Arts, Mass. Institute of Technology, Boston, Mass. | State Geologist of New Jersey,
Trenton, New Jersey. |
| Societe des Naturalistes de Kieff,
Kieff, Russia. | State School of Mines,
Golden, Colo. |
| Societe de Geographie de Quebec,
Joliette, P. Q., Canada. | Societe des Sciences de Finland,
Helsingfors, Finland. |
| Societe Francaise de Mineralogie,
15 Rue des Saints Peres,
Paris, France. | Societe Scientifique de Chevtchenko
Eemberg, Austria. |
| Societe Geologique de France,
7 Rue des Grands,
Augustins, Paris, France. | Technical Society of the Pacific Coast,
31 Post St.,
San Francisco, Cal. |
| Societe Geologique de Belgique,
Liege, Belgium. | Texas Academy of Science,
Austin, Texas. |
| Societe Imperiale des Naturalistes de Moscow,
Moscow, Russia. | Tufts College Library,
Tufts College, Mass. |
| Societe Royale Malorologique de Belgique, 10 Rue de Pontneuf,
Bruxelles, Belgium. | The Philadelphia Museums,
233 S. Fourth St.,
Philadelphia, Pa. |
| Sociedad Cientifica "Antonio Alzate"
Mexico, D. F. | U. S. Geological Survey,
Washington, D. C. |
| Societe Vaudoise des Sciences Naturelles,
Lusanne, Switzerland. | U. S. National Museum,
Washington, D. C. |
| | University Extension Office,
Cor. 15th and Chestnut Sts.,
Philadelphia, Pa. |

LIST OF EXCHANGES.

li

University of Nebraska Library,
Lincoln, Neb.

Western Society of Engineers,
1736 Monadnock Block,
Chicago. Ill.

University of Chicago,
Press Division, Chicago, Ill.

Mining and Scientific Press,
333 Market St.,
San Francisco, Cal.

Wyoming Historical and Geological
Society,
Wilkes-Barre, Pa.

National Academy of Sciences,
Washington, D. C.

Wisconsin Academy of Sciences, Art
and Letters,
Madison, Wis.

McGill University Library,
Montreal, Canada.

ABSTRACT OF MINUTES—1903.

REPORT OF OFFICERS.

NECROLOGY.

LIST OF MEMBERS.

DENVER,
PUBLISHED BY THE SOCIETY
APRIL, 1904.

OFFICIAL PART.

ABSTRACT OF MINUTES

FOR THE YEAR 1903.

THE ONE HUNDRED AND NINETY-FIRST REGULAR MEETING.

January 3d, 1803.

In the Society Rooms, Tabor Opera House Building.

First Vice-President Lee in the Chair.

There were nine members present.

COMMUNICATIONS.—Informal communication by A. F. Wuensch on the "Arizpe Meteorite" found in Mexico, and Mr. Wuensch presented the specimen, 10 x 12 inches, to the collection.

THE ONE HUNDRED AND NINETY-SECOND REGULAR MEETING.

February 7th, 1903.

In the Society Rooms, Tabor Opera House Building.

First Vice-President Lee in the Chair.

There were twenty-two members present.

COMMUNICATIONS.—"Some Present Paradoxes in the Classification of the Chemical Elements," by Charles S. Palmer. The

address was accompanied by an exhibition of Prof. H. A. Rowland's "Standard Photographs of the Solar Spectrum."

Mr. G. C. Hewett presented to the collection a piece of leather found in an abandoned Mexican mine, and around it had been precipitated calcite, pyrite and blende, practically enclosing it.

Mr. Lee spoke of the new mineral—telluride of copper—which Dr. Louis Weiss had found in the Good Hope Mine, Vulcan, Colo.

THE ONE HUNDRED AND NINETY-THIRD REGULAR MEETING.

March 7th, 1903.

In the Society Rooms, Tabor Opera House Building.

First Vice-President Lee in the Chair.

There were seventeen members present.

COMMUNICATIONS.—"The Commercial Assay of Lead Ores,"
by A. W. Warwick.

THE ONE HUNDRED AND NINETY-FOURTH REGULAR MEETING.

April 4th, 1903.

In the Society Rooms, Chamber of Commerce Building.

The President in the Chair.

There were thirty-five members present.

COMMUNICATIONS.—"The Separation of Gold and Silver from

Copper in Mattes, with Particular Reference to Pyritic Smelting," by Dr. Franklin R. Carpenter."

"The Circulation of Underground Aqueous Solutions and the Deposition of Lode Ores," by John W. Finch.

Dr. Johnston presented a communication in the discussion of Mr. Warwick's paper on "The Commercial Assay of Lead Ores."

THE ONE HUNDRED AND NINETY-FIFTH REGULAR MEETING.

May 2d, 1903.

In the Society Rooms, Chamber of Commerce Building.

The President in the Chair.

There were thirty-three members present.

COMMUNICATIONS.—"The Development of Pseudomorphs," by H. B. Patton of Golden, and illustrated fully by handsome specimens.

"Refractometers and Some of Their Uses in Analytical Chemistry," by W. F. Edwards.

THE ONE HUNDRED AND NINETY-SIXTH REGULAR MEETING.

June 6th, 1903.

In the Society Rooms, Chamber of Commerce Building.

Past President Charles S. Palmer in the Chair.

There were thirty-one members present.

COMMUNICATIONS.—“The White Country Granite of West Sugar Loaf, or Bald Mountain, Boulder County, Colorado,” by D. Carl Henry.

THE ONE HUNDRED AND NINETY-SEVENTH REGULAR MEETING.

July 11th, 1903.

In the Society Rooms, Chamber of Commerce Building.

The President in the Chair.

There were thirty-seven members present.

THE ONE HUNDRED AND NINETY-EIGHTH REGULAR MEETING.

August 1st, 1903,

In the Society Rooms, Chamber of Commerce Building.

Second Vice-President Brownlee in the Chair.

There were twenty-six members present.

COMMUNICATIONS.—“The Contact, Quaquaversal, Nevada,” by Chester Wells Purington.

“Notes on the Santa Eulalia Mining District of Chihuahua, Mexico,” by Philip Argall.

THE ONE HUNDRED AND NINETY-NINTH REGULAR MEETING.

ABSTRACT OF MINUTES.

lvii

September 5th, 1903.

In the Society Rooms, Chamber of Commerce Building.

Second Vice-President Brownlee in the Chair.

There were twenty-six members present.

COMMUNICATIONS.—“The Fossil Woods of the Platte River Valley,” by George L. Cannon.

“Mineralogical Notes on Tellurium and Tellurides,” by Dr. Wm. P. Headden.

“Mica from Left Hand Creek, Boulder County,” by T. E. Schwarz.

THE TWO HUNDREDTH REGULAR MEETING.

October 3d, 1903.

In the Society Rooms, Chamber of Commerce Building.

The President in the Chair.

There were forty-four members present.

COMMUNICATIONS.—Address by The President upon the subject of the Society's growth.

THE TWO HUNDRED AND FIRST REGULAR MEETING.

November 7th, 1903.

In the Society Rooms, Chamber of Commerce Building.

First Vice-President Lee in the Chair.

There were twenty-seven members present.

COMMUNICATIONS.—“Mine Accounting,” by W. E. Humphreys.

THE TWO HUNDRED AND SECOND REGULAR MEETING.

December 4th, 1903.

In the Society Rooms, Chamber of Commerce Building.

First Vice-President Lee in the Chair.

There were thirty-six members present.

COMMUNICATIONS.—“The Care of Cyanide Solutions,” by W. H. Davis.

“The Economy of Mill Water,” by Jesse Scobey.

“Mine Gases,” by Harry A. Lee.



ABSTRACT OF MINUTES.

li

REPORT OF THE RECORDING SECRETARY FOR THE
YEAR ENDING DECEMBER 19TH, 1903.

I beg to submit you the following report of the progress of the Society for the twelve months just ended. At the beginning of 1903, the membership numbered 120, divided as follows: Resident, 54; non-resident, 63; honorary, 3.

During 1903, changes and additions were as follows:

	<i>Elected.</i>	<i>Deceased.</i>	<i>Resigned.</i>	<i>Dropped.</i>	<i>Present Membership.</i>
Resident.....	53.....	3.....	3.....		101
Non-resident ..	6.....		2.....	1.....	66
Honorary.....					3
Life	1.....				1

This is a total of 171, or an increase of 43 per cent. during the year. In addition to this number, the Executive Committee has elected five resident and one non-resident member, of which formal report will be made to the Society at its next regular meeting.

At the beginning of 1903, the Society determined to secure more commodious quarters than those it had been for several years occupying in the Tabor Opera House Building. During this period the Library and Collections had of necessity been so much stored away and ill-displayed that they had been of little or no use to the members, and had, in addition, become greatly disorganized. The move made April 1, 1903, to the present ample rooms has proved a great advance in the Society's growth and in the interest manifested by the members in its welfare. In addition, the Society has during this portion of 1903, had the financial advantage of being free from the expense of rent, after the expenditure of a sum sufficient to render these rooms comfortable.

The increase of membership during the past year has been the greatest the Society has known, and our progress has conclusively shown that the Society may continue to grow and expand

in a ratio directly proportioned to the zeal and energy of its members. The Executive Committee therefore feels confident that the membership list will exceed 250 during the coming year, and that the Society has before it the most prosperous period in its history.

With its more material growth, the advance of the Society has maintained a high standard of worth in its publications. During the year there were 14 original papers read before the Society by thirteen members; 8 informal communications contributed by as many members, and an address by the President. Of these, 9 of the papers and 4 of the informal communications have already been printed and distributed.

The meetings and attendance were as follows:

Number of regular monthly meetings held.	12
Total number of members present at all meetings .	341
Largest number present at any one meeting (October). .	44
Smallest number present at any one meeting (January) .	9
Average attendance at meetings.....	28

The executive officers of the Society are to be congratulated upon the extremely gratifying results of the united effort put forth during the year, and they feel that they have had the earnest co-operation of a great many of the Society's members. The economies accomplished in rents has permitted the Publication Committee the use of ample sums for printing, and we have also been able to have a custodian in constant daily charge of the Library and Collections. There is much yet to be done in improving these latter, so that they shall be of greater value for reference and study, and a great deal of this work is either actually under way or is projected.

Respectfully submitted,

EDWIN N. HAWKINS, Secretary.

REPORT OF THE CORRESPONDING SECRETARY
AND LIBRARIAN.

The Library of the Society is in better condition than it has been for some years. The removal of the Library to its present quarters has allowed a much better arrangement, and the books are now in an available situation. The generosity of General Palmer of Colorado Springs in binding all the transactions of societies, Government reports and journals, has been the means of putting the most valuable portion of our Library into such shape that it can be readily used. The Library is being catalogued and the work is now almost completed. The scientific method of cataloguing used by the U. S. Geological Survey has been adopted. The Executive Committee, by its action in providing a custodian for the Society's rooms, has made it possible to properly shelve and catalogue our Library.

The Library has received numerous gifts during the past year. Among these were:

General Palmer, binding of 250 volumes.

F. L. Clerc, *Engineering and Mining Journal*, volumes 40-52; *Engineering News and Railway Journal*, volumes 19-24.

A. G. Brownlee, *Encyclopedia Britannica*; *Century Dictionary*.

W. F. Edwards, *Proceedings of the American Association for the Advancement of Science*, 1884-1896, inclusive.

Amos Slater, *Transactions Federated Institute of Mining Engineers*, volumes 8-19, and parts 20, 22 and 23.

E. Le Neve Foster, *Quarterly Journal of the Geological Society*, London; *Reports of Juries of Award for Exhibition of London*, 1862; loan of full set of *Transactions American Institute of Mining Engineers*.

E. C. van Diest, 187 volumes from the library of the late P. H. van Diest.

W. F. R. Mills, full set bound volumes of *Mining Reporter*.

The Library has an excellent collection of transactions of various societies, as also Government Reports and Monographs. It is very weak in standard text books in every branch of science. If the Library is to be what it should be, a reference and working library, this defect must be made good as soon as possible. I would recommend that the Library room be fitted up, in course of time, as a reading room.

The Library has shared in the general advance made by the Society, and a very little more work, with a comparatively slight expenditure, will make the Library of real use to the members. There is no good scientific library that is available to our members, in the city or State, and the work which is now being done will no doubt eventually give the Society a good scientific and technical Library.

A. W. WARWICK,

Corresponding Secretary and Librarian.

TREASURER'S REPORT—JANUARY 1, 1903, TO JANUARY 1, 1904.

RECEIPTS.

Annual dues	\$1,584.00
Dinner and lunch fees	118.00
School of Mines prize fund.....	250.00
Rent of former rooms	20.00
Sale of publications.....	10.00
	<hr/> \$1,982.00

EXPENDITURES.

Printing.....	\$ 563.60
Custodian's salary	240.00
Rent of former rooms.....	180.00
Dinners and lunches	176.70
Expenses of moving	40.10
Repairs on furniture, etc.....	20.00
Repairs on new rooms, including electric fixtures.....	88.95
Insurance	31.00
Services of janitor, typewriter, etc.	23.80
Library	87.15
Periodicals	46.18
Postage	61.30
Stationery	10.50
Expressage	32.65
Electricity	13.10
Furniture, carpets and curtains	116.68
Framing pictures.....	13.60
	<hr/> \$1,745.31
Receipts	\$1,982.00
Expenditures.....	1,745.31
Balance	<hr/> \$ 236.69

It should be noted that, as the \$250 of the School of Mines Prize Fund is not available for the expenses of the Society, that the Society is indebted to its Treasurer for a slight excess of its expenditures over its receipts (\$13.31). In view of the importance of properly equipping our new rooms, and of taking advan-

tage of a great bargain in some valuable works for the Library, the Society felt warranted in slightly anticipating its income for the coming year. Examination of the above expenditures will show that the Society has added to its permanent equipment of books and furniture an increment of nearly four hundred dollars.

The saving on the rent of our rooms has enabled us to open our Museum and Library to the general public by the employment of a custodian, and will, during the coming year, enable us to make important additions to the equipment of both Library and Museum.

G. L. CANNON, Treasurer.

NECROLOGY.

WILLIAM H. JAMES.
1838—1903.

William H. James was born in Monmouthshire, England, in 1838, and died January 28, 1903, at his home in Denver, Colorado. For more than 40 years he was closely identified with the mineral development of the West; first in Colorado, then in Nevada, and afterward continuously in Colorado until the day of his death. In his long period of mining activity he gained experience which resulted in the establishment of the ore-smelting industry in Leadville, and later in Denver, in conjunction with James B. Grant and Edward Eddy, as the Omaha and Grant Smelting Company. Mr. James was superintendent of the plant until 1898, when it was taken over by the American Smelting and Refining Company. The annals of successful men which illustrate the value of perseverance, grit and hard work, contain no record more worthy or pronounced than the success of Mr. James. For many years he was a member of the Colorado Scientific Society.

JAMES LATHROP JEROME.
1854—1903.

The death of Mr. Jerome, November 21st, 1903, at his country home, Buffalo Park, Colorado, removed from our membership a kindly gentleman who had always taken a large interest in the affairs of the community. Since 1873 Mr. Jerome lived in Colorado, having moved here from New York State, where he had graduated the same year from Hamilton College. After two years

in Central City, in charge of schools, Mr. Jerome began the practice of law in Denver, and continued it until he joined in the promotion of the Colorado Fuel and Iron Company with John C. Osgood, A. C. Cass and J. A. Kebler, in 1893. Mr. Jerome was treasurer of the corporation until within a few months of his death. To those who knew him intimately his personality and friendship had a rare charm and value, and the community and State, as well as his friends, have sustained a great loss by his removal. Mr. Jerome's generous interest in everything affecting the community in which he lived induced him to become an associate member of the Colorado Scientific Society, in which he had many friends who esteemed and loved him.

FRANKLIN BALLOU.

Franklin Ballou, for many years a member of the Colorado Scientific Society, died of pneumonia on March 20th, 1903, at Palm Beach, Fla., whither he went from New York on March 1st. Mr. Ballou moved from Pittsburg to Colorado in the early 70's, locating at Georgetown, where he was interested in mining and milling until 1879. He then went to Leadville, where he mined and operated a sampling works for several years. In the early 80's he assisted in organizing the Bi-Metallic Smelter, afterwards serving as vice-president and general manager until it was transferred to the American Smelting and Refining Company a few years ago. Mr. Ballou was recognized as one of the leading metallurgists of the State, and was highly respected by the miners and his associates in business, while those of the Society who have had a closer filiation feel that they have lost a true friend. He leaves a widow, daughter and two sons.

LIST OF MEMBERS.

Adams, Willber E.,
1619 Emerson St.,
Denver, Colo.

Alderson, Victor C.,
School of Mines,
Golden, Colo.

Alexander, Geo. E.,
1653 Welton St.,
Denver, Colo.

Amy, E. J. H.,
care Amy & Co.,
44 Wall St., New York City.

Argall, Philip,
730 Majestic Bldg.,
Denver, Colo.

Austin, W. L.,
P. O. Box 941,
Denver, Colo.

Beam, Thomas W.,
310 Colorado Bldg.,
Denver, Colo.

Bellinger, H. P.,
Care Solvay Process Co.,
Geddes, N. Y.

Bunce, Walter H.,
Room 10 Hess Block,
Ouray, Colo.

Brunton, D. W.,
Boston Bldg.,
Denver, Colo.

Blake, J. C.,
Mass Inst. of Tech.,
Boston, Mass.

Brownlee, A. G.,
314 Colo. Bldg.,
Denver, Colo.

Buttolph, E. K.,
11th Avenue Hotel,
Denver, Colo.

Bethel, E.,
West Denver High School,
Denver, Colo.

Bonnevie, N. C.,
17 Jacobson Bldg.,
Denver, Colo.

Boehmer, Max,
42 Jacobson Bldg.,
Denver, Colo.

Walter C. Brace,
710 Equitable Bldg.,
Denver, Colo.

Campbell, Frank J.,
807 Penn. Ave.,
Denver, Colo.

Carnahan, Chas. T.,
202 Equitable Bldg.,
Denver, Colo.

Carpenter, Franklin R.,
1420 Josephine,
Denver, Colo.

Crosadale, Stuart,
1574 York St.,
Denver, Colo.

Cross, Whitman,
U. S. Geol. Survey,
Washington, D. C.

Cannon, Geo. L.,
East Denver High School,
Denver, Colo.

Chauvenet, Regis,
937 Equitable Bldg.,
Denver, Colo.

- Coleman, Seymour,
700 Old Colony Bldg.,
Chicago, Illinois.
- Cress, Benjamin L.,
Red Cliff, Colo.
- Collins, George E.,
217 Boston Bldg.,
Denver, Colo.
- Clark, Geo. B.,
573 S. Washington Ave.,
Denver, Colo.
- Comstock, Chas. W.,
76 Grant Ave.,
Denver, Colo.
- Callow, John M.,
608 Dooly Bldg.,
Salt Lake City, Utah.
- Carr, Louis B.,
P. O. Box 707,
Pueblo, Colo.
- Clerc, F. L.,
Hotel Metropole,
Denver, Colo.
- Geo. S. Clason,
315 Colo. Bldg.,
Denver, Colo.
- Curtis, Arthur R.,
Golden, Colo.
- Dickerman, Alton L.,
Colorado Springs, Colo.
- Daily, W. H.,
222 Sansome St.,
San Francisco, Cal.
- Davis, Wm. C.,
care F. M. Davis Iron Wks. Co.,
Denver, Colo.
- Doolittle, Chas. H.,
Utah & Eastern Copper Co.
St. George, Utah.
- Dusedau, Wm.,
1717 Arapahoe St.,
Denver, Colo.
- Daue, Edwin O.,
Hotel Broadway,
Denver, Colo.
- Doveton, Godfrey D.,
319 Majestic Bldg.,
Denver, Colo.
- Edwards, W. F.,
14 Nevada Bldg.,
Denver, Colo.
- Emmons, S. F.,
U. S. Geol. Survey,
Washington, D. C.
- Edwards, J. W.,
1420 S. 15th St.,
Denver, Colo.
- Eakins, L. G.,
care American S. & R. Co.,
Denver, Colo.
- Evans, Geo. H.,
Breckenridge, Colo.
- Foster, E. Le Neve,
2105 Lafayette St.,
Denver, Colo.
- Fallis, M. S.,
311 Colorado Bldg.,
Denver, Colo.
- Forrester, Robert,
Dooly Bldg.,
Salt Lake City, Utah.
- Farish, John B.,
517 Cooper Bldg.,
Denver, Colo.

Finch, John W.,
Jacobson Bldg.,
Denver, Colo.

Frost, O. J.,
1752 Champa,
Denver, Colo.

Freeland, Francis T.,
P. O. Box 1016,
Aspen, Colo.

Franklin, Nelson,
Victor, Colo.

Frenzel, A. B.,
1540 Sherman Ave.,
Denver, Colo.

Fellows, A. L.,
Chamber of Commerce,
Denver, Colo.

Grant, J. B.,
8th and Penn. Ave.,
Denver, Colo.

Goodale, C. W.,
Butte, Montana.

Garvin C. J.,
1761 Washington Ave.,
Denver, Colo.

Gebhardt, Eugene W.,
9 Lena Ave.,
Cleveland, Ohio.

Guggenheim, S.,
71 Broadway,
New York City.

George, R. D.,
State University,
Boulder, Colo.

Holt, M. B.,
Silverton, Colo.

D. Carl Henry,
Anaconda, Mont.

Barton-Hack, E.,
107 Boston Bldg.,
Denver, Colo.

Hardinge, Hal. W.,
827 Ernest & Cramner Bld.,
Denver, Colo.

Hillebrand, Dr. W. F.,
U. S. Geol. Survey,
Washington, D. C.

Hills, R. C.,
408 Boston Bldg.,
Denver, Colo.

Headden, Dr. Wm. P.,
Agricultural College,
Fort Collins, Colo.

Hawkins, E. N.,
312-313 Colorado Bldg.,
Denver, Colo.

Hale, Irving,
1263 Columbine St.,
Denver, Colo.

Hanington, C. H.,
1080 Grant Ave.,
Denver, Colo.

Hill, L. C.,
Livingstone, Ariz.

Harsh, Samuel A.,
Box 910,
Denver, Colo.

Hodson, L. C.,
Lead, So. Dak.

Hodgson, Arthur R.,
U. S. Mint,
Denver, Colo.

Hover, Wm. A.,
14th and Lawrence Sts.,
Denver, Colo.

Hallett, Hon. Moses,
P. O. Box 626,
Denver, Colo.

Hills, Victor G.,
423 E. Carr Ave.,
Cripple Creek, Colo.

Harman, Jacob,
54 Locust Ave.,
New Rochelle, N. Y.

Hogarty, Barry,
Pueblo Plant Am S & R Co.,
Pueblo, Colo.

Hewett, G. C.,
Colorado Springs, Colo.

Haldane, Wm. G.,
School of Mines,
Golden, Colo.

House, Mrs. B. F.
Grantsville, Utah.

Humphreys, Wm. E.
310 Colo. Bldg.,
Denver, Colo.

Hurlburt, Geo. R.,
Ouray, Colo.

Haynes, Justin H.,
323 Boston Bldg.,
Denver, Colo.

Hyder, Frederick B.,
3337 W. 33d Ave.,
Denver, Colo.

Hampson, C. M.,
2098 Ogden,
Denver, Colo.

Johnston, Dr. Wm. A.,
2135 Downing Ave.,
Denver, Colo.

James, George D.,
519 Mining Exchange,
Denver, Colo.

James, Harry C.,
685 Emerson St.,
Denver, Colo.

Josephl, S. A.,
215 McPhee Bldg.,
Denver, Colo.

Keener, Geo. L.,
care Mary McKinney M. Cr
Anaconda, Colo.

King, W. G.,
School of Mines,
Butte, Mont.

Kountze, C. B.,
Colorado National Bank,
Denver, Colo.

Kurie, Frank M.,
Portland Mine,
Victor, Colo.

Kirby, E. B.,
Rossland, B. C.

Kyle, Thos. D.,
Leadville, Colo.

Kein, Ed. T.,
151 W. 2nd Ave.,
Denver, Colo.

Lakes, A.,
32 Barth Block,
Denver, Colo.

Lawrence, B. B.,
56 Wall St.,
New York City, N. Y.

Langley, Jno. C.,
Bureau Mines, State Capitol,
Denver, Colo.

Livingstone, Chas. H.,
1234 Humboldt St.,
Denver, Colo.

MEMBERSHIP.

lxxi

Leffingwell, W. H.,
Lake City, Colo.

Lee, Harry A.,
McPhee Bldg.,
Denver, Colo.

Lay, Henry C.,
Telluride, Colo.

Henry P. Lowe,
P. O. Box 285,
Denver, Colo.

Loftus, J. P.,
1824 Curtis St.,
Denver, Colo.

Morse, Willard S.,
Apartado A Aguascalientes,
Mexico.

Mentzel, Frederick,
Box 353,
Durango, Colo.

Moore, Chas. J.,
612 Kittredge Bldg.,
Denver, Colo.

Moss, Dr. Milton,
Huntsville, Alabama.

Macnutt, C. H.,
Pulacayo, Bolivia,
via Antofagasta, Chili.

Miller, D. A.,
Room 83 Equitable Bldg.,
Denver, Colo.

Mathez, Auguste,
403 Cooper Bldg.,
Denver, Colo.

Minard, F. H.,
Equitable Bldg.,
Denver, Colo.

Mills, Wm. F. R.,
P. O. Box 1711,
Denver, Colo

McClurg, James A.,
Majestic Bldg.,
Denver, Colo.

Moore, Willis G.,
1034 E. Platte Ave.,
Colorado Springs, Colo.

Mines and Minerals,
Scranton, Pa.

Mitchell, Wm. G.,
Breckenridge, Colo.

McNeil John L.,
930 Logan Ave.,
Denver, Colo.

McElvenny, Robt. F.,
Washington, D. C.

McReynolds, Orval O.,
709 Equitable Bldg.,
Denver, Colo.

Newhouse, Edgar L.,
American S. & R. Co.,
71 Broadway,
New York City.

Nesmith, John W.,
12th and Penn. Aves.,
Denver, Colo.

Norman, Jno. E.,
1343 High St.,
Denver, Colo.

Olcott, Eben E.,
36 Wall St.,
New York City.

Porter, J. A.,
Denver Club,
Denver, Colo.

Pearce, Richard,
1712 Sherman Ave.,
Denver, Colo.

Pearce, H. Vyvyan,
B. & C. Smelting Co.,
Argo, Colo.

Page, Wm. Byrd,
932 Equitable Bldg.,
Denver, Colo.

Palmer, Wm. J.,
Colorado Springs.

Patton, H. B.,
State School of Mines,
Golden, Colo.

Penrose, Prof. R. A. F.,
400 Bullitt Bldg.,
Philadelphia, Pa.

Platt, E. H.,
Denver Eng. Wks. Co.,
Denver, Colo.

Peirce, Geo. W.,
McPhee Bldg.,
Denver, Colo.

Parmelee, H. C.,
1755 Arapahoe St.,
Denver, Colo.

Purinton, Chester W.,
319 Majestic Bldg.
Denver, Colo.

Paul, Russel B.,
Box 596,
Denver, Colo.

Ricketts, L. D.,
Bisbee, Arizona.

Royer, Frank W.,
4001 West 35th Ave.,
Denver, Colo.

Raymer, Geo. S.,
Rotch Bld, Harvard University
Cambridge, Mass.

Roeser, Fred,
American S. & R. Co.,
Pueblo, Colo.

Rogers, Ed. M.,
32 Broadway,
New York City.

Rhodes, Jr., Nelson,
404-7 Tabor Bldg.,
Denver, Colo.

Richards, Jno. W.,
1732 Champa St.,
Denver, Colo.

Sigel, Fred. L.,
2363 Stout St.,
Denver, Colo.

Sticht, Robert,
Mt Lyell Mng & Rail Co, Ltd
Queenstown, Tasmania.

Schwarz, T. E.,
Colorado Bldg.,
Denver, Colo.

W. G. Swart,
225 So. Washington Ave.,
Denver, Colo.

Scobey, Jesse C.
Altamaha Apartments,
Denver, Colo.

Slater, Amos,
408 Boston Bldg.,
Denver, Colo.

Smith, Frank M.,
East Helena Smelter,
Helena, Montana.

Sprague, E. M.,
405 Jackson Bldg.,
Denver, Colo.

Stockton, Robert S.,
Geol. Sur., Cham. of Com.,
Denver, Colo.

Stoddard, W. B.,
Boulder, Colo.

Stahl, J. H.,
1717 Pearl St.,
Boulder, Colo.

Smith, Harry C.,
1049 Pearl St.,
Denver, Colo.

Stott, J. B.,
3263 Perry St.,
Denver, Colo.

Smith, Thos. G.,
Care C. J. Adams,
Butte, Mont.

Schneider, Geo. W.,
S. 135 Logan Ave.,
Denver, Colo.

Stover, Geo. Henry, M. D.,
1443 Glenarm St.,
Denver, Colo.

Traphagen, Frank W.,
School of Mines,
Golden, Colo.

Tindall, Wm. F.,
1727 Stout St.,
Denver, Colo.

Tyler, S. W.,
1625 Franklin St.,
Denver, Colo.

Titworth, Fred S.,
202 Boston Bldg.,
Denver, Colo.

Underhill, James, Box 67,
Idaho Springs, Colo.

van Diest, E. C.,
P. O. Box 826,
Colorado Springs, Colo.

Van Cortlandt, E. N.,
305 Cooper Bldg.,
Denver, Colo.

Vail, Guy M.,
2646 Lafayette St.,
Denver, Colo.

Warwick, A. W.,
Club Bldg.,
Denver, Colo.

White, E. Lyman,
Bureau of Mines, State House,
Denver, Colo.

Wittle, Wm.,
Rico, Colo.

Wolcott, Henry R.,
Boston Bldg.,
Denver, Colo.

Ward, Wm. S.,
Boston Bldg.,
Denver, Colo.

Wood, Henry E.,
1734 Arapahoe St.,
Denver, Colo.

Wuenssch, A. F.,
1234 Corona St.,
Denver, Colo.

Wilson, J. H.,
Sheffield Sm. Co., Ltd.,
Sheffield, England.

Wilfey, A. R.,
2805 Humboldt St.,
Denver, Colo.

Woodward, E. C.,
26 E. Kiowa St.,
Colorado Springs, Colo.

Wilkinson, Thos. Lee,
Boston Bldg.,
Denver, Colo.

Wood, F. P.,
504 Charles Bldg.,
Denver, Colo.

Weiss, Dr. Loui,
Del Norte, Colo.

Williams, Fred T.,
Box 248,
Victor, Colo.

Watts, Alfred C.,
116 E. 11th Ave.,
Denver, Colo.

Young, L. E.,
School of Mines,
Golden, Colo.

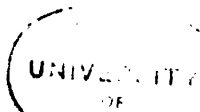
PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. VII, PP. LXXV-XC

VII

ABSTRACT OF MINUTES—1904.

REPORTS OF OFFICERS.

DENVER,
PUBLISHED BY THE SOCIETY
APRIL, 1905



OFFICIAL PART.

ABSTRACT OF MINUTES.

FOR THE YEAR 1904.

THE TWENTY-FIRST ANNUAL MEETING.

December 21, 1903.

In the Society Rooms, Chamber of Commerce Building.

President G. C. Hewett in the Chair.

There were seventeen members present.

The following officers for the year 1904 were declared elected:

President	Harry A. Lee.
First Vice-President,	A. G. Brownlee.
Second Vice-President,	Philip Argall.
Treasurer,	Geo. L. Cannon.
Secretary,	Edwin N. Hawkins.
Cor. Sec. and Librarian,	Amos Slater.

EXECUTIVE COMMITTEE.

Geo. L. Cannon,	Wm. A. Johnston,
Charles W. Comstock,	W. F. Edwards,
Stuart Croasdale.	

The reports of the Secretary, Treasurer and Corresponding Secretary and Librarian were presented and ordered printed.

Several matters of interest to the welfare and growth of the Society were discussed, after which the meeting adjourned.

THE TWO HUNDRED AND THIRD REGULAR MEETING.

January 16, 1904.

In the Society Rooms, Chamber of Commerce Building.

President Lee in the Chair.

There were thirty-one members present.

The Executive Committee reported the election of the following gentlemen to active membership: Max Boehmer, Denver, Colo.; R. D. George, Boulder, Colo.; J. H. Haynes, Denver, Colo.; F. B. Hyder, Denver, Colo.; T. D. Kyle, Leadville, Colo.; O. O. McReynolds, Denver, Colo.; A. C. Watts, Denver, Colo.

The Lead Committee reported progress.

Arrangements for Dr. Hammer's lecture on Radium were inaugurated to be given under the auspices of the Society.

COMMUNICATIONS.—Discussion on Mr. Lee's paper, "Mine Gas," by Mr. Traphagen. This discussion was also joined in by Messrs. Edwards and Warwick.

THE TWO HUNDRED AND FOURTH REGULAR MEETING.

February 6, 1904.

In the Society Rooms, Chamber of Commerce Building.

President Lee in the Chair.

There were thirty-four members present.

The Executive Committee reported that it was in communication with Mr. Hammer and that the lecture would probably be given the last of February.

The Lead Committee did not report.

COMMUNICATIONS.—Mr. H. C. Parmelee exhibited a number of radiographs and explained in detail the method of exposure. Mr. Traphagen also showed some radiographs he had taken and described them. Dr. Richard Pearce made a few remarks on Pitch Blende and referred to a former paper of the Proceedings on the subject. Mr. Schneider also mentioned his experience with Pitch Blendes in Gilpin County, Colo.

THE TWO HUNDRED AND FIFTH REGULAR MEETING.

March 5, 1904.

In the Society Rooms, Chamber of Commerce Building.

President Lee in the Chair.

There were twenty-six members present.

The lecture on Radium was given by Mr. Hammer under the auspices of the Society, on Feb. 26, and was successful. Treasurer Cannon reported that the Society cleared about \$115.00. A committee was appointed to select a list of periodicals for the Society, to be on the reading table, and report at the next meeting.

COMMUNICATIONS.—Dr. Franklin R. Carpenter presented a paper, "New Geology and Vein Formation." This paper was discussed by Messrs. George, Headden and Brunton.

THE TWO HUNDRED AND SIXTH REGULAR MEETING.

April 2, 1904.

In the Society Rooms, Chamber of Commerce Building.

President Lee in the Chair.

There were twenty-six members present.

The Committee on the selection of periodicals for the Library presented the following list:

Journal of the Society of Chemical Industry, London.

Chemical News, London.

Engineering News.

American Naturalist.

Electrical Review.

School of Mines Quarterly, Columbia College.

Technical Quarterly.

Dingler's Polytechnic Journal, Berlin.

Annals de Chimie et de Physique, Paris.

Quarterly Journal Microscopical Society, London.

On motion it was decided to get out a booklet with the Constitution and By-Laws, with a list of members.

COMMUNICATIONS.—Discussion of Dr. Carpenter's paper of the previous meeting by Messrs. C. J. Moore, Cannon and Loftus.

"Progress of Gold Mining in Kalgoorlie, Western Australia, in 1903," was given by Mr. E. Barton-Hack.

THE TWO HUNDRED AND SEVENTH REGULAR MEETING.

May 7, 1904.

In the Society Rooms, Chamber of Commerce Building.

Second Vice-President Argall in the Chair.

There were twenty-six members present.

The Executive Committee reported the election of Mr. Mark G. Evans to active membership.

A letter was read from the Secretary of State, which in substance was that upon inquiry he ruled that the Charter of the Society was perpetual. Letter filed.

COMMUNICATIONS.—Further discussion of Dr. Carpenter's paper on "The New Geology" by Messrs. Moore, Finch and Lakes.

A paper by Mr. W. F. Edwards on "Some Notes on Vanadium." His paper was informally discussed by Messrs. Lakes, Comstock, Moore, Slater, Brace, Finch, Fleck and Cannon.

The Secretary reported the gift of fifty-two numbers of the *Engineering and Mining Journal* by Mr. Clerc.

THE TWO HUNDRED AND EIGHTH REGULAR MEETING.

June 4, 1904.

In the Society Rooms, Chamber of Commerce Building.

The new rules of the Executive Committee regarding the withdrawal of books from the library were presented as follows:

1. Books may be issued only by the Custodian in charge, who will make a record of each book issued, together with the name and address of the person withdrawing the book.

2. No person may have more than two books out of the library at any one time.

3. A book may be retained one week, and may be renewed for one week, if not in demand by others. It may not be again withdrawn by the same person until two weeks after its return.

4. A fine of five cents will be collected for each time a book is retained beyond the allowed time.

5. When a book has been retained one week beyond the allowed time the holder shall be notified by the Custodian.

6. After two weeks of delinquency a messenger will be sent for the book and a messenger fee of twenty-five cents, in addition to the above mentioned fine, will be charged to the delinquents.

7. Failure to pay fines or to comply with any of the Library rules will subject the offender to forfeiture of Library privileges.

8. The Custodian may refuse to issue books which are either rare, valuable or difficult of replacement.

COMMUNICATIONS.—None.

THE TWO HUNDRED AND NINTH REGULAR MEETING.

July 2, 1904.

In the Society Rooms, Chamber of Commerce Building.

Past President Regis Chauvenet in the Chair.

There were sixteen members present.

The Secretary reported the following gifts to the Society: A rare old volume of Philosophy by Mr. R. C. Hills, a mumified bug, found in a piece of Marshall coal, by Mr. Clark.

COMMUNICATIONS.—Mr. Charles W. Comstock presented a paper on "Hoisting in Deep Shafts." Mr. Collins and Mr. Wilkinson briefly discussed the paper informally.

THE TWO HUNDRED AND TENTH REGULAR MEETING.

August 6, 1904.

In the Society Rooms, Chamber of Commerce Building.

First Vice-President Brownlee in the Chair.

There were twelve persons present.

The Lead Committee reported that all the samples, with one or two exceptions, had been collected and that four samples had

been sent to each of fifteen chemists and assayers. Mr. W. A. Hover kindly presented all the sample bottles needed.

COMMUNICATIONS.—Dr. F. R. Carpenter presented a paper, "A Contribution to the Planetesimal Theory."

THE TWO HUNDRED AND ELEVENTH REGULAR MEETING.

September 3, 1904.

In the Society Rooms, Chamber of Commerce Building.

Past President Cannon in the Chair.

There were twenty members present.

The Executive Committee reported the election to active membership of Roscoe C. Blake, of Idaho Springs, and to associate membership of Carlton M. Bliss, of Denver.

The Lead Committee reported that the work of distributing the samples was in progress.

COMMUNICATIONS.—Mr. F. C. Bowman presented a paper on "An Oil Burning Assay Furnace."

THE TWO HUNDRED AND TWELFTH REGULAR MEETING,

October 1, 1904.

In the Society Rooms, Chamber of Commerce Building.

Past President Cannon in the Chair.

There were twenty-two members present.

The Lead Committee reported that new samples had been distributed and some results had been received.

The subject of the housing of the several societies under one roof was again brought up and discussed. The possibility of securing quarters in the Colorado Museum Association (Carter Museum) in City Park, was talked over. The facts were later brought out that the Colorado Museum Association was not in a position at this time to make any proposition to the Society.

COMMUNICATIONS.—Discussion of the "New Geology" led by Mr. Geo. L. Cannon and Prof. R. D. George. Messrs. Carpenter and Comstock also took part in the discussion.

Prof. George's comments were along the lines of Prof. Chamberlain's work.

THE TWO HUNDRED AND THIRTEENTH REGULAR MEETING.

November 5, 1904.

In the Society Rooms, Chamber of Commerce Building.

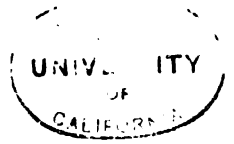
Past President G. C. Hewett in the Chair.

Twenty-two members were present.

Neither the Executive nor the Lead Committee had anything to report.

Since the last meeting the rooms had been changed from the third to the second floor.

COMMUNICATIONS.—A paper by Mr. Geo. L. Cannon on "The Drift Apron of the Front Range."



ABSTRACT OF MINUTES.

lxxxiii

THE TWO HUNDRED AND FOURTEENTH REGULAR MEETING.

December 3, 1904.

In the Society Rooms, Chamber of Commerce Building.

President Lee in the Chair.

There were twenty-five members present.

The Executive Committee reported the election to active membership of Frederick H. Morley.

On motion the Chair appointed a committee of three members, consisting of Messrs. Wilkinson, Clerc and Beam on nomination of officers for the ensuing year.

This committee, later in the evening reported the following names:

President,	A. G. Brownlee.
First Vice-President,	Philip Argall.
Second Vice-President,	T. E. Schwarz.
Secretary,	E. N. Hawkins.
Cor. Sec. and Librarian,	Amos Slater.
Treasurer,	Geo. L. Cannon.

MEMBERS OF THE EXECUTIVE COMMITTEE.

Geo. L. Cannon,	W. A. Johnston,
Charles W. Comstock,	W. F. R. Mills,
H. C. Parmelee.	

This report was adopted.

Other nominations were made as follows:

President,	Philip Argall,
First Vice-President,	Charles W. Comstock.
Second Vice-President,	H. C. Parmelee.
Secretary,	J. W. Finch.

MEMBERS OF THE EXECUTIVE COMMITTEE.

Victor C. Alderson,	Thomas L. Wilkinson,
R. D. George,	A. W. Warwick,
Harry A. Lee,	E. Lyman White,
G. C. Hewett.	

Six volumes of reports of the Field Columbine were presented to the Society by Mr. J. A. Thatcher.

The committee for the Annual Dinner was appointed.

COMMUNICATIONS.—Mr. James Underhill presented a paper, "Tables for the Microscopical Determination of Rock Analysis." This paper was informally discussed by Messrs. George. Cannon, Warwick and Traphagen.

REPORT OF THE RECORDING SECRETARY,
FOR THE YEAR ENDING DECEMBER 21, 1904.

I desire to submit you the following report of the progress of the Society, for the year 1904. The membership of the Society on December 19, 1903 numbered 171. It is at present 190, both divided as follows:

	<i>Dec. 19, 1903.</i>	<i>Elected.</i>	<i>Resigned.</i>	<i>Present Membership.</i>
Resident,	101	9	—	110
Non-Resident,	66	11	1	76
Honorary,	3	—	—	3
Life,	1	—	—	1

Of this total membership thirteen are associate members. While this increase of eleven per cent. is not as great as we hoped one year ago to secure it is still a healthy one. A number of applicants for membership in the past three months decided to await the beginning of 1905 before joining the Society, and the Executive Committee now has five or six proposals under consideration.

During the latter part of this year the Society moved to the first floor of the Chamber of Commerce Building and the Library and collections are even better displayed than in the old quarters.

During the year the attendance at the meetings has been good. Eleven original papers have been read before the Society by members, and six informal communications have been contributed by as many members. Of the papers eight have been printed and distributed and two of the informal communications also.

The meetings and attendance were as follows:

Number of regular monthly meetings held,	. . . 11
Total number of members present at all meetings,	. 260
Largest number present at any one meeting (February)	34
Smallest number present at any one meeting (August)	12
Average attendance at meetings,	. . . . . 24

The Annual Dinner of the Society was held Dec. 26, 1903, at the University Club, and was attended by forty-four members and their guests.

EDWIN N. HAWKINS,
Secretary.

REPORT OF THE CORRESPONDING SECRETARY AND LIBRARIAN.

The following report embodies the main points passed over during the year of 1904.

At the beginning of the year, the rooms and library, especially the latter, were without proper attention and care, necessitating a change of curators, this change was made during the latter part of March, Miss Bacon replacing Mr. Beebe.

Since March indexing and cataloguing of books has been in progress, and in a short time will be finished. When this indexing is complete a catalogue will be printed and forwarded to the members.

On January 5, 1904, we shipped 265 unbound books to the bindery at Colorado Springs, 166 books have been bound and returned. The binding of the remaining unbound volumes other than those at the bindery, will cost approximately \$400.00, it is hoped that means to that end can be obtained and thus place the library on a sound basis.

The following gifts have been received by the Library during the year:

F. L. Clerc, 52 numbers of the *Engineering and Mining Journal*.

Thos. L. Wilkinson, 10 numbers of various publications.

R. C. Hills, a rare volume on Philosophy, published in 1783.

E. LeNeve Foster, *Quarterly Journal of the Geological Society of London, Journal of Society of Arts.*

Geo. L. Cannon, *Journal of Geography, School of Science and Science.*

General Palmer, to the binding of various volumes.

The lecture by Mr. Hammer on Radium, presented under the auspices of the Society, furnished money to further the library by adding a list of publications much needed.

These publications under subscription will be continued from year to year, back numbers will be obtained, by so doing, it will be but a short time when we shall have one of the best reference libraries in the West.

Publications subscribed for:

American Journal of Science.

American Geologist.

American Naturalist.

Electro-Chemical Industry.

Electrical Review.

Engineering News.

School of Mines, Quarterly.

Technical Quarterly.

FOREIGN.

Annals de Chemie et de Physique.

Dingler's Polytechnisches Journal.

Chemical News.

Quarterly Journal of Microscopical Society.

During the year the Exchange list has been increased, it represents nearly every important proceeding of this and other countries and should be of great use to the members.

PAPERS READ BEFORE THE SOCIETY AND PUBLISHED.

Economy in Mill Water, Jesse Scobey, Jan, pp. 151-162.

Gases in Metalliferous Mines, Harry A. Lee, Feb., pp. 163-192.

Death Gulch, F. W. Traphagen, Feb., pp. 163-192.

The Circulation of Underground Aqueous Solutions and the Deposition of Lode Ores, John W. Finch, March, pp. 193-252.

New Geology and Vein Formation, Franklin R. Carpenter, March, pp. 253-266.

The Progress of Gold Mining in Kalgoorlie, Western Australia, in 1903, E. Barton-Hack, May, pp. 267-288.

Discussion, The New Geology and Vein Formation, W. F. Edwards, May, pp. 289-296.

Some Notes on Vanadium, W. F. Edwards, May, pp. 297-312.

Hoisting in Deep Shafts, C. W. Comstock, July, pp. 313-340.

The Use of Crude Oil for Fire Assaying, F. C. Bowman, October, pp. 341-346.

The subscription list should be increased from time to time, so as to represent all of the best technical and scientific journals, and further, the volumes should be bound as they are completed, thus serving a two-fold purpose, of preventing the loss of numbers making up the volume and presenting the contents for immediate reference.

While the work in the Library has been that of transition from unclassified to classified, it has not been of great use to the members during the present year. However, it is earnestly hoped that the future will show its value.

Respectfully submitted,

AMOS SLATER,

Corresponding Secretary and Librarian.

TREASURER'S REPORT, 1904.

Annual dues.....	\$1630.00
Receipts from Hammer lecture.....	814.25
Dinner and lunch fees.....	235.00
School of Mines Prize Fund.....	250.00
School of Mines Prize Fund interest.....	7.50
Sale of publications.....	15.00
	<hr/>
	\$2951.75

EXPENDITURES.

Printing.....	\$ 911.59
Radium lecture expenses.....	689.75
Dinner and lunch expenses.....	268.83
Custodian and janitor wages.....	366.00
Stationery.....	20.60
Postage.....	85.45
Periodicals.....	59.30
Insurance.....	36.65
Library.....	30.30
Expressage.....	17.83
Lead Committee.....	14.35
Light.....	16.90
Furniture.....	23.63
Legal advice.....	25.00
Sundries.....	14.16

\$2580.34

Receipts.....	\$2951.75
Expenditures.....	2580.34

Balance.....	\$ 371.41
Deduct School of Mines Prize Fund.....	250.00
Balance.....	<hr/>
	\$ 121.41

G. L. CANNON,
Treasurer.

5 OCT 9 1901
PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. 7, PP. 13-36.
1-2-2

A MICA-ANDESITE OF WEST SUGARLOAF MOUNTAIN,
BOULDER COUNTY, COLORADO.

SOME RELATIONS OF TETRAHEDRAL COMBINA-
TIONS TO CRYSTALLINE FORM.

BY

JOHN CHARLES BLAKE

DENVER
PUBLISHED BY THE SOCIETY
APRIL, 1901

A MICA-ANDESITE OF WEST SUGARLOAF MOUNTAIN, BOULDER COUNTY, COLORADO.

BY JOHN CHARLES BLAKE,
Department of Chemistry, University of Colorado.

Read at the meeting of the Society, February 2, 1901.

West Sugarloaf (or Bald) Mountain is situated about ten miles west and one mile north of the city of Boulder, between Four Mile and Boulder creeks, and forms the next prominence west of Sugarloaf Mountain, from which it takes its name. In an analysis of the andesite forming the latter peak,* reference was made to an andesite of somewhat similar appearance occurring on West Sugarloaf Mountain, with a bare conjecture as to their possible relationship. This paper deals with the rock thus referred to.

On first examination, West Sugarloaf Mountain, unlike its namesake, is seen to be made up of several distinct outcrops of eruptive rock, together with at least three varieties of country rock. The mining town of Sunset, situated in the canon at the foot of this mountain, will serve as the principal landmark in the following description.

The Colorado & Northwestern railroad runs along the canon of Four Mile Creek to Sunset, where, crossing the creek, it turns back upon its track and ascends to higher ground along the north bank of the canon. Directly opposite this ascent, on the south side of the canon, is an old railroad grading (never utilized except

*B. Hogarty, The Andesite of Mount Sugarloaf, Boulder Co., Colo., Proc. Colo. Sci. Soc., March 4, 1899.

as a wagon road), which ascends from Sunset in a similar manner, thus cutting the north slope of West Sugarloaf Mountain. Along this grading the interior of the mountain is laid open, so to speak, and it is here that it is best studied. We will trace the various formations thus disclosed for a distance of about four miles, to the depression between Sugarloaf and West Sugarloaf mountains.

At the beginning of the ascent, at Sunset, occurs a prominent outcrop (best seen on the opposite bank) which we will call the Decomposed Calcareous Andesite of Sunset. This rock is now being analyzed in this laboratory. The outcrop is about one hundred feet in width, and, provisionally, its character is sufficiently suggested in the name applied.

At the second ravine crossed by the grading occurs the (herein) first observed outcrop of "The Sunset Trachyte," recently analyzed in this laboratory.* This occurrence is slightly west of opposite from the hill described in the paper referred to as "Trachyte Hill," on the north side of the creek.

Onward half way to the next prominent outward bend of the grading occurs an andesite somewhat resembling the rock herein described in the amounts of sanidine and plagioclase present, but carrying no remaining phenocrysts of mica, quartz, pyroxene, or amphibole, and having a very fine-grained groundmass. This rock is now being analyzed in this laboratory.

At the next outward bend, at the farther end of the cut, occurs a whitish-gray rock which readily crumbles to powder and appears to be a decomposed trachyte. Whether this rock is related to "The Sunset Trachyte" has not been determined, although the general appearance of the two rocks is quite dissimilar.

In the next inward bend is another occurrence of "The Sunset Trachyte," and at the next outward bend is the principal occurrence of this rock on this side of the creek, about one hundred feet in width.

At the beginning of the next inward bend is an andesite which has been much crushed and broken up. However, some

*R. Breed, The Sunset Trachyte, Boulder Co., Colo., Proc. Col. Sci. Soc., June 3, 1899.

crystals appear that have retained their form complete. It contains sanidine, plagioclase, calcite, magnetite, and hornblende (partly decomposed to chlorite), imbedded in a rather coarse-grained groundmass.

Just before reaching the centre of the next inward bend occurs a gray rock mottled with green blotches, which is now being analyzed in this laboratory. This is a trachyte, containing sanidine, (somewhat kaolinized), with traces of limonite in a very compact groundmass. It also carries fresh phenocrysts of magnetite and a great abundance of what was probably hornblende, now almost completely decomposed to chlorite (the green blotches).

A few feet farther on is an outcrop about fifteen feet in width which much resembles a trap rock in general appearance, but which proved to be an intimate mixture of the country rock with some undetermined eruptive material. It is dark-colored, crystalline, but nevertheless carries no phenocrysts of definite form. It seems to consist of a network of iron oxide, as a decomposition product, filled in promiscuously with poorly defined chlorite and fragments of orthoclase and quartz. Far up the mountain above this point is another occurrence of "The Sunset Trachyte" with quite an extensive talus.

A few feet farther on is the only observed outcrop of the rock herein described, about one hundred and fifty feet in width. The dike ("stock-rock") runs almost due north and south, and forms a separate spur of the mountain. Below the grading it is covered by debris, but above the grading it may be traced far up the mountain side. The centre of the dike is extremely coarse-grained, some of the phenocrysts being more than an inch in diameter. The phenocrysts gradually become smaller, however, toward the sides, where the rock has been altered, more or less, by chemical intermixture with the country rock. The latter consists essentially of two varieties at this place: a light-colored, coarse-grained granite, and a dark, greenish, schistose rock, carrying fibrolite. The west contact of the dike is dark-colored, very fine-grained, and almost glassy. The east contact is equally fine-

grained, light-colored, with a decidedly blue cast a little nearer the centre. It is mineralized with pyrites (about five per cent.), but the blue color is not due to copper. The central portion of the dike is seamed in all directions with a light-colored, decomposed elastic material, which is probably related to the flow-structure sometimes observed in quartz-porphyrries.* There is no evidence as to the time of eruption.

This occurrence is about two miles east of Sunset along the grading. Beyond this point the rocks have been studied with but one object—to ascertain whether there are any other occurrences of this rock between this point and Sugarloaf Mountain. Although no such further occurrences were found, the remaining outcrops will be briefly referred to as a preliminary survey for the future study of the rocks in this neighborhood.

At the second outward bend beyond the point last noted occurs a mica-andesite whose phenocrysts have, for the most part, been disintegrated without physical decomposition. However, feldspars, biotite, chlorite, magnetite, pyrites, and kaolin may be distinguished. The groundmass is mostly feldspar, and is crystalline. The rock is light-colored, very compact, and undecomposed.

At the next inward bend the country rock changes to the same granite which extends to the foothills about eight miles to the east. Just west of this point the rock is much mineralized and universally iron-stained.

At the next outward swell in the grading occurs an altered andesite, apparently not micaceous, much decomposed. Numerous cavities filled with a brown decomposition-product (iron oxide) show the negative forms of augite and hornblende. The rock is light drab where not discolored by decomposition-products.

Finally, at the sway between Sugarloaf and West Sugarloaf mountains, occurs a ferruginous andesite, mostly groundmass. Iron oxide and phenocrysts of feldspar are the only features noticeable under the hand lens. The groundmass is purplish-drab.

From this point the grading bends westward toward the Pennsylvania Avenue mine. The mountain has not been studied

* Palmer & Fulton, Quartz-Porphyry of Flagstaff Hill, Boulder County, Colorado, Proc. Colo. Sci. Soc., 1890. Bull. No. 43, U. S. Geol. Surv.

along this back grading, nor on its eastern side. Indeed, there may be other eruptive rocks along the route described which are not cut by the grading and have no prominent outcrop. The mountain, as a whole, presents a most attractive subject for study along the lines of petrographic geology.

THE MEGASCOPIC EXAMINATION.

The rock is particularly noticeable on the mountain side, where freshly cut by the abandoned railroad grading, by reason of its brilliant reflections in the sunlight, due to large phenocrysts of sanidine and many smaller ones of a black mica. Phenocrysts of a dull-looking plagioclase, together with magnetite and threads of kaolin also occur. The central portion of the dike weathers to a pinkish-buff, weathered surfaces having largely lost their phenocrysts, thus leaving their negatives especially noticeable. The mineralized portion weathers to brown and black. The specific gravity of the sample analyzed is 2.601 at 26°, as determined by means of a heavy solution soon after introduction of the sample into the solution.

THE MICROSCOPIC EXAMINATION.

The Phenocrysts make up about one-third of the rock. They consist of sanidine, labradorite, calcite (including altered augite), biotite, magnetite, kaolin, quartz, sphene, and apatite, named in order of abundance.

The Sanidine composes about eighteen per cent. of the rock. It contains very few inclusions and was probably one of the first ingredients to crystallize out of the magma. The largest crystals (in the sample analyzed) are somewhat more than one centimeter in length and about two-thirds as broad. A secondary structure of intergrowth with calcite resembling micropegmatite is quite common, the calcite usually forming the centre of the crystal. A very few microscopic crystals of apatite are also included. Twinning according to the Carlsbad law is common, with zonal structure somewhat rare.

The Labradorite is the only plagioclase distinguished. It forms about seven per cent. of the rock. It is identified by extinction angles both between twinning lamellae and along cleavage cracks. The crystals are usually rectangular with the end terminations poorly defined. The largest ones are about one centimeter by half a centimeter. Twinning according to the albite law is universal, with some crystals in which twinning according to the pericline law is also represented. Occasional twinning according to the Baveno law may likewise be observed. The inclusions are much the same as those of the sanidine, with some indications that the labradorite preceded the sanidine in order of crystallization.

The Calcite (secondary), composing about five per cent. of the rock, is universally broken up into aggregates which extinguish with a shimmer. The largest of these aggregates are about half a centimeter in diameter. They contain inclusions of most of the other phenocrysts, the magnetite and secondary quartz being especially noticeable and well crystallized. Calcite frequently surrounds large crystals of feldspar and biotite, and forms the "eroded" centre of many large feldspar crystals, as indicated above; although this is probably not related to the erosion of fusion, as no eroded "bays" have been noticed. The aggregates seem to feather off into the groundmass, although it will subsequently be shown that there can be but little calcite there. About one-tenth of the calcite appears to be altered augite, carrying many inclusions of magnetite and biotite.

The Biotite composes about two and one-half per cent. of the rock. It contains inclusions of magnetite, together with some (secondary) calcite and a few microscopic crystals of apatite. Most of the crystals are fresh, except that the ends have been broken into. However, some crystal fragments also occur. The largest crystals are about two or three millimeters by one.

The Magnetite, with a trace of *Limonite*, forms about one and one-half per cent of the rock. It occurs as inclusions in most of the other phenocrysts, especially in the biotite, calcite and de-

composed augite. It also occurs as separate grains and aggregates; and as dust it forms an essential part of the groundmass.

The Kaolin forms about one per cent of the rock. It exists as irregular threads and ill-defined patches which shade away into the groundmass.

The Quartz is all secondary, crystallized with the calcite, and forms about seven-tenths of one per cent. of the rock.

Crystals of *Sphene*, more or less decomposed, form about two-tenths of one per cent. of the rock; while microscopic crystals of *Apatite* occur included as mentioned above, and also sparingly in the groundmass.

The Groundmass forms about two-thirds of the rock. It seems to be cryptocrystalline, except for the kaolin, as it lights up quite brilliantly between crossed nicols. It is, however, scarcely resolved into its constituents even by a one-tenth immersion lens. This power shows many grains of magnetite, some limonite, scattered patches of kaolin, and occasional needles of apatite, all in a network of feldspar whose individual crystals seem inextricably blended together. Gas or liquid inclusions are not numerous.

The decomposition-products here present seem to have come mostly from the feldspar. The kaolin still shows the trace of plagioclase striations; but the fact that it occurs in the form of streaks and threads instead of in the form of plagioclase pseudomorphs, seems to indicate that the crystals yielding the same must have been crushed, a fact which would have rendered them the more readily decomposable. The calcite likewise gives no suggestion of the form of feldspar crystals, although all of it excepting that replacing augite is probably a feldspar substituent.* The replacement of the central portion of unbroken and otherwise decomposed feldspar crystals by calcite, as described under sanidine, seems to confirm the foregoing supposition as to the origin of the decomposition-products. The substitution of feldspar for calcite and kaolin in the above estimates would not change the character of the rock from that of a mica-andesite.

*Zirkel, Lehrb. der Petrographie, II., 605.

The percentages given above may be taken as very fair approximations, as they are the averages of estimates made on many fields.

THE ANALYSIS.

The sample of the rock taken for analysis was selected from that portion of the undecomposed dike whose structure is only moderately coarse-grained, and yet not near enough to the sides to show any alteration due to contact with the country rock. The analysis mainly follows Hillebrand's "Methods of Silicate Analysis,"* which is invaluable as an introduction to work of this kind. Re-precipitation was resorted to where applicable.

The silica was most readily and completely rendered insoluble in hydrochloric acid by evaporating at 105–10° after fusion, then holding at 120° for thirty minutes. The evaporate was then moistened with concentrated hydrochloric acid and taken up with hot water. About one milligram of silica was uniformly found with the iron and aluminum in the third group precipitate.† The main silica precipitate was evaporated with sulphuric and hydrofluoric acids, and the slight residue added to the third group precipitate.

The titanium dioxide was determined in a separate portion by colorimetry. The rock powder was decomposed by sulphuric and hydrofluoric acids, the solution filtered, oxidized by hydrogen peroxide, and compared with a standard solution of titanium sulphate similarly oxidized.

The alumina was determined in a separate portion as follows: The rock powder was decomposed by sulphuric and hydrofluoric acids, and evaporated to dryness without decomposing the sulphates of iron and aluminum thus formed. A mixture of sodium and potassium carbonates was then added and heat applied at the top. When the fusion was complete, the melt was leached with hot water. In this manner the aluminum and phosphorus were

*Bull. No. 143, U. S. Geol. Surv.

†Here and elsewhere in this paper the groups are numbered according to the customary order of precipitation.

separated from the iron and titanium. The aluminum and phosphorus were then re-precipitated by ammonium chloride. This method was resorted to only after failure to obtain concordant results by difference. It offers considerable convenience in the ease of filtering and washing both the iron, which is left in a semi-granular form, and the aluminum, which is re-precipitated as the met-hydroxide.

The ferrous oxide was determined by decomposing the rock powder with sulphuric and hydrofluoric acids in an atmosphere of carbon dioxide, and then titrating with a standard solution of potassium permanganate without filtering. The total iron was determined in the filtrate from the silica by reducing with hydrogen sulphide and titrating with a standard solution of potassium permanganate. The ferric oxide was determined as difference by calculation from the data thus obtained.

The manganous oxide was determined by precipitating the sulphide, converting into the acetate, and re-precipitating as ammonium-manganous phosphate.

The calcium oxide was determined by precipitating the oxalate and burning it to the oxide.

The magnesium oxide was determined by precipitation as ammonium-magnesium phosphate. The somewhat unsatisfactory results obtained for calcium and magnesium were due to the mutual contamination of these ingredients, even after repeated precipitation.

The alkalies were determined by the J. Lawrence Smith method, the potassium being weighed as potassium chlor-platinate, and the sodium determined as difference by calculation from the weight of the total chlorides.

The water was determined at 105° (ten degrees above boiling point) and at ignition by direct absorption in concentrated sulphuric acid.

The phosphoric acid was determined in a separate portion by precipitation as ammonium phospho-molybdate and re-precipitation as ammonium-magnesium phosphate.

The vanadic acid was determined by the method recently outlined by Hillebrand.* Mercurous vanadate was first precipitated. After changing this to vanadic acid, it was reduced to the tetrad stage by hydrogen sulphide, and titrated with a standard solution of potassium permanganate. No corrections have been made on account of vanadium, nor was any attempt made to determine whether its original stage of oxidation was triad or pentad.

The carbon dioxide was determined by direct absorption, the apparatus consisting of a potash bulb to remove carbon dioxide from the air, the flask containing the rock powder, a U-tube containing a little water immersed in a beaker of cold water to remove hydrochloric acid (which served its purpose effectually, as proved by negative tests for chlorides in the weighed potash bulb after the operation was over), a sulphuric acid bulb, and finally a weighed potash bulb and a weighed sulphuric acid bulb connected with a suction pump. On a blank charge this apparatus may run for half an hour or longer without appreciable change in weight.

Traces of zirconium, chlorine and sulphur were found.

The following elements were tested for with negative results: metals of groups one and two, chromium, zinc, cobalt, nickel, strontium, barium, lithium and fluorine.

*Amer. J. Sci., Sept., 1896.

THE ACTUAL ANALYSIS.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.
SiO ₂	57.59	57.52																	
TiO ₂				.21	.28	15.48	15.58												
Al ₂ O ₃																			
Fe ₂ O ₃		2.68						2.43	2.52										
FeO																			
MnO	.10	.10																	
CaO	5.94	5.75																	
MgO	1.08	1.45	1.39							3.00	2.90								
K ₂ O										4.86	4.94								
Na ₂ O												.84	.91						
H ₂ O at 105°												1.31	1.23	.83	.83	.02	.02	3.52	3.62
H ₂ O above 105°																			
P ₂ O ₅																			
V ₂ O ₅																			
CO ₂																			

Zr, Cl, S and SO₂ trace.

THE ANALYSIS COLLATED.

SiO ₂	57.55
TiO ₂.....	.24
ZrO ₂	Trace
Al ₂ O ₃	15.52
Fe ₂ O ₃	2.68
FeO.....	2.48
MnO.....	.10
CaO.....	5.85
MgO.....	1.37
K ₂ O.....	2.95
Na ₂ O.....	4.90
H ₂ O.....	2.15
P ₂ O ₅.....	.83
V ₂ O ₅.....	.02
CO ₂	3.57
S and SO ₂	Trace
Cl.....	Trace
	100.21

The above percentages are the averages of two determinations, except magnesium oxide, which is the average of three.

DISCUSSION OF THE ANALYSIS

By calculating the different ingredients corresponding to the percentages of phenocrysts given on a previous page, the microscopic examination and the analysis may roughly be compared and mutually confirmed. The following table is here presented for the purpose of facilitating discussion in this behalf rather than for the purpose of calling attention to multitudinous details wholly unsubstantiated. The table is, for the most part, self-explanatory. The composition given for the different phenocrysts was taken from Dana's "System of Mineralogy" by making a rough average of the most closely agreeing analyses of the typical minerals. The fourth horizontal column from the bottom represents (roughly) the composition of the rock as it would be if it had the same composition throughout that the phenocrysts have (phosphorus, vanadium and manganese omitted, as not occurring in the phenocrysts estimated). The bottom column is obtained by subtracting the percentages representing the composition of the phenocrysts from the percentages given by the analysis; and the second column from the bottom represents the composition of the rock as it would be if it had throughout the same composition that the groundmass has.

COMPARISON OF ANALYSIS WITH MICROSCOPIC EXAMINATION.

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO	MgO	K ₂ O	Na ₂ O	H ₂ O	CO ₂	Total.	Esti- mated.
Sanadine	11.79		3.24	.13		.14	.05	1.80	.90			18.05	18.00
Labradorite	3.85		1.99	.16		.74	.01	.04	.34			7.03	7.00
Calcite						2.80					2.20	5.00	5.00
Biotite	.95		.40	.13	.38		.38	.20	.03	.06		2.53	2.50
Magnetite				1.03	.47							1.50	1.50
Kaolin	.47		.39							.14		1.00	1.00
Quartz	.70											.70	.70
Sphene	.06	.08				.08						.20	.20
Total	17.82	.08	6.02	1.35	.85	3.74	.44	2.04	1.27	.20	2.20	36.01	35.90
Phenocrysts calc. to 99.26%	49.13	.22	16.60	3.71	2.34	10.31	1.21	5.63	3.50	.55	6.06	99.26	99.26
Analysis	57.55	.24	15.52	2.68	2.48	5.85	1.37	2.95	4.90	2.15	3.57	99.26	99.26
G. M. calc. to 99.26%	62.35	.25	14.91	2.08	2.56	3.30	1.46	1.43	5.70	3.08	2.15	99.25	99.26
Groundmass	39.73	.16	9.50	1.33	1.63	2.11	.83	.91	3.63	1.95	1.37	63.25	63.36

A glance at the above table shows that the phenocrysts are, as usual, more basic than the groundmass. Probably not all of the carbon dioxide is present as calcite, as this would require nearly the whole of the lime present, leaving only about one per cent. for the feldspars. However, the relative amounts of soda and potash allotted to the groundmass indicate that soda-lime feldspars must largely predominate there. This would require that a large per cent. of the lime be not present as calcite. The phenocrystic calcite estimated above would require only about three per cent. of lime, thus leaving about the same amount for the feldspars. There can, therefore, be but little calcite in the groundmass.

If part of the plagioclase be regarded as oligoclase or andesine (instead of labradorite), especially for the feldspars in the groundmass, this would conveniently dispose of the rather large amount of soda as compared to lime allotted to the groundmass—a ratio far larger than that existing in labradorite and not sufficiently cut down by the sanidine in the groundmass, limited in amount by the potash present. However, the excess of soda may even more appropriately, perhaps, be disposed of by mating it with the excess of carbon dioxide present, as indicated above, predicating amorphous sodium carbonate for the groundmass.

This disposes of about the only apparent difficulties here presented. However, the ratio of ferrous and ferric iron in the groundmass is considerably too large for ferrous iron if the iron in the groundmass is mostly in the form of magnetite. No indication of biotite in the groundmass has been observed. This leaves about one per cent. of ferrous oxide as yet unaccounted for. The presence in the groundmass of about the same amount of magnesium oxide, otherwise unaccounted for, seems to indicate either that the per cent. of phenocrystic biotite has been underestimated, or that the groundmass carries some amorphous mineral whose composition is similar to that of biotite. The small amount of (decomposed) phenocrystic augite present offers but a partial explanation. More phosphorus was found than would correspond to the microscopic crystals of apatite (not estimated in the above

table) and the trace of chlorine present. This relatively rather large excess of phosphorus might conveniently be disposed of by mating it with the excess of magnesium and ferrous iron (together with water) as amorphous hydrous phosphates in the groundmass. The water is probably present, for the most part, in the groundmass and the kaolin, with traces in the biotite.

The titanium is very well accounted for by the sphene and magnetite present. The manganese (not estimated in the above table) is sufficiently accounted for by its customary ubiquitous occurrence in rocks of this character.

Thus the analysis and the microscopic examination agree fairly well within the limits of petrographic error.

COMPARATIVE ANALYSES.

A casual comparison of this paper with the one referred to in the opening paragraph hereof is sufficient to answer in the negative the conjecture therein contained. Indeed, the dike of the rock herein described runs at right angles to the line connecting Sugarloaf and West Sugarloaf mountains. From a somewhat extended examination of published analyses, especially those published by the United States Geological Survey, the two given below have been thought most comparable with the one herewith presented. The criterion of this selection was to find andesites which carry mica and at the same time contain a fair per cent. of carbonates, together with comparable amounts of silica, alumina, total iron and total alkalies. The two analyses chosen will be seen to fulfill these conditions quite satisfactorily, at the same time agreeing quite well microscopically, with the single exception that analysis B seems to carry no ferric iron.

A. Mica-andesite, Huronian volcanic from Michigamme iron district, Michigan. Contains plagioclase, biotite with secondary chlorite, iron ore, calcite, epidote and sphene. Description by Prof. Van Hise. H. N. Stokes, analyst. (Bull. No. 148, U. S. Geol. Surv.)

B. Mica-andesite, from six miles northeast of Grant's, Mount Taylor region, New Mexico. Principally plagioclase and biotite, with less epidote, quartz, sphene, and carbonates. Description by J. S. Diller. T. M. Chatard, analyst. (Bull. No. 148, U. S. Geol. Surv.)

C. Mica-andesite, West Sugarloaf Mountain, Boulder County, Colorado. Contains sanidine, labradorite, calcite, biotite, magnetite, kaolin, quartz, and sphene. J. C. Blake, analyst.

	A.	B.	C.
SiO ₂	47.20	49.80	57.55
TiO ₂	3.30	2.67	.24
ZrO ₂			Trace
Al ₂ O ₃	15.36	15.33	15.52
Cr ₂ O ₃	None		None
Fe ₂ O ₃	3.06		2.68
FeO.....	8.87	7.44	2.48
MnO.....	.20	.30	.10
CuO.....	Trace		None
CaO.....	5.05	7.19	5.85
SrO.....	Trace		None
BaO.....	Trace		None
MgO.....	4.20	6.61	1.37
K ₂ O.....	1.40	4.36	2.95
Na ₂ O.....	4.72	3.71	4.90
Li ₂ O.....	Trace		None
H ₂ O at 110°.....	.16	1.38	.88*
H ₂ O above 110°.....	3.04		1.27
P ₂ O ₅.....	.36	.73	.83
V ₂ O ₅.....			.02
CO ₂	3.34	2.56	3.57
S and SO ₃	Trace		Trace
Cl.....			Trace
F.....	Trace		None
	100.26	101.08	100.21

This is to be regarded as one of a series of papers issued from the Chemical Laboratory of the University of Colorado from time to time on "The Eruptive Rocks of Boulder County," under the direction of Professor Charles S. Palmer, whose assistance and advice have been invaluable in the work here presented.

Boulder, Oct. 1, 1900.

*105° at the altitude of Boulder.

Mr. Palmer:—At present the work is being conducted on about half a dozen rocks in the vicinity of West Sugarloaf Mountain, which are probably contiguous in geological relation. I hope we shall have more to say later on, before the Society, in relation to these rocks.

Mr. Cannon:—How large pieces of fibrolite have you found?

Mr. Blake:—The fibrolite in this schistose rock seems to have crystallized in between the other ingredients, so that it occurs commingled.

Mr. Hills:—Has it any dark silicates?

Mr. Blake:—It has only mica, biotite.

Mr. Cannon:—Nothing else?

Mr. Blake:—No.

Mr. Blake then read the following paper:

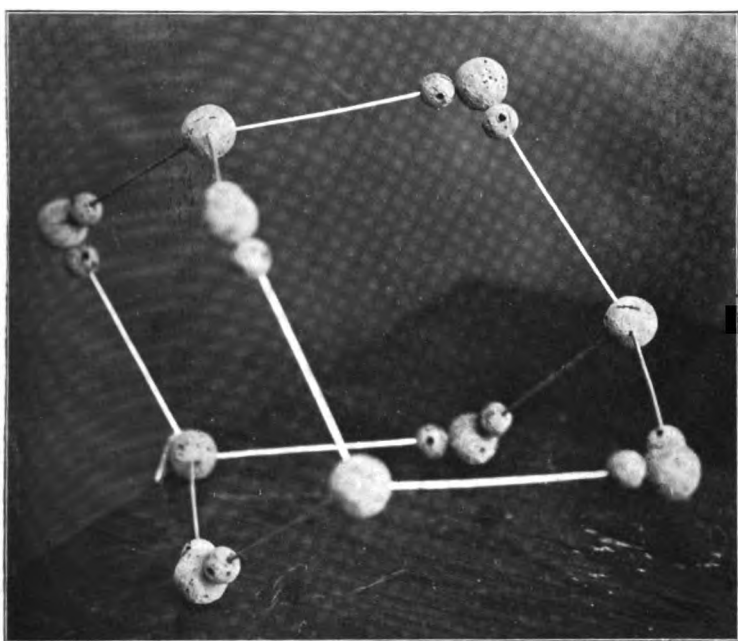


Fig. 1.

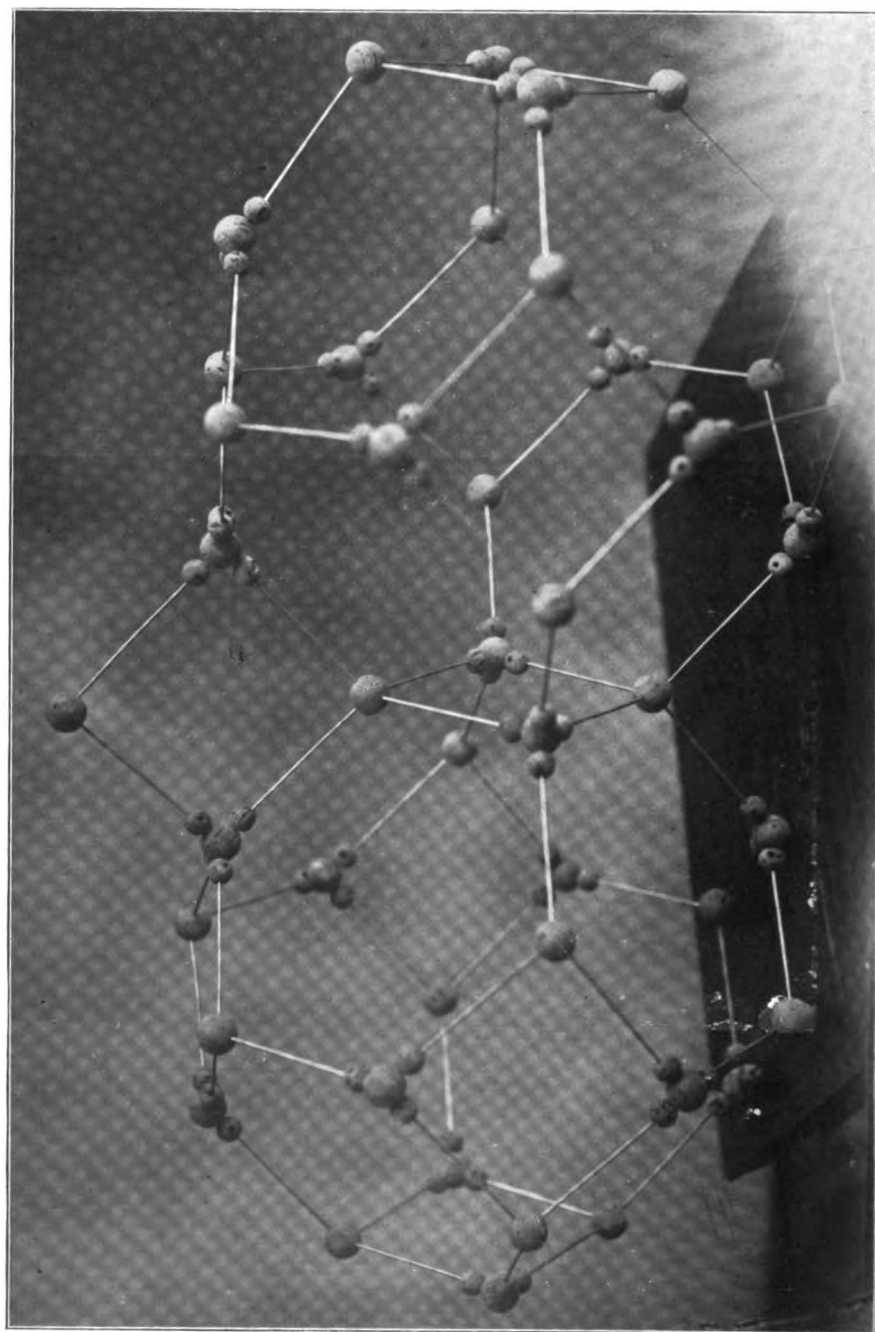


Fig. 2

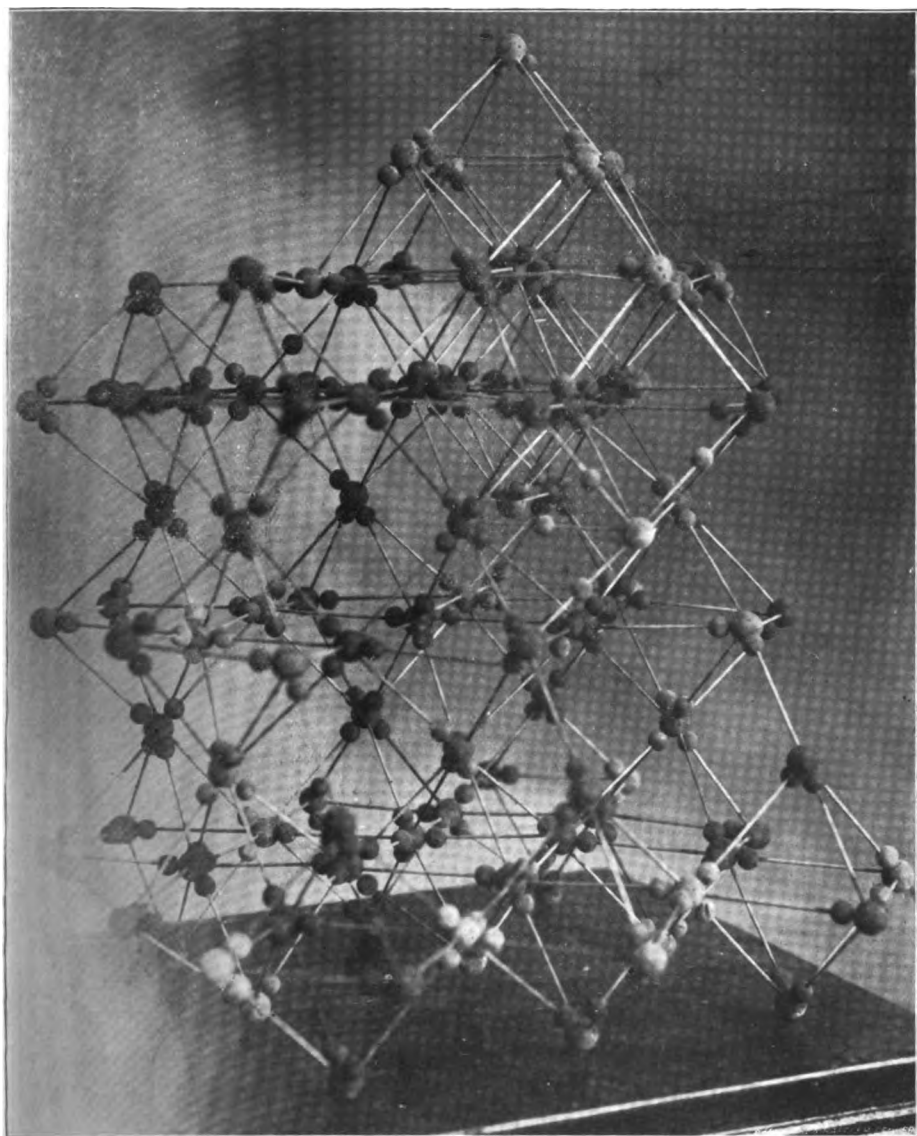


Fig. 3.

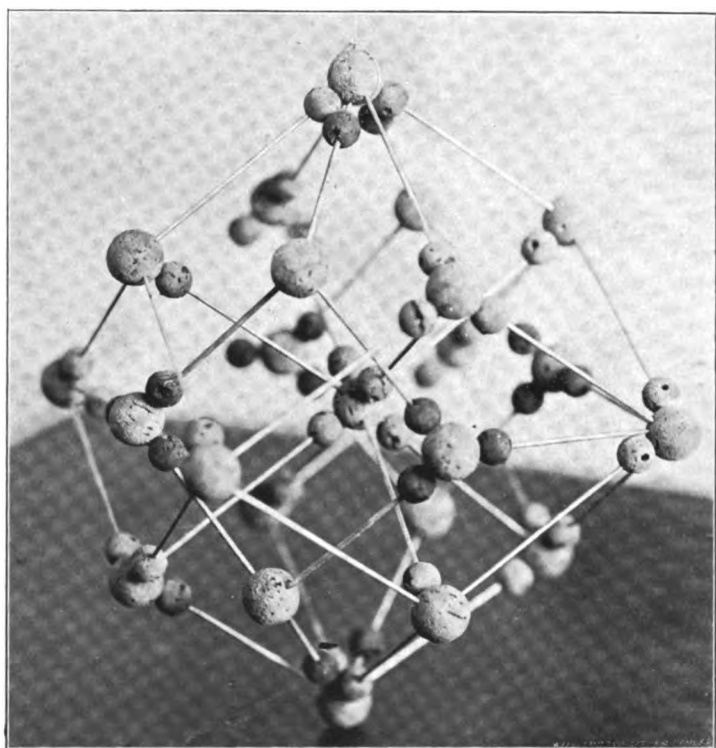


Fig. 4.

SOME RELATIONS OF TETRAHEDRAL COMBINATIONS TO CRYSTALLINE FORM.

BY JOHN CHARLES BLAKE,
Department of Chemistry, University of Colorado.

Read at the meeting of the Society, February 2, 1901.

The simplest definite way in which particles can vibrate, possessing components in the three rectilinear directions, is for them to meet at the centre of a tetrahedron, from its four corners. This method of vibration may be varied: (1) By varying the angle between the path of one particle and that of the particle whose path is nearest its own, regarding these two particles as a *pair* opposed by the other two of the same tetrahedral combination; (2) by varying the plane of one pair with respect to the plane of the other pair; (3) the plane in which one particle meets with another to form a pair at one end of its free path may vary with respect to the plane in which it meets with another particle to form a pair at the other end of its free path in an adjoining tetrahedral combination, and the direction of approach of the second particle at the second centre may be positive or negative with respect to the first; (5) the number of particles which meet at a centre may vary by multiplication (condensation) of the tetrahedral idea, yielding eight, twelve, etc., particles meeting at the same point, and all twelve of them (e. g.) may meet at the centre at once, or by fours or sixes; (4) the angle at which one particle meets another at one centre to form a pair may vary with respect to the angle at which it meets another particle at the

other end of its path to form another pair. Particles may meet at a centre according to plans not tetrahedral. Two or more systems may be combined whose particles have the same frequency, but different free paths, velocities and sizes. Other variations are suggested, and combinations of those already given.

By use of the different methods of vibration given above it is possible to build up most (all?) of the crystal forms, suggesting a conceivable explanation of many of the crystalline and physical properties of matter. A considerable amount of work has been done relative to the mathematical, physical, chemical and crystallographic properties represented by such systems, but all of this is withheld for the present, on account of its incompleteness. More extended investigation is being made along these lines. However, many such properties are suggested by the accompanying figures, which will be allowed, for the present, to speak for themselves.

The work was carried on by means of models made of spheres of cork wood and wires sharpened at both ends. Spheres three-fourths of an inch in diameter were used to represent tetrahedral centres and to hold the wires together; spheres one-half inch in diameter being used to represent the particles.

A few of the models have been figured: Figure 1 represents the simplest and most general method of combination (except for the limiting values assigned to the angles). The angle mentioned in variation-method (1) is ninety degrees; the planes mentioned in variation-method (2) are at right angles; the planes mentioned in variation-method (3) are identical, and the direction of the second particle is positive; the angles mentioned in variation-method (4) are equal; and all of the particles have the same size, velocity and free path. All of the other models figured have the same properties, except in so far as differences are particularly pointed out. It will be seen that this method of combination yields only skeleton crystals, which, however, become completed forms when variation-method (5) is applied.

The method by which Fig. 2 is built up differs only from that just given in that the direction of the second particle accord-

ing to variation-method (4) is negative. This is a special case, far more limited in its application than the method given above. The figure speaks for itself for the purposes of this paper.

Figure 3 has been built up by a method which differs from that of Fig. 2 only in that it has been multiplied by four, according to variation-method (5), the upper right-hand corner having been multiplied by six. For it also, a detailed description is out of the question in this place. Indeed, such a description would be almost impossible in any event without the actual model.

Figure 4 represents a combination of the dodecahedron and the octahedron, produced by two different structures, whose particles have different free paths. The dodecahedron is made up by the method given for Fig. 1, except that the angle mentioned in variation-method (1) is $109^{\circ} 29' 3''$, and the system has been multiplied as in variation-method (5) several times. The octahedron is only partially represented. The method of multiplication (5) must be applied to it in order to show the octahedron complete. The part figured has been built up by a method not mentioned above, which differs but slightly from the methods given for Figs. 1 and 2. It would probably not have been noticed for some time except for its connection with the dodecahedron, as in the figure, and furnishes a good illustration of the way in which the work carries itself along.

In conclusion I may say that the work is enchanting, both in its concrete developments and in its theoretical suggestions, and I desire to be allowed a further opportunity for more extended research in connection therewith.

My thanks are due to Dr. Charles S. Palmer for much encouragement in this behalf.

Boulder, Feb. 1, 1901.

The foregoing paper was then generally discussed by most of the members present.

Mr. Argall:—If there are no further remarks, I would like to move a vote of thanks for Mr. Blake's very interesting paper. I know it is not the custom of the Society, but this is an extraordinary occasion, and I think we ought to break the rule.

The motion was seconded and carried unanimously.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. 7, PP. 23-40.

TEST OF THE CORLISS ENGINE AT THE SARATOGA
MINE, CENTRAL CITY

SOME PUMPING DATA

DESCRIPTION OF THE TABOR STEAM ENGINE
INDICATOR

BY

THOMAS L. WILKINSON

DENVER
PUBLISHED BY THE SOCIETY
MAY, 1901

TEST OF THE CORLISS ENGINE AT THE SARATOGA
MINE, CENTRAL CITY.

SOME PUMPING DATA.

DESCRIPTION OF THE TABOR STEAM ENGINE
INDICATOR.

BY THOMAS L. WILKINSON.

Read at the meeting of the Society, April 6, 1901.

If the testing of steam engines, as well as steam boilers, were more common practice, then, not only would guarantees be less recklessly made by manufacturers, but the owners of steam plants would know what their plants were doing. It is usually the custom of engine and boiler manufacturers to guarantee that the engine they make will develop a horse-power on so many pounds of steam per hour, or that their boiler will evaporate so many pounds of water per pound of coal per hour.

Many make these guarantees in good faith, knowing that if put to the test they will come out all right, but there are many others, who anxious to secure an order, very readily make a guarantee that is beyond the range of possibility, and they do this simply with the idea, that if they capture the order, that neither the engine nor boiler will ever be tested, to ascertain whether or not they come up to the qualifications, as specified. And as a rule such

a manufacturer is perfectly safe in doing what he has done, because a very small percentage of engines and boilers are ever tested.

However, the buyers of engines and boilers are being educated in the proper direction, and as a result engine and boiler testing is coming more and more into general practice. Many contracts and specifications now contain a clause providing for such test.

A recent case in which a test showed the failure to fulfill the guarantee, and which will probably lead to the improvement in one make of engine at least, occurred at Minneapolis.

Three 125 H. P. tandem compound engines (presumably non-condensing) were placed in the new court house. The requirements of the specifications being a water consumption not exceeding 24.5 pounds per horse-power per hour, and a regulation within one per cent.

The results of the tests of the three engines gave the water consumption respectively of 31.05, 30.43 and 27.88 pounds, and the regulation, 4.4, 5.4 and 5.4 percent. The engines were run at about their rated power, and were furnished with steam at 125 pounds pressure, dried by passing it through a separator.

It is to be presumed that the report of the test was accepted, and that the engines had to be removed at the expense of the engine company installing the plant.

Another case in which the writer took part in the test, showed that the engine failed by only 0.6 of one pound of steam per horse-power per hour to come up to the specifications. The contract was thus void, and the engine was removed and another of different make installed. Here was a large loss to the first company which put the engine in. Other instances of this kind might be cited.

This goes to show the importance of testing, and it protects the buyer and seller alike.

The objects of an engine test may be several: 1. To adjust the valves or working parts of the engine. 2. To determine the indicated or brake horse-power. 3. To determine the friction for different speeds and conditions. 4. To determine the consumption

of fuel or steam per horse-power per hour. 5. To determine the efficiency as a heat engine, etc., etc. 25

In the engine test under discussion this evening, the first two objects were sought, e. i. the adjustment of the valves and the determination of the indicated horse-power under actual working conditions.

In April of 1900, at the request of the manager, Mr. E. Le Neve Foster, (president of this Society,) I went to the Saratoga Mine, located near Central City, Colo., and set the valves of the engine, and determined its horse-power.

This engine is a Corliss, was made by McFarlane & Co. of Denver and was installed at the Saratoga Mine in 1895.

The dimensions are as follows:—

Diameter of cylinder.....	16"
Stroke	36"
Diameter of piston rod.....	2½"
" " steam pipe.....	4"
" " exhaust.....	5"
" " fly wheel.....	12'
Weight of fly wheel.....	12000 pounds
Revolutions of engine (nominal).....	75

For this work I did not need the other dimensions of the engine so did not take them.

This engine operates the Cornish pump and does no other work whatever.

Mounted on the main shaft of the engine is a pinion 20" in diameter. This pinion has 21 teeth by 12" width of face. Into this pinion is geared a large wheel 94·52" in diameter, with 99 teeth. The ratio of the large gear wheel to the pinion is 4·71 to 1. On the shaft of the large gear wheel is the crank arm of 3'–0" centers. A connecting rod 22'–0" long connects the crank pin and the walking beam of the Cornish pump.

The total lift of this Cornish pump is 740 feet, divided as follows: -

From sump at 9th level to 8th level.....100'

“ 8th level to 6th level.....200'

“ 6th “ to 4th “200'

thence 240 feet to a place where the water is discharged into an adit, some 500 or 600 feet long, then into a tunnel leading to the surface.

At the time I indicated this engine the revolutions were considerably below the normal, and were uniformly 40 and the gauge pressure ranged between 75 and 80 pounds. The steam pipe (4") leading from the boilers is about 40 feet long. It is covered, yet the fall in pressure, as shown by the indicator cards, was more than it should have been. It is my opinion, however, that the gauge read several pounds too high.

The pump rods are of wood 8" x 8" by 30'-0" long and at the joints are heavily strapped with iron. To overcome the weight of the rods, a counterweight of 8 tons is suspended from the opposite arm of the walking beam.

The discharge pipe is 8" in diameter, the stroke 6'-0" and the plunger 8" in diameter, thus giving a discharge of 15 gallons per stroke. There are $8\frac{1}{2}$ strokes per minute or 125 gallons per minute and so 1062.5 pounds, and in one hour 93,750 pounds.

Indicator card No. 1, which represents the condition of the engine before the valves were set, gives the horse-power at 29.13. It will be noticed what a wide range exists between the crank and head ends of the cylinder, almost 15 pounds. The cut-off in the crank end is one-sixth and a fair card.

Card No. 4 shows even a worse condition than No. 1.

In foot pounds card No. 1, 29.13 H. P., equals 961,290

And card No. 5 after the valves were set equals 837,540

123,750

or 13 per cent. That is, by proper setting of the valves, so that the work done on each side of the piston rod was nearly equal. The same amount of water is lifted with a less expenditure of steam, and this saving amounts to 13 per cent,

After the valves had been set and other cards taken I found that the cards were not uniform, and that at first we could not discover the cause. Upon further examination we found that the eccentric had slipped back and would not remain in the new position. One of the set screws had broken, and the other could not be screwed up tight.

Marks were made on the wrist pin plate so that when the eccentric was properly adjusted the engine would be working so as to give cards as in No. 5.

This saving of 13 per cent. in steam will be felt in the coal supply. The steam source consists of three return tubular horizontal boilers — two 80 horse-power and one 60 horse-power.

Two boilers are required to be in operation at all times. I was told that at various times the coal used had been weighed and the average amounted to about 2,400 pounds each 24 hours, or 100 pounds per hour.

Besides the steam required for this engine, the boilers also furnish steam for the feed pumps and the mine hoist, which has two cylinders, each $10' \times 12'$. These engines are known to be heavy steam consumers.

From the data I have, I computed the amount of steam used as given by the indicator card No. 5 which gave 38.75 pounds per horse-power per hour or 983.47 pounds per hour for the 25.38 horse-power.

If the water pumped was pure enough to use for condensing purposes, from 10 to 20 per cent. in power would be gained. But this engine is working only about one-fourth of its rated capacity. The water pumped at the Saratoga mine is so filled with impurities that a condenser is out of the question.

On the 9th of April last I again went to Central City and re-set the valves of the engine at the Saratoga Mine. The resulting cards, two of which are shown, Nos. 1 and 5 were taken after the valves had been properly set. The engine is now cutting off at one sixth stroke and the cards shown are representative cards. The engine is doing its work easily, but not nearly up to its capacity.

SOME PUMPING DATA.

The results of two tests made on two pumping plants will be interesting reading. Both plants are at the works of the Cleveland Mining Company, at Ishpeming, Michigan. The object of the tests was to obtain the efficiency of each.

One plant consisted of a Cornish pump with 14-inch poles, 9-foot stroke, and geared with a reduction stroke of 8 to 1. The engine is a Corliss, 18×60 inches, and is connected with a Bulkley condenser, which gets its supply from the column pipe.

The other plant is a double acting, duplex compound, condensing pump.

The high pressure cylinders are 14 inches in diameter, and the low pressure cylinders 24 inches. The plungers are 6 inches in diameter, and the stroke of piston and plungers is 20 inches.

The results obtained from the Cornish pump are as follows: Lift of pump, 600 feet; speed, 4 to 6 revolutions per minute; water per I. H. P. per hour, 19,410 pounds; coal consumed per I. H. P. per hour, 2,539 pounds; work done per 100 pounds coal consumed, 62,813,300 foot pounds.

Results obtained from duplex, compound, condensing pumps are as follows: Lift, 825 feet; speed, average, 12.2 revolutions per minute; average horse-power computed from cards, 26.55; water per I. H. P. per hour, 95.93; coal consumed per I. H. P. per hour, 13.37 pounds; work done per 100 pounds coal consumed, 12,725,200 foot pounds.

Unfortunately these are the only data at present at hand concerning these two plants. The Cornish pump has, from the beginning, been an economical pump. Probably no large pumping engines have held so high a reputation in the past as have the Cornish engines for deep mine pumping. It is probable, also, that the principle upon which Cornish pumps were designed and built was so well adapted for their purpose that, even up to the present time, that principle has not been much improved upon.

That the Cornish pump is economical is readily seen by comparing the work done in these two plants—the Cornish pump doing over 62,000,000 foot pounds of work, while the direct-acting pump did one-fifth that amount on the same amount of fuel. A manufacturer of Cornish pumps says this of them: “While in first cost they are more expensive than the highest quality and most efficient direct-acting steam pumping outfit, they are more economical, both in fuel and in repairs. The difference in saving of fuel is so great that the Cornish pumping plant will save almost its cost in fuel the first year.” This last sentence may be discounted, as local conditions will change costs very considerably. The high duty obtained by Cornish pumping engines of early date, which was not equalled by any other class of pumping engines until of late years, has been somewhat of a surprise to a great many engineers. The Cornish pump did not possess what the double-acting pumps had: high steam pressure and large number of strokes, which were requisite for economy. But the Cornish might have been worked condensing, and I presume that many are at the present day.

The largest Cornish pumping plant in the world is the huge Chapin pump of the Chapin Mining Company, at Iron Mountain, Michigan. The pump is designed to pump 3,000 gallons per minute, from a depth of 1,500 feet. Some idea of the enormous proportions of this pump may be found from its dimensions. The engine is of the vertical type and compound, and stands 54 feet from the floor. The high pressure cylinder is 50 inches, and the low pressure cylinder is 100 inches in diameter, and the stroke is 10 feet. The fly wheel is 40 feet in diameter and alone weighs 164 tons, without doubt the heaviest fly wheel ever built. The total weight of the engine, exclusive of pumps and shaft work is 600 tons.

The pump end is attached directly to the beam end which overhangs the shaft. The pumps are of the single-acting Cornish type, with plungers 28 inches in diameter and 10-foot stroke.

The number of strokes vary from 4 to 10. The pumps are arranged in series, each set having a lift of about 200 feet. This plant was designed and built by the E. P. Allis Co., of Milwaukee.

THE PUMPING SYSTEM AT THE ONTARIO MINE, UTAH.

Perhaps the largest pumping engine in the Western part of the United States is the large Cornish pumping engine at the Ontario mine, at Park City, Utah. I quote largely from the article of W. P. Hardesty on this subject.

As the various shafts and levels have been extended, the amount of water to be handled has steadily increased. Up to the time that the drainage tunnel was constructed from No. 3 shaft, at the 600 foot level, all the water amounting to about 4,500 gallons per minute, was pumped and discharged through a short tunnel about 500 feet from the surface. This first drainage tunnel from No. 3 shaft carried off all the water of the mine as low as the 600-foot level.

Below this level, however, all the water had to be pumped, and as the management had found that the use of steam pumps below the surface had proved rather too expensive, it was decided to erect a large Cornish pump. The large pump, that was installed at the mouth of shaft No. 3, was from the design of W. R. Eckhart, of San Francisco, and was built by the I. P. Morris Company, of Philadelphia.

The two cylinders are nearly vertical, being at the same height and inclined toward each other at the top. The high pressure cylinder is $38\frac{1}{2}$ inches in diameter, and the low pressure 70 inches, and the stroke of each 10 feet. The cylinders are both steam jacketed, and have cut-off valves, though the steam is usually controlled by the throttle valve. The piston rods are connected to the opposite ends of a walking beam or 'bob' while the connecting rod to the crank which turns the fly-wheel is attached to a pin at the top of the bob. This connecting rod is 28 feet long, while the arms are 14 feet 6 inches. The fly-wheel is 30

feet in diameter and weighs 50 tons, its shaft being 22 inches at the fly wheel, 16 inches at the outboard, and 20 inches at the crankrod journal. The engine's speed is 5 to 7 revolutions per minute, and it works with a steam pressure of 100 pounds. The engine uses a jet condenser. The connecting rod to the pump rod is attached to the bob at the same end as the connecting rod of the high-pressure cylinder, but lower down, the distance from center of pins being 4 feet 2 inches, with 14-inch diameter journals, the journals for pins for the engine connections being $10\frac{1}{2}$ inches in diameter. The total weight of the bob is 75 tons. The foundations of the engine are 54 feet below the surface, the cut stone necessary being carried up. Over 7,000 tons of quarried work were required in the foundations. The pump shaft is 7×9 feet, with enlargements at pump and bob stations, and is heavily timbered.

"The pumps are located at the 1,000-foot and 800-foot levels, water being pumped up to the 600-foot level. The pump-rod is made of 16-inch square Oregon pine, in 60 to 80 feet lengths, the joints being made by four straps of iron, 1×12 inches by 30 feet, thus giving a lap of 15 feet. The two pump columns are 18 inches in diameter, and are riveted wrought iron.

"At the 300-foot, 500-foot and 700-foot levels are placed balance bobs connected with the pump rod, the design being to give the engine the same amount of work on the up and down strokes.

"These balance bobs each have counterweights of 29 tons. The two pumps at the 1,000-foot level have 20-inch plungers, with 10-foot stroke. The sump is 45 feet deep, but is nearly always full, the suction never exceeding 10 feet. Between 300 and 350 gallons are pumped at each stroke, the water discharging from the lower pumps into a tank located upon the 800-foot level, where two pumps similar to those at the bottom are put in. The capacity is about 2,500 gallons per minute. The engine and pumps cost at the factory \$110,000, while the total cost, including foundations, erection, buildings, pump, shaft equipment, etc., was about \$250,000. Besides the Cornish pump there are four steam pumps

underground to relieve it in emergencies, and to act as auxiliaries during the largest flows of water. There is one each at the 1,000-foot and 800-foot levels of shaft No. 3. These are 23-inch and 42-inch Knowles compound pumping engines, and have a capacity of 1,600 gallons per minute raised 200 feet, the raise being divided into 200-foot lifts by the 800-foot level. There are two additional columns of 15 inches diameter each in the pump shaft for these pumps. Steam is supplied to the pumps in No. 3 shaft by a 6-inch pipe, jacketed with $1\frac{1}{2}$ inches of asbestos, and about 1,000 feet long in all. The work done by the Cornish pump has been a great saving over the direct-acting pumps underground. Coal is hauled from the mines at Coalville, 22 miles distant, on the U. P. Ry., and costs \$4.00 to \$4.50 delivered at the mines."

In 1888, at the Ontario mine, a tunnel was begun at the foot of shaft No. 2, at the 1,500-foot level. This tunnel was to drain all the workings above that level. It required six years of the most difficult kind of work, with many mishaps from excessive flows of water, to complete this work. The tunnel was entirely through rock, no earth at all. The tunnel is about three miles long and cost in the neighborhood of \$500,000 complete.

The large amount and continuous flow of water through this tunnel led to the idea of using this otherwise wasted energy. A plant was determined upon to utilize this water to light the mine and furnish power for the shops of the mine.

The plant is driven by a 3-foot Pelton wheel which is estimated to deliver to the main belt 80 H. P. at 280 revolutions under an effective head of 120 feet. The dynamo is an eight-pole 60 K. W. monocyclic alternator driven at 900 revolutions by a 12-inch belt from the pulley on the wheel shaft. The length of the line of transmission is six and one-half miles over a rough and broken country, 9,000 feet above the sea-level. The loss in transmission at full load is estimated to be 11 per cent. This plant supplies light to 700 lamps of 16 C. P., at 110 volts, also drives three motors, two of 15 H. P. and one 25 H. P.

"Two engineers are employed to run the Ontario electric system, each of whom runs the plant twelve hours daily. No labor is involved, owing to the steadiness of the load both day and night, the attention required in the power house is limited to the inspection of oil in the various bearings and the starting and stopping of the plant at the beginning and end of each run, at which time the machinery is wiped off. The entire system at any instant involves only the attendance of the engineer at the power house, who also makes any slight repairs or alterations required from time to time throughout the distribution. The operating expenses therefore include only the engineer's pay, occasional repairs and lamp renewals."

It is estimated that the saving in oil and fuel by the use of this plant is \$3,000 per year.

The drain tunnel is being extended so as to drain the Daly mine also. This will give additional power and the present plant has probably been enlarged as was contemplated. In this way Park City may be lighted and also power supplied to various industries, thereby making the plant pay dividends.

The great Cornish engine is retained to be put into service when the time comes to go below the 1,500 foot level. The steam pumps which were used underground have been taken out, chiefly on account of excessive cost of operation and partly on the supposition that the Cornish pump will be able to handle the water until a very much greater depth than 1,500 feet has been reached, as the drainage tunnel takes care of all the water above the 1,500-foot level. The Cornish pump would pump and discharge all water below the 1,500-foot level into the drainage tunnel, thus increasing the power of the electric plant.

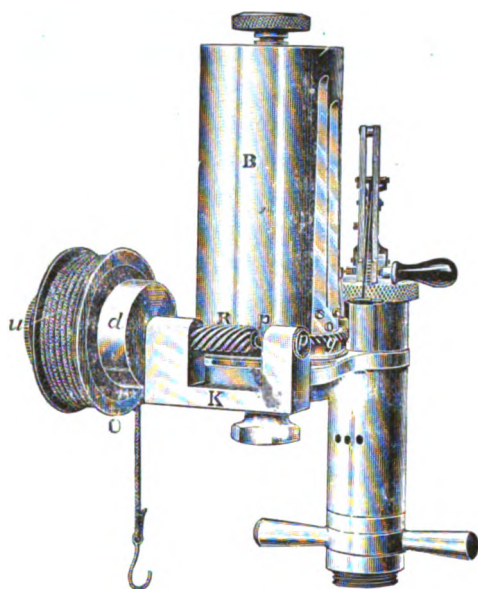
THE STEAM ENGINE INDICATOR.

The steam engine indicator is an instrument which has made possible the high perfection attained in the steam engine. As the steam indicator has been improved, it has been followed by an improvement in the steam engine. The reason for this is that, primarily, the steam engine indicator is an instrument or machine, if you please, for the recording of pressure; it is an instrument, the results of which show exactly what has taken place inside the steam cylinder. As the physician is enabled to diagnose a case by certain symptoms and characteristics, so the steam engine indicator, by an inclosed line, called the indicator diagram, shows to the engineer the faults as well as the merits of his engine.

The modern steam engine indicator has, in a very large measure, placed the science of steam engineering in the advanced position it now occupies. Invented by Watt about 1814, to assist him in the improvement and developement of his steam engine, it has gone through various stages of advancement, until to-day we have it as nearly perfect in finish and action as it is possible to make it. Its workings are perfect and its results truthful, and to be thoroughly relied upon, limited only by our present knowledge of steam engineering.

The results of the application of the steam engine indicator to the steam engine show the engineer what power his engine is developing and the defects which cause the waste of steam. It shows by the diagram whether or not the valves are working properly and economically, whether the engine is working beyond or under its rated power.

A large number of engines are to day running at a great loss to their owners, and are annually wasting thousands of dollars in fuel, simply because their owners are either ignorant of the indicator's usefulness, or are making too much money to care how



Tabor Indicator with Houghtaling Reducing Motion.

much their engines waste. The application of the indicator would lead to the discovery of the cause for this waste and point out the remedy. Valves are not set now by guess work or rule of thumb, but by the indicator. Most makers of high-grade steam engines now guarantee their engines to develop a horse-power on a definite number of pounds of steam per hour, and will back up their guarantee by a test.

A cut of the Tabor indicator is shown above. This indicator is supplied with the Houghtaling reducing motion, and the letters refer to a description of this device rather than to the indicator proper.

The steam engine indicators on the market at present are built upon one general plan of construction. There is a steam cylinder and a paper drum, B. The steam cylinder is made to be

attached to the engine cylinder, and so takes steam when the engine does. A small piston, which moves inside the indicator cylinder, gives motion to a pencil, which moves in a slot in a straight line, and this movement is limited by the resistance of a spiral spring against which the piston acts. The paper drum is a cylindrical shell mounted on its axis and is moved forward and backward by the Houghtaling reducing motion, which is the latest prominent feature of the Tabor indicator, as it does away entirely with the use of the pantograph and other attachments, the cord being level directly from the indicator to the cross-head of the engine. The motion of the paper drum, upon which the cord is placed, coincides with the motion of the piston of the engine, and the height to which the pencil rises is in accordance with the varying pressures of the steam, so the indicator diagram thus traced by the pencil shows a record of the pressures of steam in the engine at every point in the stroke. The Tabor indicator, as now manufactured, differs from others in the parallel motion of the pencil, produced by a pin moving in a slot. The curve of the slot balances the tendency of the pencil to move in a straight line, which gives a straight line motion. The outside of the curve is nearly a true circle of one inch in radius. The indicator springs, which are of known resistance, differ also from those of other makes. The Tabor springs are duplex and so mounted on the bearings that the points of connection of the two coils lie on opposite sides.

The Tabor indicator was invented by Mr. Harris Tabor, of New York, in 1879, and since then has undergone improvements, the latest being the Houghtaling reducing motion, which came out in 1893. This patent reducing motion is composed of a supporting base piece, K, provided with short standards that form bearings for the worm shaft, R, on which the flanged pulley, O, is rotated, the outer bearing being a pivot, p, which receives the entire thrust of the shaft, R, thus reducing the friction to a minimum. It is connected direct to the indicator upon the projecting arm that supports the paper drum, B, and the teeth of the worm shaft, R, mesh

directly with the teeth on the spool, g. Connected to the base piece, K, is a spring case, d, and on the extreme end of the worm shaft, R, is a thumb piece, u. There is also secured upon this worm shaft, R, a collar, not shown in the illustration, and through which a clutch pin secured directly to the thumb piece, u, slides. The flanged pulley, O, runs freely and independently on worm shaft, R, and has on its outside a clutch-shaped hub. To this pulley, O, is connected the actuating cord, which should encircle it a sufficient number of times to have its length, when unwound, a little more than equal the length of the stroke of the engine. The other end of the cord is secured either to the cross-head of the engine, to a standard bolted to the same, or to any moving part that has an exact similar motion, and must be connected in line from the pulley, O. Enclosed in the spring case, d, is a small plain spiral steel spring, which operates to return the pulley, O, back to its starting point, after it has been revolved in one direction by the forward movement of the engine cross-head. As this pulley, O, has an independent, rotating-back-and-forth motion on the worm shaft, R, the necessity of unhooking the cord, when the indicator is not being operated, is entirely overcome. The paper drum, B, is rotated forward by means of the pulley, O, through its worm shaft, R, engaging with the worm gear, g, and in the opposite direction, or backward, by the action of its own retracting spring. On top of the paper drum, R, is a knurled thumb-piece, made with a projecting pin on its under side to engage with a similar pin located in the top of the drum, and is to be used by the operator for moving the paper drum slightly forward, when taking a diagram, to prevent it from striking against its stop on the return motion.

To operate this device, first select a pulley whose circumference is from one-quarter to one-fifth the length of the engine stroke, so as to allow of its being revolved four or five times with each stroke of the engine. In placing this pulley on the worm shaft, R, after removing the clutch and its collar, care should be

taken to have it set on the small projecting pin on the cover of spring case, d; then replace the clutch collar and clutch, pushing the collar on to the shaft as far as it will go and holding it in place by the set-screw. Next, place the indicator in position and run out the loose end of the cord in a direct line with the pulley, O, to the point on the engine to which it is to be connected; then bring the cross-head of the engine to the extreme limit of its backward motion and attach the loose end of the cord, being particular to have sufficient cord wound on the pulley to meet the extreme limit of the forward travel of the cross-head and with one or two turns of the cord left on the pulley unwound. When the cross-head, with cord connected, is at its extreme *forward* travel, there should be just sufficient tension on the spring enclosed in spring case, d, to take up all slackness of the cord when running, and without overtaxing the spring. If, upon starting the engine, the cord should at first run unevenly on the pulley, O, turn the indicator slightly until a perfect and uniform winding of the cord is obtained, and which can always easily be secured. When pulley, O, is running, motion to the paper drum, B, is obtained by pushing in the thumb-piece, u, to which the clutch pin is secured. When ready to take diagrams, after placing the paper on the drum, B, it is necessary to advance the drum fully one-quarter inch, and which can be done by turning with one hand the knurled top thumb-piece. While holding the drum in this position, with the other hand push in gently the thumb-piece, u, to start the paper drum in motion. The motion of the paper drum, B, can at any time be instantly stopped for removing the diagrams taken and removing the paper, by withdrawing the clutch thumb-piece, u, or by turning the top thumb-piece, the latter method being preferable. The stopping of the paper drum will not have any effect in the motion of the pulley, O, which will continue to revolve independently while the engine is in motion.

The indicator is a delicate instrument, and to use it success-

fully, one must thoroughly understand it, for there are many details in its construction, operation and care that must be studied. Almost any skilled mechanic may readily learn to use it, while it is one of the principal instruments of the mechanical engineer. This instrument complies with all the requirements of stiffness, lightness of parts, correct standardization and beauty of finish.

32
49
PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
VOL. 7, PP. 41-54.

THE COLORADO CENTRAL LODGE, A PARADOX OF
THE MINING LAW.

BY

ERNEST LE NEVE FOSTER

DENVER
PUBLISHED BY THE SOCIETY
MARCH, 1902

THE COLORADO CENTRAL LODE, A PARADOX OF THE MINING LAW.

BY ERNEST LE NEVE FOSTER.

Read at the Meeting of the Society, February 1, 1902.

Between two of the sources of Clear Creek which rise in the Continental Divide of the Rocky Mountains southwesterly of Georgetown, the one near Argentine Pass, the other near Gray's Peak, a spur of the mountain breaks off from the main range near Gray's Peak and extends for seven or eight miles, till it terminates at the head of the valley at Georgetown, where these streams unite.

The upper portion of this spur is known as McClellan Mountain, whilst the lower end which overlooks Georgetown is called Leavenworth Mountain. These mountains embrace part of the rich silver-bearing locality known as the Georgetown district. It was on this spur that the first discoveries of silver were made about 1864, in what was at that time named the Belmont Lode, but has subsequently been renamed, and is now known under the less euphonious title of the "Johnson Lode."

At the time when Wm. P. Linn, in the fall of 1872, discovered the Colorado Central Lode, on Leavenworth Mountain, Clear Creek County, Colorado, the principal mining carried on in the then Territory of Colorado was restricted chiefly to Clear Creek and Gilpin Counties (the boundaries of which are to-day the same as they were at that period), though some mining was also done in Boulder County, and the rich placers of Summit County, in

Georgia and French Gulches, were turning out considerable gold. The means of communication at that time being very limited, except by the stage coach, the ox team and the burro, the more distant parts of the mineral-bearing area of Colorado were but little heard of. The chief interest in Colorado at that time centered in the silver industry, and Georgetown became the most important town in the Territory, the search for silver being the lodestone which attracted the miners from the gulches which had formerly occupied their attention.

On account of the large amount of rich float ore which was found on the southerly slope of Leavenworth Mountain, commencing about a mile and a quarter from Georgetown and extending for upwards of a mile along its trend, affording an excellent living to a large number of men, who dug for and collected it, the opinion became prevalent that a rich mine must exist in the vicinity, the finding of which would mean a realization to the fortunate discoverer of the hope of every prospector. This led to a large amount of prospecting work being constantly carried on, and, in addition to the ordinary trenching, boom ditches were dug to wash away the superincumbent overburden, or "slide," as the prospectors technically called it, to lay bare the bed-rock, with hope of finding the long sought-for treasure.

The overburden on the mountain where the rich ore was found was exceedingly deep, varying from 40 to 125 feet in depth, which rendered the search for the original lode quite difficult, and it was not until Wm. P. Linn, led partly by chance, partly from keen observation of the prospector, sunk a shaft through this detrital matter, and had the good luck to alight upon a large body of rich argentiferous ore at the depth of fifty feet, that what was afterwards known as the Colorado Central Lode was uncovered and it became generally admitted that the long-sought goal had been at last reached, although portions of the lode had been previously found; but, not showing the extreme richness expected, had either been entirely or temporarily abandoned and neglected.

But Mr. Linn and his successors were not destined to enjoy

the fruits of their toil without much opposition. Claims and counter-claims have continually beset the owners of this property from the time of its discovery to the present time. Only within the last month a suit to recover damages for ore claimed to have been taken by the owners of the Colorado Central from an adjacent claim has been instituted.

The litigation over this mine has been among the most important and persistently fought in the courts of this State, the Colorado Central having at all times to defend its rights against all comers, those upon both sides of it claiming that the ore being extracted belonged to them.

The geological conditions which exist are by no means complex, the rocks being considered archæan. They may generally be described as gneiss, yet the lithological character will be found to vary considerably, as well as the physical characteristics of color, texture and compactness, and almost every grade of condition, from pure mica schist and gneisses to the highly crystalline metamorphosed granites can be found. These, again, are intersected by porphyry dikes and igneous rocks, indicating, at least, that Leavenworth Mountain is partially of igneous origin.

The litigation in which the Colorado Central Lode has been involved almost from the day of its discovery to the present time, first in the Territorial and State courts and later in the Federal courts, the decisions of the latter being carried to the U. S. Court of Appeals and the Supreme Court of the United States, has undoubtedly been due, first, to its great richness, the output having been something like \$8,000,000, and, secondly, to its physical characteristics, which could not be made to conform to the simple definition of a lode, and even this restricted to a narrow width, which Congress must have contemplated when it framed the mining law of 1872.

"The space occupied between planes more or less parallel and extensive for a greater or less length, both in depth and horizontally, which have been filled with a variety of minerals, metallic and non-metallic."

and which has led to the paradox of two cases determined before the same court (the U. S. Circuit Court for the District of Colorado) under identically the same facts, conditions and class of testimony presented to it, and curiously enough with nearly the same attorneys opposed to one another, yet deciding in the first instance (*Equator Co. vs. Colorado Central*) that there was a large broad lode, containing numerous ore-streaks, but in the other, on the adjacent ground west (*Turek vs. Colorado Central*), that it was no such thing, but that it was a series of narrow parallel lodes.

Whilst courts and juries listen to a number of witnesses who are more or less practical and theoretical, as to the facts of the occurrence, which is then confused and rendered as complicated, unintelligible and contradictory as possible by the cross-questioning of attorneys, in arriving at a conclusion they appear to consider of greater importance the technicalities of the language of the statutes than the genesis of ore deposits, or the probable method of their formation, and are thus able to arrive at paradoxical conclusions. On the other hand, the duty of the geologist and scientist is to delve more deeply into the mysteries of nature and obtain facts from which fair deductions may be made as to the class of deposit under investigation.

The Colorado Central Lode was described in 1874 by Raymond*, thus: "It is an enormous size, being in the Weaver shaft, more than seventy feet, cross-cuts having been run to that distance without reaching any walls." In his conclusions then made, with only a limited amount of development, I do not think he was in error, and as will be shown you hereafter even a greater width may be assigned to it in many places.

The lode has a strike of about N. 40° to 45° E, and is practically parallel to the trend of the mountain, its dip is a little to the northwest. It has been explored and exploited for three-quarters of a mile in length, under different names and with profitable results. Its back or apex has, for long distances, the

*The Mineral Resources West of the Rocky Mountains, p. 296.

appearance of having at a remote period been the bed of an ancient water-course, which probably flowed from the foot of the old glaciers which undoubtedly at one time covered that portion of the Rocky Mountains. That this was the case is evidenced by the boulders and various erratic stones, strangers to the locality itself, which are found filling the lode space just below and above the bed-rock and from their spherical and amygdaloidal shapes attesting most conclusively that they have come from a long distance.

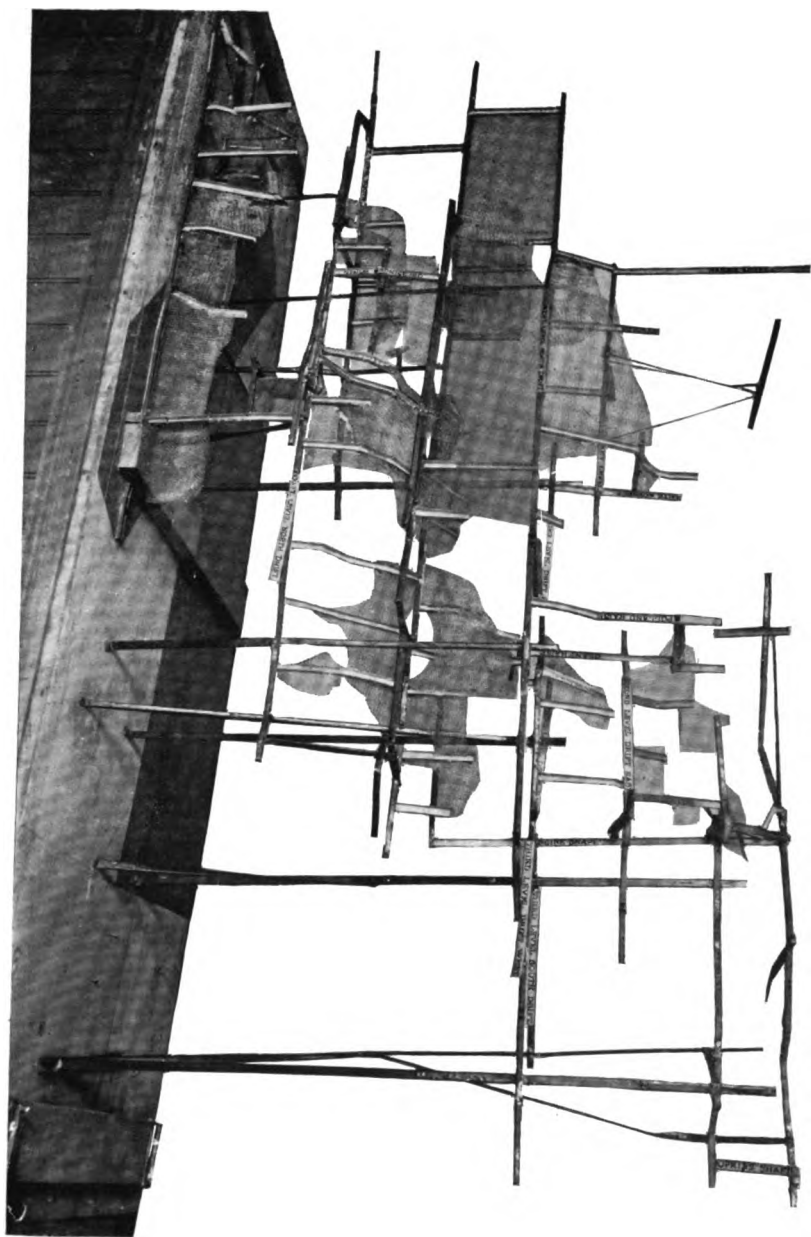
The lode, by those who have looked upon it as the mother-vein, has always been considered as having for its walls porphyry dikes on both the hanging and foot-wall sides, and whilst this is true to a large extent, it is not entirely so. There are parts where the granite seems to be the true wall of the lode. It may, therefore, be concluded that the original fissuring which resulted in the formation of this vein was caused by the intrusion of these porphyritic masses.

An interesting feature in the so-called porphyry found upon the north wall of the lode is its lithological character, which conclusively points to an igneous origin for parts of Leavenworth Mountain. The rock, of which specimens are before you, show it to be a pitchstone, which by regular gradation passes at times into large bodies of true obsidian, locally called "abyssinia" by the miners. For twenty years after the discovery of the lode, this was considered the boundary of the ore-producing area, but about 1892 cross-cuts were driven through it at the 600-foot level and developed on its north side a very rich vein of argentiferous ore. The dike at this point was found to be only twelve to fifteen feet in width, and subsequent development shows it continues very uniformly so for a long distance, though east it appears to thin out and the ore vein north unites with that on the south. Going west-erly it is not yet determined whether it continues to separate or comes back again into the lode. Toward the surface it maintains itself as a separate vein the whole distance till the debris is reached.

For the greater clearness in explaining the peculiar characteristics of this large ore-bearing zone, varying from 25 to 150 feet in width, which I have designated as a mother-lode, whilst others have seen fit to call it a number of lodes, I have the advantage of showing you a model, which I made to scale several years ago, of a part of the workings of the lode 1,200 feet in length and 750 feet in depth.

The model* being of rather unusual construction, a brief description of it will not be out of place, especially as, in my opinion, it is the most clear way of representing underground workings that has ever been devised, therefore I will digress for a few minutes from my subject to explain it. It perhaps is best described as a skeleton in which the excavations for levels, shafts and stopes are represented by a solid material, whilst the country rock and unworked ground is supposed to be removed, and hence appears as space. In this model the configuration of the surface is not shown, but there is no difficulty in so doing by the use of a screen cloth of suitable texture formed to represent it by means of the necessary contour lines. In order to construct the model, a complete survey and plans is necessary, then by means of trough-shaped or solid strips of tin or other metal, each level is made to conform accurately to the map. The shafts are also made in the same way, and the levels are connected together by means of the shafts and winzes in their exact relative position, easily determined by using a map as the base on which to build up, and dropping plumb-lines at different points to insure the levels being perpendicular over the points shown in the plan. Any good tinner can do this work under the direction of a surveyor, and perfect accuracy can be obtained. In almost all cases the stability of the structure will be sufficient from the shafts and winzes which connect the levels, otherwise a special wire here or there may be used

*This is not an original idea, but is constructed in its leading features after a model in the Museum of Practical Geology, Jermyn St., London, constructed by T. B. Jordan, of the Holmbush Mine, and was exhibited at the International Exhibition, in London, in 1862, described in Reports of the Juries' International Exhibition, 1862, p. 13.



for that purpose. To designate the ground that is worked out, pieces of screen-cloth cut to the shape of the stopes, soldered in their proper position to the channels forming the drifts, will be found the most convenient material to use.

If it is desirable to show the width of the stopes, which is seldom the case, it can also be done by using double widths of screen-cloth, separating them by scale measurement to their proper width. On the base of the model from which the plat used in construction has been removed, can be painted the surface lines of the claims, thus also showing very clearly the relative position of the surface claims to the underground workings. Therefore, by coloring the different workings by a suitable system, it matters not how complicated the network of shafts, levels and stopes may be, they are all shown in their natural position, and at a glance the bends and caprices of the workings and ore channels both horizontally and vertically, no matter how intricate, can be grasped.

The material forming the matrix of the lode, locally called "crevice matter," has a resemblance in many instances to the surrounding country rock, and contains the same constituent minerals as gneiss and granite, as well as of the adjacent pitchstone dike.

In most places, however, it has undergone more or less change due in all probability to the same causes which operated in the deposition of the silver-bearing minerals in the numerous ore channels which ramify in all directions through the matrix of this large lode. It is, therefore, not surprising that sometimes in cross-cutting through the matrix, places are encountered where this vein-matter has a great resemblance to the country-rock of the district, and if examined alone would likely be considered a portion of the country-rock, but the facts connected with its occurrence demonstrate that it comes from within the boundaries in which at any point ore in paying quantities is liable to be met with, and being within the walls of the lode must either be considered as country-rock (forming a horse within the lode) or as a part of the matrix of the lode itself, but in any case it is a portion of the lode.

That these masses of rock which have the appearance of gneiss and mica schist (a large amount of mica being often present) at certain points are not part of the general country-rock of the district, but should be considered as true vein filling, or lode matrix, is most clearly demonstrated when an attempt is made to follow them for any considerable distance, or in most cases even for short distances, as it is found that they either gradually change into what no one would deny to be lode matrix or cut-off in every direction, and are, as it were, detached masses, horses, or islands of this class of rock in the general matrix of this broad lode.

The ores, which occur in streaks and seams, which I have designated as "channels," as being a more appropriate term with which to describe them, on account of their irregularity, are chiefly the sulphides of lead and zinc (galena and zinc blende) though iron pyrites in small quantities also occurs, enriched by true silver ores. And of these there have been found in this lode argentite, pyrargyrite, proustite, tetrahedrite, stephanite and polybasite. These occur sometimes quite massive, at other times so finely distributed between the cleavage planes of the sulphides as not to be distinguished by the eye. Crystallization of the minerals is extremely rare, few instances having come under my observation.

Concerning the effect of depth upon the value of the ores, although the mine is worked to a depth of 1,000 feet, no particular difference is to be noted. Rich and poor ore channels are found at all depths. Within 100 feet of the surface some of the richest and some of the poorest were encountered, and the same might be stated of almost any depth. Upon the same horizon were found bodies of ore which were rich in silver and others which were poor in that metal. The poor ores were apparently the same galena and zinc blende which in another place were enriched by the true silver minerals, and were therefore rich in silver.

The average silver contents of this ore for a period of sixteen years, of which I have a record, was upward of 200 ounces per ton and I have no doubt that the whole output of the lode, from the

time of its discovery to the present time, is equally as high, since from an old report, made in 1877, being previous to the time of which I have any record, I found the average contents of the three years prior given as 350 ounces silver per ton. In my connection with the property for sixteen years, I know of only one instance in which gold was found in sufficient quantity to be paid for by the smelter, and that was in a lot of concentrates containing considerable pyrites, which yielded about one-quarter ounce gold per ton.

The ore bodies have sometimes been of considerable extent laterally, but more frequently have been short, in width the workable ores have been from one inch to as much as four feet, but their mode of occurrence is the most convincing feature that they belong to one great lode, and are not distinct lodes separated by country-rock. They occur in what I have before termed channels, as expressing more clearly their character. These are most intricate in their characteristics, and show as many warps and windings as are seen in the bed of a stream crossing over flat ground. Yet there appears to be one main, and I might say, universal law which they follow, which is that they all finally make over to the north wall of the lode. This would seem to imply that whatever force may have caused the erratic fissuring of the mass of the vein matrix, the ore deposition whether by infiltration, precipitation or gaseous vapors, in all probability found its access along the north wall, and from it into the numerous subsidiary channels which ramify in all directions through the matrix.

An examination of almost any of the cross-cuts driven through the matrix shows general fissuring of the mass filled with metallic minerals, from the thickness of a thread to some several feet in width; as an instance, the Nelson cross-cut at the 750-foot level, showed metallic contents at 7, 13, 17, 22, 27, 38, 44, 50, 61, 72, 81 and 96 feet, measuring from the north side of the north drift. Some of these were workable seams, others not.

An observation of the ore-channels as they occur throughout the matrix, shows them to have no regularity of strike or dip, and

even the large ones frequently become barren of valuable mineral contents, and finally fade out or are completely lost in the general matrix of the lode, so that the presence of ore bodies may even remain unknown, though a cross-cut may be driven entirely across the lode only a short distance from them. A striking example of this fading away of an ore channel into the matrix of the vein was developed at the 500-foot level of the workings of the Colorado Central Mine. At a point about 170 feet east of the Eudy cross-cut, starting from the south ore channel, an intermediate one branched off and separated from it, carrying a large-sized body of rich silver ore. This ore channel was followed for a distance of about 100 feet into the center of the lode, and to within about 60 feet of the Eudy cross-cut. It would be natural to expect this intermediate ore channel would be intersected in the Eudy cross-cut, but the fact was proven that nowhere in the vicinity where the crossing should have been found was any channel visible, proving conclusively that it must have faded away in the unbroken 60 feet of ground, and of this class of ore channels numerous other similar instances could be given.

This is one proof that the channels exist for only a limited distance and that they are not separate and distinct parallel veins occurring in country-rock. Perhaps the best illustration of the way in which ore channels fade out is explained by the manner in which colored streaks occur in a glass marble, some of which may be wide in places and yet thin out until they become invisible, yet no one would attempt to deny the existence of streaks because they did not permeate every portion of the marble.

In stoping it was found that the same ore channel did not always follow continuously from one level to another, but as one in its upward course faded out into the matrix another was found by cross-cutting a few feet into the matrix to one side or the other, or possibly a small thread of mineral might lead from one to the other, indicating the variety of directions in which these subsidiary ore channels dip and strike.

The variety of strike and dip in these ore channels is well ex-

emplified by the following: The main ore channel along the north wall upon the 400-foot level has a general direction of north 42° east, and stands nearly vertical.

Just west of the Harris shaft on this level is an ore-channel with a strike south 15° west and a southeasterly dip of 60° to 65° . At the 500-foot level, a diagonal ore channel crosses the matrix at the Longacre cross-cut, another at the Forslund cross-cut and still another at the Hoaglund shaft. At the 600-foot and other levels similar occurrences are found. At the 650-foot level, the Stewart ore channel was followed on a course south 70° east, or nearly at right-angles to the main course of the lode, and it stands nearly perpendicular. At the 750-foot level there are several ore channels having courses diagonally to the main ore channel on the north porphyry, which unite with it at various angles of dip and strike. At one place in the stopes above this level there was a channel followed for a considerable distance which was nearly horizontal. A section at the Hoaglund shaft shows a fine exemplification of the dip and strike of a number of workable ore channels. Near the top of this shaft is the Eudy cross-cut, 70 feet long, exhibiting a good section of the mine. Just south of this there was a body of ore in the south ore channel, and with it, few feet above the level, united what was known as the great flat ore channel, its strike was about south 70° west and dip 50° north, whilst that of the south ore channel was about south 35° west, its dip 10° northerly. On this flat ore channel, the Hoaglund shaft was sunk to the north 600-foot level, and connected with it by a short cross-cut. As the flat ore channel unites with the north ore channel a little below the 600-foot level, the north ore channel at this point was also productive, being nearly perpendicular, the inclination being not to exceed 10° to the north. Between the north and south ore channels, which were considered the boundaries of the lode, two other workable ore channels were found and stoped upon. The strike of these agreed with none of the others—the first, found at a depth of 40 feet, had a small dip to the north nearly parallel to the south ore channel, though with a dif-

ferent strike, whilst the second one, 20 feet lower in the shaft, had a southerly dip, with still another direction of strike, and going upward united with the north ore-channel. The great flat ore-channel shows a still further peculiarity, in that it is not perfectly tabular like a regular vein, but forms a kind of wave both on its dip and strike. At the Hoaglund shaft it unites with the north ore channel below the 600-foot level. To the west of this point and near the Webster shaft, the union occurs some 50 or 60 feet above the 600-foot level, whilst about 200 feet further west, in the Nelson mill-hole, the junction has again come down nearly to the 600-foot level. The above have only been given as examples of these occurrences, and not as all that are known to exist, since their enumeration in the seven or eight miles of workings which have been made on this lode would be a long task and of no value to this paper, for the characteristics of all are similar.

A careful, unbiased and systematic examination of the occurrence of the ore channels in the Colorado Central and adjacent mines which form part of this great ore-bearing zone, the observations of their immediate connection by branches, seams, stringers and thread-like veinlets, either upon the dip or strike in the most irregular and erratic manner, together with all their relations to one another and the general matrix that surround them, the movements that have taken place in this matrix, as evidenced by the great number of slickensides frequently seen, would seem to lead to but one conclusion as to the origin of them all, and that is: That it is not possible to separate each ore channel as a distinct formation, lode or ore-vein, but that the ore channels have one common source and were probably all formed simultaneously by the same great effort of nature, and that the subsequent deposition of metallic filling was contemporaneous and from the same solutions; leading to the inevitable conclusion that, geologically at least, the whole ore-bearing zone, no matter what its width may be must be considered as one lode.

It is more than likely that the intrusion of the porphyry or pitchstone dike on the north, fissured the country-rock by main

and subsidiary cracks along the line of the country where this large ore-bearing zone now exists, breaking it up more or less extensively throughout the area which now forms the matrix of the lode, that through the intricate net-work of small and large fissures thus formed, the mineralizing solutions subsequently found their way, penetrating all portions of the mass thus broken up, attacking and decomposing the rock more or less thoroughly as conditions were favorable or otherwise to such action, forming what is now known as the gangue of the lode or crevice material, and depositing in the fissures and cracks, no matter what their size, the mineral which is now found there. Where the ore channels are large, the usual characteristics of deposition common to mineral veins are found, from the banded structure to the irregular cementing together of breccia. Metasomatic action has undoubtedly also taken place, and thus in many places larger space than the original fissures of the lode matrix have become mineralized.

Notwithstanding that, from a legal standpoint, paradoxical conclusions concerning this large mineral zone have been arrived at, and the deposit under consideration has been classed as both "fish and fowl," nothing is proved unless it be the inadequacy of the present law of the apex to provide for the great variety of mineral deposits which nature has placed in the earth. I do not hesitate to express the opinion, that the unbiased geologist will be irresistibly led to but one of two conclusions, either that it is one broad lode, the matrix of which is impregnated with seams, veinlets and irregular deposits of metallic minerals, or else that it must be classed among the variety of deposition known as stock-works. To my mind, after much careful observation, with frequent opportunity to do so, as for many years scarcely a week passed without my having been in the workings, the conclusion is reached that it belongs to the former class, and is properly termed a "broad lode."

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. 7, pp. 55-66.

NOTES ON SOUTHWESTERN UTAH AND ITS
IRON ORES.

BY

G. C. HEWETT

DENVE
PUBLISHED BY THE SOCIETY
DECEMBER, 1902

NOTES ON SOUTHWESTERN UTAH AND ITS IRON ORES.

By G. C. HEWETT.

Read at the Meeting of the Society, April 5, 1902.

The area embraced in the St. George topographical sheet of the U. S. Geological Survey is an extremely interesting one, and, having made several visits there to examine properties, widely separated upon it, I have acquired details at several points and a general impression of it which may be of use to others. These examinations are, as we all know, necessarily hurried—clients are waiting—and this must be my excuse for the many omissions from the map herewith.

This area includes the southern extremity of the rim of Salt Lake basin in the Pine Mountains, the Escalante Desert and Cedar Valley, which were covered by the waters of Lake Bonneville.

Prof. J. J. Stevenson, with Lieutenant Wheeler's expedition, was the first—in 1868—to write of it, in Vol. III and Supplement of that report to the War Department. But, unfortunately, the design of this survey was never completed, and most of its work was in New Mexico and Arizona. This is the only government survey of the region. Captain C. E. Dutton's High Plateaus of Utah covers the area east of the Hurricane fault, which deserves his designation of "great," as it has a length of 140 miles, and an upthrow to the east, at Cedar, of 12,000 feet. It is as well marked topographically as geologically, the summit

of the Colob plateau being 4,000 feet above the desert valley below it. Mr. G. K. Gilbert, the authority on Lake Bonneville, has shown that the Hurricane fault has been the site of movement in post Bonneville time, and considers it probable that the movement is still in progress. About 1880, Prof. J. S. Newberry visited the iron ores, and published a note in the *School of Mines Quarterly*, which is probably as inaccessible to our members as it has been to me. I have been unable to find a copy.

The Tenth Census, Vol. XV, contains some notes by B. T. Putnam and a number of analyses, which agree well with those given here.

Prof. W. P. Blake writes, in Vol. XIV, *Transactions Amer. I. M. E.*, of a hurried examination made by him and Prof. G. W. Maynard, but he probably was not at liberty to go into details, and the result of their work does not appear to be in print elsewhere.

Professor Stevenson says that Lake Bonneville had no southern outlet, and he probably examined the ground personally and is correct; but his assistant, Mr. E. E. Howell, writes that he and his party were unfortunately prevented from completing their work at this point.

A comparison, however, of their respective drainage basins and the amount of erosion performed by the Ash, Santa Clara and Virgin would suggest that a greater volume of water must have gone down the former than the area of the present basin would produce, but possibly the movement of the Hurricane fault may account for some of the greater amount of erosion by the former.

The Summit on the O. S. L. Railway, southwest of Desert Spring, is flat and gentle on both sides, and the descent to Meadow Valley wash on the west, though the steeper, is gentle, and it would appear that the water of Lake Bonneville never was high enough to make an outlet there. The Mountain Meadow Pass, the only other possible outlet, is 250 feet higher than the O. S. L. Summit, and 1,000 feet higher than that of Ash Creek. The little park at this summit was the scene of the famous massacre of an immigrant train by a band of outlaws, some of whom had been

employed by the Mormon Church, but which has always disclaimed any responsibility therefor; and there is little doubt that the main object of the attack was robbery, and not religious persecution.

The mountain range on the Nevada State line is largely eruptive and contains, as shown, the promising gold camp of State-line. There is evidence that the eastern boundary of this eruptive is a fault line, and the quartzite and limestone forming the eastern ridge are occasionally copper-stained, though no values are known to have been obtained here. The Horn Silver Mine, fifty miles northeast, is adjacent to a prominent fault line, which is said to be the same as that shown, or a parallel continuation of it.

East of the Hurricane fault the Colob plateau is composed of sedimentaries dipping about 5 per cent. north 20° east, and much covered by lava extrusions. The lowest measures exposed in the southeast escarpment are Trias and Jura red sandstones. These are covered by about 2,500 feet of Cretaceous, which, at an altitude of 9,000 feet, reaches the Laramie. This formation here contains two coal beds; the lower could not be measured. The following is a section of the upper, taken eighty feet in the workings:

- Bituminous clay shale roof;
- Twenty-four inches coal and bone;
- Nineteen inches of coal;
- Four inches sandstone;
- Eighteen inches coal;
- Forty inches coal, soft;
- Seventy-seven inches coal.

The lower bed is not so thick, but is believed to be freer from impurities. The cover over the upper is about 500 feet, part of which is lava, which, from its freshness, would appear to have come up through the coal beds on a crevice having a course of about southeast. The face of the escarpment does not disclose any dike, but the surface is steep enough to carry away any lava boulders, and the oak scrub is quite dense.

The Laramie sandstones and shales, with lava flows, cover the plateau northward until the head of Cedar Creek is reached. Just off and east of the edge of the map, the Eocene conglomerates and sandstones form precipitous cliffs. Northward to the departure of the Laramie from the map, the Tertiaries rapidly increase in thickness, owing to the dip of the Laramie.

The Hurricane fault is a single one at many points, but at the mouth of Cedar Creek there are several planes of faulting, and at least one fault branching off to the northeast at an angle of about 30° . This has disturbed and twisted the coal horizon so that no development there has been successful. On the gulch entering from the south, three openings have been made on the coal, and one in an undisturbed area where the bed is nearly clean and about six feet in thickness.

Further up the stream, on the south side, is another opening on good coal, though there is a probability that a fault exists between it and the main mountain to the south. Above the forks of the creek, where the coal horizon comes down to the ascending creek, is a promising mine, where the bed measures, viz.:

Shale roof;

Fourteen inches coal;

Fifteen inches coal;

One inch rock;

Twenty-six inches coal;

Clay and coal pyritous.

Maple Creek, entering from the north, cuts the Laramie deep enough back of the faulted area to allow a promising mine opening, though sufficient prospecting has not been done to show the size of the beds in place.

These coal beds, unfortunately, do not yield a coking coal with usual and commercial treatment, nor is there any reason to suppose, from geological surroundings, that this desirable quality has been given them at any point in the plateau. There is one locality

where the close proximity of an eruptive has reduced the percentage of combined oxygen to a point at which the coal will just barely agglutinate, but no further improvement is to be expected.

Average samples of the beds were taken at several points, and below is a representative analysis:

Water	7.24
Vol. H. C.....	42.01
Carbon	44.67
Ash	6.08

Sulphur, mostly organic, 5.77 per cent.

These beds, at favorable localities, produce a good coal, are firm, bright, and can be commercially freed from contamination. It is also possible that it may be coked by new and more expensive methods of treatment. Then may remain the question—for some uses of the coke—of the sulphur.

The above percentage of sulphur, though very high, is still not necessarily a bar to the use of the coal for steam production. To throw some light on this, a weighed coil of small-gauge iron wire was covered in a crucible full of the powdered coal and heated in a muffle to the heat used in gold assaying, or say 1800°; in eight minutes the wire was found to have gained in weight 5 per cent., part of which was oxygen, but the greater part must have been sulphur.

The permanency of these coal beds is open to some question, but enough exploration has been made to show that the district will compare in this respect with some of the large producing districts of Colorado. Nevertheless any large development should be preceded by detailed examination, as there are large areas where the coal beds will prove unprofitable.

Near Cedar, the western side of Hurricane fault is covered with lava overflow, alluvium and the desert.

The ridge between Cedar Valley and the Escalante Desert has an eruptive core north of the map, and the Cedar Creek gap, or Iron Springs, is near the southern end of this intrusion. The eruptive here is a diorite, which on the north side of the gap in-

cludes three dikes of magnetite with courses approaching an east and west direction with length from 250 feet to 700 feet, from 5 feet to 15 feet in width, and standing as much as 18 feet above the general surface.

Southward of the gap, after the desert land is crossed, the diorite again forms the surface, and above it, and about 250 feet above the desert level, are three drifts in a distance of half a mile, dislosing from three feet to twelve feet of stratified soft limonite ore. The southernmost drift shows the ore interbedded with limestone; in the others the limestone is near, but its relation to ore is not distinct. On the hill between is a dike of magnetite similar to those at the north, but not so highly magnetic. Westward and over the ridge, in a low, sandy wash, are a number of occurrences of both magnetite and limonite, but the prospecting was so slight and the mantle of the debris so heavy that their relations could not be deciphered.

Southward this ridge is sandstones, and westward lie two low buttes, called desert mounds, composed of sedimentaries showing diorite exposures and debris. One of the summits has scattered fragments of magnetite.

Ten miles southwest of Iron Spring is the boss, or eruption, of Iron Mountain, which uplifts heavy limestone measures from the northeast around to the west, where the Eocene is in contact with it. Whether the Eocene was involved in the upheaval is uncertain. On the extreme north, lava and desert sand covers the eruptive contact, but from their dip it is probable the limestones are below the surface. The age of this limestone was supposed by Professor Newberry to be Silurian. No fossils were found in it, and it is thought to be the same age as the Eureka limestone of the Tintic district, which, on the evidence of one fossil, is placed in the lower Carboniferous by the U. S. Geological Survey. The Tintic folio, U. S. Geological Survey, describes two iron ore occurrences, one on the contact between the monzonite and the Eureka

limestone, and one near it, and an earlier and more acid eruptive. The iron ore there is supposed to be a leaching from the eruptive.

Some ten years ago, on the northeast edge of the eruptive contact with the limestone, some horn and native silver was found in a copper-stained crevice. There have been three shafts sunk in the search for a lode, and in the work some pockets of copper sulphate and silicate were disclosed. Cross-cutting in one shaft has opened about fifteen feet of limonite ore in the limestone, much intermixed with clay, and some copper salts deposited in small pockets. This iron ore is unstratified. This property is being prospected for copper.

West of this, and up on the mountain in the eruptive, are some iron prospects which were not visited.

At three points on the eruptive contact, to the east, south and southwest, tunnels penetrating the limestone show interbedded bodies of limonite ore with some hematite from eight feet to thirty-five feet across, dipping with the limestone. This ore is low in silica, with a small amount of clay in bunches and thin seams. At two points the ore shows bedding planes parallel with the limestone.

The limonites were all sampled across their width, the large samples cut down to a sample sack full, or about two pounds, and analyzed for iron and phosphorus. The average of all is 56.66 Fe. and the phosphorus ratio, or part to 100 Fe, determined as .194, which is well within the limit for the acid Bessemer process for steel.

Inclosed in the diorite laccolite are four ledges of magnetite showing bedding planes like the limonite, varying in thickness from six to fifteen feet and lengths from 80 to 850 feet. These ledges or dikes in the eruptive stand nearly perpendicular and may go to considerable depth. The longest one forms the crest of the diorite mountain mass and is horizontally over one and one-half miles from the nearest limestone contact. They would appear to have fallen into or been caught in the eruptive before the solidifi-

cation and the heat to which the limonite was subjected was sufficient to expel the water and part of the oxygen. At the extreme southern contact on the southern line of section 36, township 36, south Range 20 west, is the so-called Great Blowout, or Iron Butte, a mass of magnetite and hematite 200 feet in width, 100 feet visible height and 475 feet long. This mass certainly contains 250,000 tons, and may easily yield, in depth, several times that amount. In some places quartz is visible, as the filling of cracks and lining of vugs, in such a manner as to prevent selection by cobbing and to indicate deposition from water.

The average of eight samples of the ledges of magnetite shows iron 62.56 per cent and phosphorus ratio .146. Mr. Putnam's analysis of some exposures gives 65.76 Fe, phosphorus ratio .123.

The limonite ore is very regular in analysis, is sometimes pulverulent and of low specific gravity, and again solid and hard enough to require explosives to mine it.

The magnetite reefs are usually hard, dense and tough. Silica is more often visible on the bedding and joint planes. In one of the magnetite reefs north of Iron Spring apatite crystals are arranged largely perpendicular and close to the bedding. These crystals reach one and one-quarter inches in length by one-quarter inch in breadth, so that the phosphorus could be reduced by cobbing and selection. Professor Blake says the northern reef at Iron Spring furnishes the strongest lodestones found in the United States.

The average of 32 analyses is: Iron, 63.50; silica, 8.36; sulphur, .06; phosphorus, .132; phosphorus ratio, .207.

Two assays were made for gold and silver, and the best gave 80 cents in gold.

The amount of visible ore in the whole district approaches a half million tons, with probability of double that amount. In addition, there is a reasonable expectation that prospecting in the limestone will open large amounts of limonite ore. It should be

remembered here that the Silurian and Cambrian are the ages of large iron ore bodies in the Appalachian valleys from Pennsylvania to Alabama; also in other parts of the world.

The iron ores have been known since 1850, and in 1870 and subsequently the Great Western Mining and Manufacturing Company, fostered by the Mormon Church, expended perhaps \$100,000 in blast furnaces and other development, endeavoring to use the adjacent coals, and finally produced, it is said, 400 tons of pig iron, which was probably used in stamp shoes and dies at the Horn Silver Mine.

The water facilities at this southern field are quite meagre. Within a radius of five miles there are but four springs of water, and that radius could be doubled without adding substantially to the supply. However, there is probably water sufficient for domestic uses and for the steam power that may be necessary. But smelting or manufacturing are prohibited unless underground supplies can be developed, which would appear to be possible.

In the northern, or Iron Springs district, all the drainage of Cedar Creek, which irrigates about 1,500 acres of tilled land, must be not far below the surface.

In Bull Valley, beyond the edge of the map forty miles to the west, and on the Nevada line, there is said, on credible information, to be similar interbedded iron ores in limestone.

STATE LINE.

This gold camp on the western edge of the map has much low grade ore in sight, and one mine which has yielded several cars of high grade. There are a large number of narrow, decomposed lodes with north 10° east course in rhyolite, which covers most of the area. Crossing these nearly at a right angle are several large and quite permanent lodes, with vein-filling of baryta and quartz; these ordinarily carry silver sulphides and a little gold. One of these lodes where the gold is predominant and largely free, has had a 20-stamp mill erected, and ran profitably

for some time, but is now said to be idle, presumably for lack of ore.

The high-grade mine is at the intersection of the projections of two of these different lodes, and at the contact of a later intrusion, and is possibly a concentration of values from the earlier lodes. A diligent search has not yet revealed similar conditions elsewhere, but there is a great probability that other local enrichments will be found with further development.

Copper.—The mine marked, in the Beaver Dam Mountains west of St. George, is the Dixie copper mine, which is a replacement in limestone of oxidized ore on the contact of an eruptive dike, which has been worked for 300 feet in depth and will have much further to go to reach unoxidized ore. This mine supplies a 50-ton smelter at St. George, eighteen miles distant, whence the matte is hauled to Modena, the recent station near Desert Spring on the Oregon Short Line Railroad.

The copper mines to the south, in Arizona, viz.: Grand Gulch, Copper Mountain and Savanic, were not seen, but are thought to be concentrations from decomposed and eroded eruptives. None are now supposed to be present, and the ore occurs as carbonates, oxides and sulphates, in the joint and bedding planes of sandstones of Jurassic age.

SILVER REEF.

This old camp still produces some chloride and horn silver, but the pockets are small, and the mill, which wastes one-half of the value, is operated occasionally on lessees' ore.

The ore occurs in a cross-bedded Jurassic loose-textured sandstone, often where the same is bound by impervious clay shale and where carbonaceous plant remains are present.

The sandstones have been tilted to the north 30° by some disturbance to the south. There are no eruptives in the immediate vicinity of the ore. The productive horizon is not far from that which now yields the warm and tepid springs, which are the

domestic and irrigation supplies of the towns of Washington and St. George. No water flows on the surface from the Pine Valley Mountains to the Virgin River, though the Santa Clara carries a little in flood season. Nearly the entire precipitation appears to sink, to issue 800 feet in level above the river in a line of great springs, some of them too hot for use.

The water of the Virgin River is too alkaline for any other use than irrigation; even cattle are said to refuse it.

Those interested in Silver Reef Mines will find them described in Volume IX, Transactions American Institute of Mining Engineers.

At the time of my visit the lower workings were filled with water, but the upper—old works—suggested to me a similar ore deposition to that of copper in the Permian of Texas.

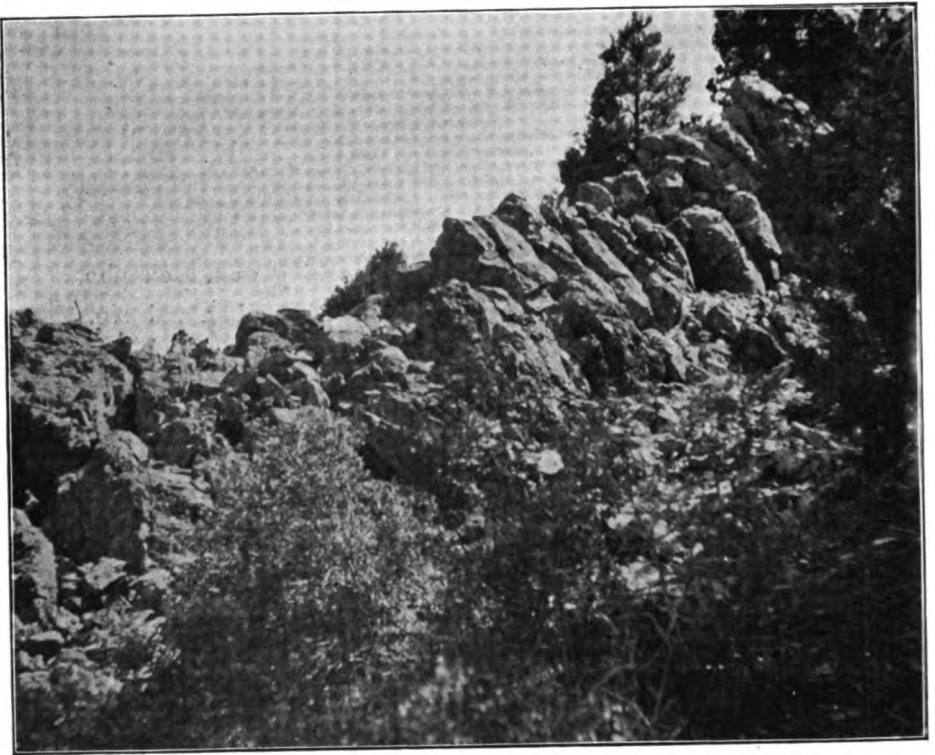
Mr. Hollister, in Volume XIII, refers to this silver-bearing sandstone as 100 miles in length, but this is certainly persiflage, as in all my travels in the district no mention has been made of similar values elsewhere, and there is no reason to suppose that they are any more than local.

Figs. 1 to 4 show the top of Iron Butte looking east, each photo being taken 75 to 150 feet west of the preceding, and No. 4 the west end.

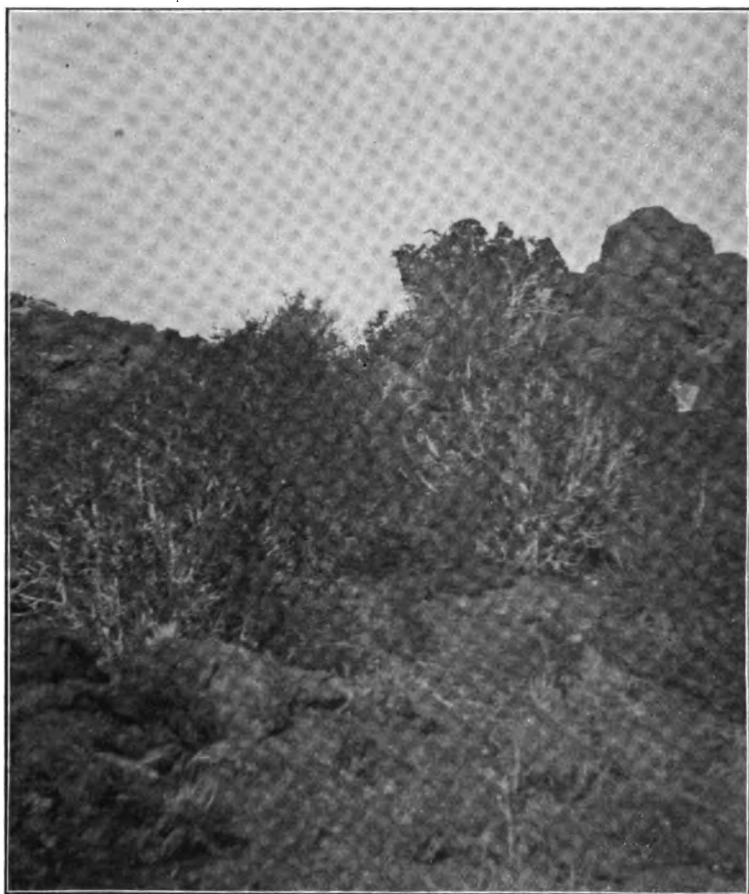
No. 7 shows south slope.

No. 11 shows eastern end.

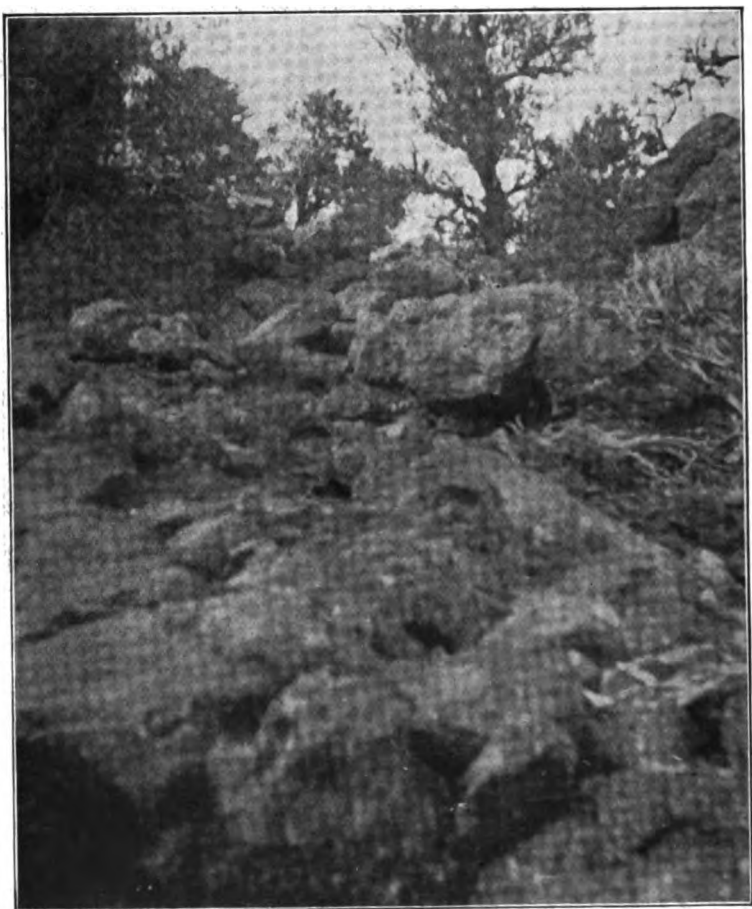
No. 9. Magnetite dike on top of Iron Mountain looking north from highest point and showing bedding planes in ore.



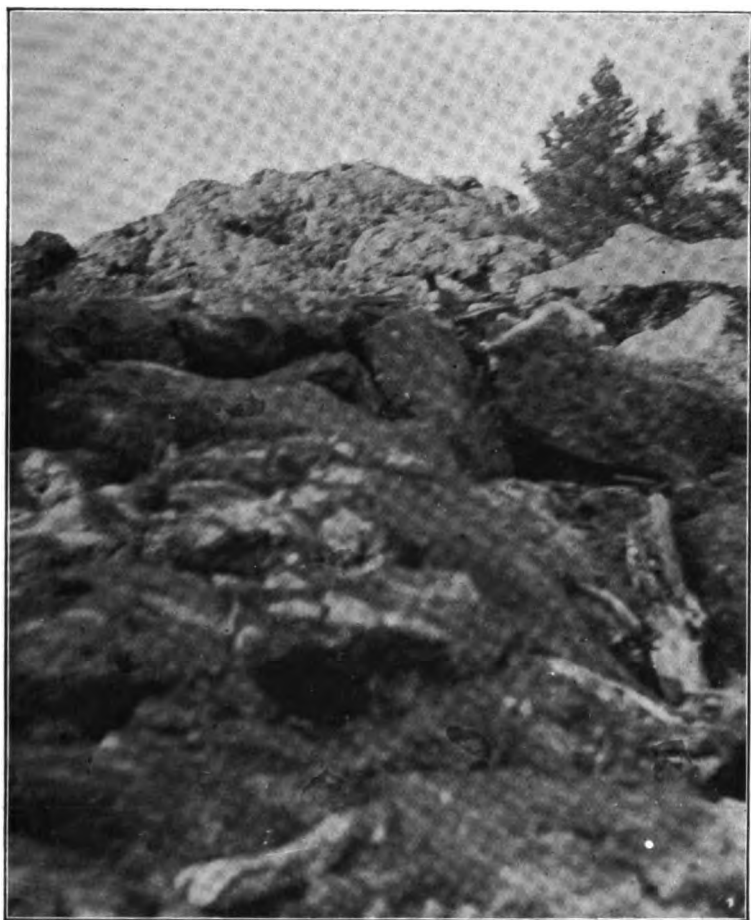
No. 1.



No. 2.



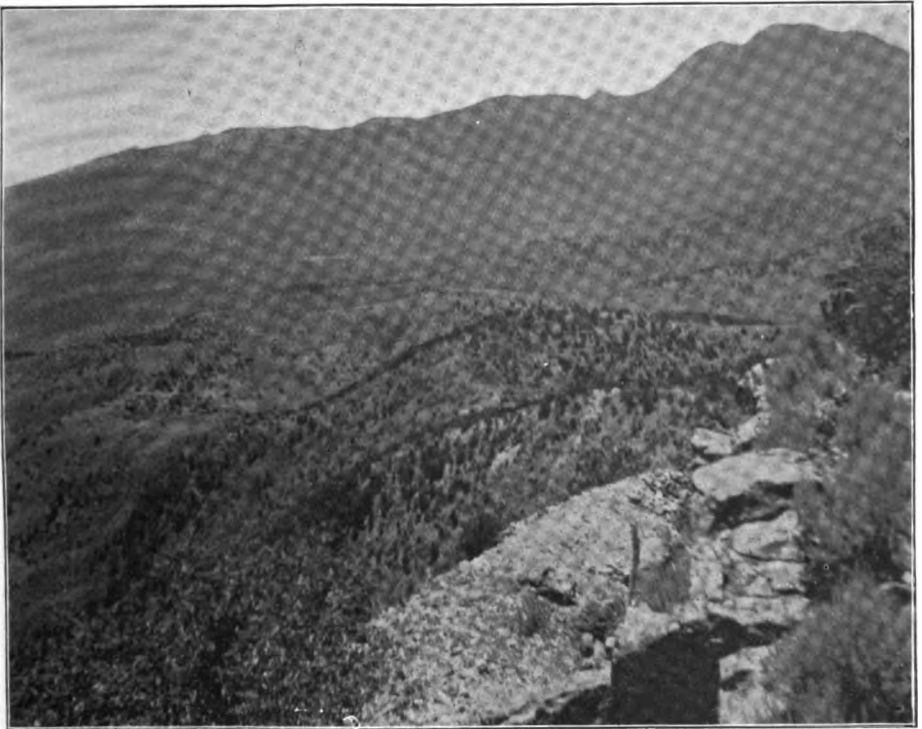
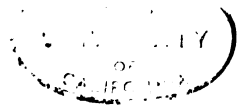
No. 3.



No. 4.



No. 7.



No. 9.



No. 11.

67-76

THE ARIZPE METEORITE.

By A. F. WUENSCH.

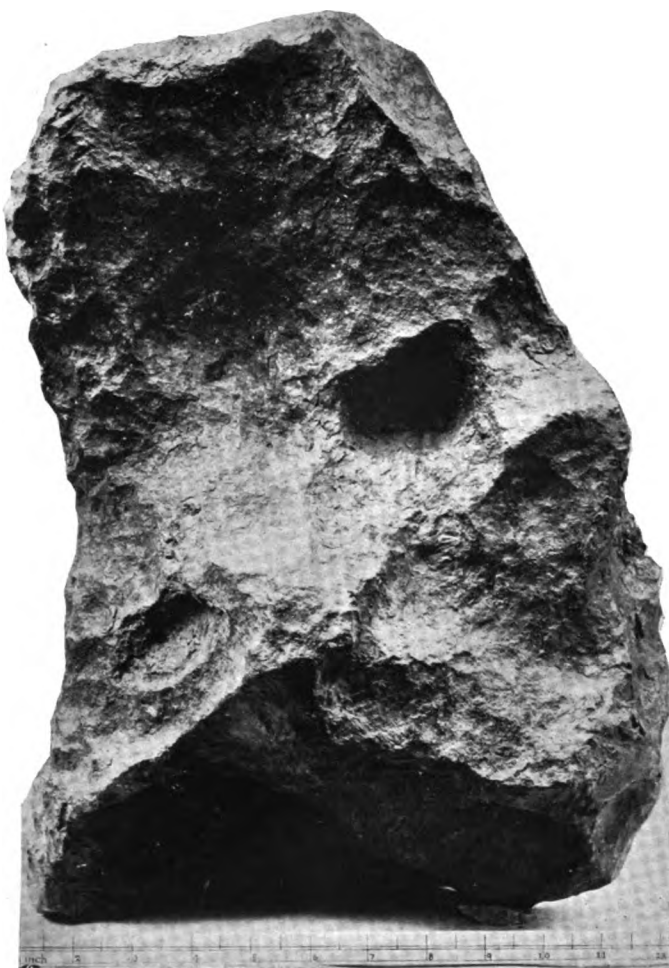
ABSTRACT OF SOME MATERIAL PRESENTED TO THE
COLORADO SCIENTIFIC SOCIETY.

By CHARLES SKEELE PALMER.

THE CHEMICAL ASSAY OF LEAD ORES.

By A. W. WARWICK.

DENVER,
PUBLISHED BY THE SOCIETY
MARCH, 1903



Arizpe Meteorite.

THE ARIZPE METEORITE.

BY A. F. WUENSCH.

Read at the Meeting of the Society, January 8, 1908.

Mr. A. F. Wuensch exhibited for the inspection of the members present a polished and etched slice of a meteorite, which has been christened the Arizpe Meteorite. The original was found in Sonora, Mexico, and brought to Denver, and subsequently sent to Prof. Henry A. Ward, of Rochester, New York, for slicing and technical determination. The slice exhibited measured about 60 centimeters in length and 35 centimeters at the greatest width, and 2 centimeters thick. It weighed 10,376 grammes. It presented one of the largest and finest polished and etched surfaces of meteoric iron ever produced. Describing it, Mr. Wuensch said:

"The original specimen weighed about 272 pounds, and in external appearance presented nothing remarkable, the pittings being numerous and shallow. One deep cupping may have contained a large triolite, as this mineral is found in the interior of the meteorite, in smaller nodules in the solid mass. These nodules are surrounded by schreibersite, and they also show masses of chromite 4 to 5 millimeters in diameter. Crystals in aborescent form have also been distinguished, apparently cohenite, the carbide of iron. The masses of schreibersite are numerous and large. The Widmanstätten figures are sharp and clear and very large, showing octahedral structure of the iron. The kamacite plates are of unusual width while the taenite films are small."

Prof. J. E. Whitfield of Philadelphia announced the following analysis of the Arizpe Meteorite:

Iron	92.268
Nickel	7.040
Specific gravity	7.853

Mr. John M. Davis of the Reynolds laboratory of Rochester, reported:

"I find traces of platinum in the Arizpe siderite; also a greater amount of schreibersite than ever heretofore encountered in a meteorite."

An interesting history in connection with finding and acquisition of the meteorite was related by Mr. Wuensch, as well as a review of its subsequent disposition, through Prof. Henry A. Ward, the noted collector and authority on extra-terrestrial minerals. An assurance was also extended by Mr. Wuensch that in due time the Society should receive a suitable slice for its collection, together with photographs, and a fuller description of the same.

ABSTRACT OF SOME MATERIAL PRESENTED TO THE COLORADO SCIENTIFIC SOCIETY.

BY CHARLES SKEELE PALMER.

Read at the Meeting of the Society, February 7, 1908.

The speaker first exhibited a set of Rowland's Standard Photographs of the Solar Spectrum, and incidentally read a letter from Professor Rowland, discussing the nature of the "D" lines. In this connection, the speaker briefly discussed the ruling machine, by means of which grating was made, and by which, in turn, the photographs were produced. The complete set of photographs, after deducting for overlapping of the ends, would count a total of about forty-five feet.

SOME APPARENT PARADOXES IN THE PRESENT CLASSIFICATION OF THE ELEMENTS IN REFERENCE TO THE PERIODIC SEQUENCE.

1. THE INVERTED SEQUENCE OF COBALT AND NICKEL AND OF TELLURIUM AND IODINE.

An examination of the relations of these elements would indicate that we probably are not yet in full possession of the facts regarding the real atomic weights.

2. THE RARE EARTHS, OR THE SO-CALLED CHEMICAL ASTEROIDS.

The problems suggested here are sufficiently defined by an enumeration of the following: La 139, Ce 140, Pr 141, Nd 144, -145, -147, Sm 148, Eu 151, -152, -155, Gd 156, -159, -160, -Tb 163, Ho 165, Er 166, -167, Tm 171, Yb 173, -176, -178, Ta

182, W 184. The relations of these elements to each other were discussed, and the opinion was advanced that in the separation and identification of these elements the results are chiefly the separations of qualitative analysis. It is impossible, according to the present knowledge, to group these elements in the Periodic Sequence in the Cæsium series, if this series should prove to have room for only seventeen elements; but it is quite possible that, as the Sodium series, having seven elements, is followed by the Potassium and Rubidium series, each probably having seventeen elements, so the Cæsium series may have relatively as many more elements than the Rubidium series as the Potassium series had more than the Sodium series. It should also be noted here that just as it is impossible to compare the members of a short series with those of a long series in vertical groups, so it will prove more misleading to try to compare in vertical groups the members of a long series with the members of a still longer series, such as the Cæsium series seems to promise with its "chemical asteroids." The problems connected with these rare elements are by no means disheartening, but rather would seem to promise a great future for the development of chemical classification and comparison.

3. THE NEW CHEMICAL MOLECULE CALLED THE ION.

The problems presented here are not directly concerned in the making of difficulties for the Periodic Sequence, but rather in the explaining of some supposed anomalies, although it must be confessed that the introduction of the new theory of solution has emphasized a great many gaps in our knowledge, as, for instance, the apparent lack of any case showing ionic oxygen abundantly in any known solution.

4. THE ARGONOID ELEMENTS, INCLUDING HELIUM, 4; NEON, 20; ARGON, 40; KRYPTON, 81; XENON, 132.

Reference was made to a very valuable paper by Prof. Henry P. Talbott, in the June number of the *Technology Quarterly* of the

Massachusetts Institute of Technology. A great deal is known about the physical properties of these substances, but up to the present time they have no known chemistry. The speaker preferred to regard them as elements which were neutralized in their making; and, for short, they may be called "salt elements." They probably have a very close relation to the active elements of the Periodic Sequence, and their true locus is probably to be found *between* the series, whether long or short, but not *in* any series. This is very well shown by the curve of refraction equivalence and atomic weights, by Ramsey and Travers. We are probably not yet in possession of all the facts regarding the specific gravity and "molecular weight" of these elements, and instead of being disturbed at any apparent and incidental lack of harmony with the Periodic Sequence, we should rather wonder that the Argonoid elements can show such approximate harmony with the general classification of the elements.

5. THE RADIO-ACTIVE ELEMENTS.

These elements are either radio-active varieties of well-known elements, such as uranium, thorium, and the like, or they may be radio-active individuals associated with these elements. To the cautious judgment, the proof in evidence at present is not certainly convincing either way; but it would appear to be quite possible that Polonium, which in qualitative analysis comes down with bismuth, and radium, which comes down with barium, and also a so-called "radio-active lead," it is possible that these may be distinct elements; and if they should succeed in establishing this reputation for themselves, there is no doubt that further study of their relations to the Periodic Sequence will show that this host will be capable of entertaining these chemical guests and of recognizing them as permanent members of his family.

6. ELECTRONS.

The electron is one of the marvels of modern physics. The electron would seem to be a little corpuscle—in the case of hydro-

gen about $\frac{1}{1836}$ part the weight of an atom of hydrogen. This corpuscle, or electron, at one moment would seem to be an electrical charge of an ion, and again it would seem to be a piece of matter. Reference was made to a very suggestive paper in the *Journal of Physical Chemistry*, December, 1901, by Felix Lengfeld, on "Some Applications to Chemistry of J. J. Thomson's Work on the Structure of the Atom." The paradox presented here is not that of any particular lack of harmony with any part of the Periodic Sequence but rather a general suggestion that our so-called atoms are not simple things, and are not elementary things, in the real meaning of the words. Of course the ancient speculation of the Greeks, the a-priori study of our seventy or eighty so-called elements—not to mention the marvelous complications in the spectra of our so-called elements—all of this has prepared us somewhat for the future science of the "sub-atom."

As a result of this somewhat hasty consideration of the problems of the student of chemical classification, on the whole there is nothing alarming but everything promising, and we may say that probably never in the history of chemistry has the progressive student been confronted with so much that is novel and yet auspicious of new knowledge just at hand.

THE COMMERCIAL ASSAY OF LEAD ORES.

BY A. W. WARWICK.

Read at the Meeting of the Society, February 7, 1908.

No one who is familiar with the methods in vogue for the commercial assay of lead ores can feel at all satisfied with them. The fire assay is so inherently inaccurate that it is a wonder that the sellers of such ores have not made an organized resistance to the valuation of lead ores by such a method. It is utterly unscientific, and it seems to some members of the Scientific Society that it might well be the subject of investigation by us.

It is, of course, well known by the members of this Society that two methods of lead assay are practiced in the West: The barbarous fire assay—a relic of the times when Paracelsus and other alchemists were leading lights of science—and the volumetric method, based upon the precipitation of ammonium molybdate, and known sometimes as Alexander's method. This latter is an excellent one, being rapid and accurate enough for all commercial purposes.

Both these methods are used by the smelters, care being taken, however, to use the method which gives the lowest results. Thus, the ores of Breece Hill and the Lilian Mine are assayed by the volumetric method, on account of the ores (containing bismuth) giving lower results than the fire assay. All other ores are purchased on the valuation set by the fire assay.

It is notorious that the fire assay for lead ores becomes increasingly inaccurate as the ores become more complex and of

lower grade. Thus, ores containing 8 per cent. of lead, by chemical analysis, may not show more than 4.5 to 5.0 per cent. by the fire assay—an error of about 40 per cent. The writer has caused a number of comparative tests to be made as to the results obtained by both methods of assay, and the figures are decidedly interesting.

The ores assayed from 5.7 per cent. lead to 20.6 per cent. by the volumetric process, and the composition of the ores treated had analyses which varied between the limits given below:

	(1)	(2)
Pb	5.7.....	20.6
Zn	10.1.....	23.8
Fe	5.0.....	8.4
SiO ₂	64.2.....	27.8

The analyses gave the following comparative results by volumetric and fire assays:

	<i>Volumetric.</i>	<i>Fire.</i>	<i>Difference.</i>
1.....	6.4.....	4.8.....	2.1
2.....	5.7.....	3.8.....	1.9
3.....	10.1.....	8.6.....	1.5
4.....	10.5.....	9.5.....	1.0
5.....	12.6.....	10.9.....	1.7
6.....	10.7.....	7.8.....	2.9
7.....	20.6.....	17.6.....	3.0
8.....	9.8.....	6.3.....	3.5
9.....	7.4.....	4.8.....	2.6
	<hr/> 10.4	<hr/> 8.3	<hr/> 2.1

It will be noticed that the differences between the fire and volumetric assays vary so greatly that it amounts to a farce to call the fire assay a determination of lead.

It is not, however, merely a question of a loss of 2.1 per cent. of the lead contents that is involved, but also the entire contents of certain lots, viz.: 1, 2 and 9, these being below the specified amount of 5 per cent. paid for by the smelter. As usual, the ores which need the most consideration get the least.

The smeltermen argue that the fire assay gives the yield that is obtained in practice, and therefore it is a fair method of valua-

tion. This is absolutely false. Some of the members may recollect that the smelters brought forward a similar argument when the question of copper assaying was a live one, some ten or twelve years ago. It was proved to be incorrect for copper, and the writer, for one, believes that the same is true for lead. As a result of the copper debate, the smelters were forced to yield, and a rational process of assaying that metal was adopted.

It may be interesting, however, to point out that the prices paid the miner for the lead contained in the ore are so low that the profit of the sales by the smelter must more than cover any loss. For example: on ores assaying 5 to 10 per cent., fire, the price paid by the smelter is 25 cents per unit, or 1.25 cents per pound. The smelter gets 4 cents per pound, and hence he has 2.75 cents per pound to cover refining and transportation to New York. This presumes, of course, that he only gets as much out of the ore as the fire assay shows. On the actual lead contents of the ores bought by the smelters he may pay as little as 0.7 cent per pound, leaving the difference of 3.3 cents to pay for the losses, as well as the other items mentioned.

It is not the intention of the writer to argue that the smelters should not make all they possibly can out of their business, but it seems to him that the ore sellers should have something to say as to the method of valuation. No one can argue that the fire assay is satisfactory, and it should be replaced by a scientifically accurate method. It may be suggested that a committee be appointed to investigate this matter, and report. The organization of the committee may be along the lines of that appointed some years ago to investigate the assay of zinc ores.

DISCUSSION OF A. W. WARWICK'S PAPER.

THE SEPARATION OF GOLD FROM COPPER, WITH
ESPECIAL REFERENCE TO PYRITIC SMELTING.

By F. R. CARPENTER, M.A., Ph.D.

DENVER,
PUBLISHED BY THE SOCIETY
APRIL, 1903

DISCUSSION.

Dr. W. A. Johnston.—In reviewing the article of Mr. Warwick on "The Commercial Assay of Lead Ores," read at our last meeting, it seems to me that it is not as thoroughly scientific as it should be, and it certainly is inaccurate and misleading. It starts out by saying the fire assay is so inaccurate that it is a wonder the sellers of ores have made no organized resistance to the fire assay, leaving us to infer that the buyers object to this method, while as a matter of fact the smelters want accurate assay methods. Many years of experience in comparing assays for settlement convince me that the smelters get no advantage by fire assay.

It is not a fact that all smelters use both the chemical and fire assay, being careful to adopt that method which gives the lowest results. Such a statement would argue that the miners were devoid of ordinary intelligence and the smelters were oblivious to all sense of decency and fairness. The smelter does not object to either method, but does object to using both methods on the same ore and settling on the one that gives the highest results.

It is not a fact that smelters are buying Breece Hill and Lillian Mine ore on chemical assays and all other ores on fire assay. In some cases of ore containing bismuth the volumetric assay is used, because the miner would get more for the bismuth than for the lead, and, besides, bismuth is considered undesirable in smelter mixtures and a detriment to the quality of the lead.

The article says: "It is notorious that the fire assay for lead ores becomes increasingly inaccurate as the ores become more complex and lower grade" (lower grade in lead). No. 1 sample carried $10\frac{1}{2}\%$ by volumetric and $9\frac{1}{2}\%$ by fire assay, a difference of 1%. No. 7 carried 20.6% by volumetric and 17.6% by fire method, a difference of 3%, or just the reverse of the above statement. The statement that complexity of ores increases the inaccuracy of the fire assay is not very satisfying—it is rather indefinite and too general. What we want to know is what are the usual ingredients in the ores that influence the fire assay? Can't an ore be complex and yet the fire assay be fairly correct?

In the complex ores containing arsenic, antimony, bismuth, copper, and iron, fire assay is very apt to give results above those of chemical method. His table of comparative tests of nine samples is too one-sided to be convincing. It proves nothing; merely show that the volumetric method on these samples showed higher results than the fire test.

It is not usual, nor a fact, that the ores which need the most consideration get the least. It is to the interest, and has been the policy, of the smelters, to make prices which will keep as many mines producing as possible, and any discrimination in prices has favored the low-grade producer.

In many cases of ores carrying under 5 per cent. lead, the lead is paid for as iron.

I am not prepared to say, as a fact, that the loss of lead in a blast furnace should average up with a loss by fire assay. Everyone knows that the conditions of handling ore in a furnace are quite different from that of an assay test, and that in the practical working of furnaces lead goes into fumes, into slag and into matte, and, in the latter, being subject to a second loss by roasting and resmelting; but I do know a smelter does not sell as much lead as it purchases.

Mr. Warwick gets away from the scientific side of the question entirely when he goes to talk about what the smelters pay for lead and what they sell it for. He figures the smelters' schedule for the lead contents, and leaves the story of the balance of the schedule untold.

It is the custom in Colorado to buy lead in ores at so much a per cent., and if the smelter has a margin in the lead it is otherwise with the balance of the price.

There is no question in my mind that the smelters desire, and would advocate, the chemical method, but I am not so sure that Alexander's method is the best—I am told that it is very unreliable in ores carrying lime.

If the Society cares to investigate this subject further, I would approve of Mr. Warwick's suggestion to appoint a committee to investigate the subject.

THE SEPARATION OF GOLD FROM COPPER, WITH ESPECIAL REFERENCE TO PYRITIC SMELTING.

BY F. R. CARPENTER, M.A., PH.D.

Read at the Meeting of the Society, April 4, 1903.

The metallurgical product obtained in pyritic smelting is ordinarily a low grade copper matte. In the revival of this ancient process of smelting, the old methods of refining and separating the gold and silver from the matte have received but little attention, owing to the fact that it could be readily sold to the lead smelters. As long as competition existed between them this left nothing to be desired, and even now, when every matte smelter is, in a small way, a competitor of the American Smelting and Refining Company, commonly called the "Trust," very good terms can be made; but as the Trust is not an eleemosynary institution, it does not do this refining as an act of charity; besides, one is always haunted by the fear that they may some time refuse to do it at all.

In the old days of European practice, refining the matte was always done at the works where it was made. It was usually accomplished by a process known as lead soaking, and if the matte carried copper, this was supplemented by liquation. Both processes were truly ancient, but when combined, as at Kongsberg, Norway, they were very effective, and held their own until displaced very recently by electrolysis. I wish to remark that the matte obtained in pyritic smelting differs in no way from that obtained in the reverberatory process, except, perhaps, in the per

cent. of copper, and not always in this, as at Zalathna and at Deadwood. It is also worthy of remark that when pyritic smelting was generally employed at Freiberg some three hundred years ago, the reverberatory furnace was preferred to the blast furnace as in every way more economical, but at Mansfield, Saxony, which process I modified for use at Deadwood, the blast furnace has always been preferred. In Wales, in Butte, Montana, and at other places, the reverberatory still holds its own, but the product is everywhere the same, viz.: a matte with varying percentages of copper, gold and silver.

In the present state of metallurgical knowledge, the best way of treating this matte would be to concentrate it to black copper and employ electrolytic methods; but pyritic smelters are not usually of sufficient magnitude to justify an electrolytic plant, and the difficulties in the way of sampling and selling the black copper are very great.

In connection with my son, Arthur Howe-Carpenter, I have made many experiments, often at considerable cost, trying to devise some dry method whereby the matte might be refined at the plant where it is made, some account of which may be of interest to the Society.

At Mansfield, amalgamation of the matte gave way to the Augustin process, and this in turn to the Ziervogel method—a beautiful process, but one requiring much skill, and not providing for the extraction of gold—a matter of no import at Mansfield, as the ores are exclusively silver-copper ores. When the process was introduced into America, it became necessary to supplement it with some means of saving the gold, but how this was accomplished, beyond the fact that the gold is first concentrated into copper bottoms, we are not informed.

I began my work at this point. I do not know the name of the genius who first refined copper by means of the copper-bottom process, but it is ancient, and was long employed in Wales in the process for making "Best Selected Copper." It was, also, very

early known that these bottoms carried down, with the other impurities of the matte, practically the whole of the gold, and a process for treating the gold contained in these bottoms was well known and employed for its recovery as early as 1780. In the copper-bottom process, it will be remembered that the matte is enriched by wasting and re-smelting until it carries about 60-65 per cent. of copper. This enriched matte is subjected to a roast-smelting whereby a reaction takes place between the oxide and the sulphide, and a certain per cent. of metallic copper is set free, carrying down with it many of the impurities existing in the matte, and among them almost all of the gold. This selecting process has been most fully examined and set forth by Allan Gibb, to whose work reference may be had for details. Now, when one remembers how the first bottom is obtained, which should equal 14.2 per cent. only of the copper of the original matte, all he needs to do is to cast this copper back into matte, and repeat this selecting process upon a smaller scale, or until a bottom of sufficient size is obtained to be refined by any of the ordinary methods. This is the process described by Jars in 1780, and which was employed, but doubtless with some modifications, by certain Welsh smelters until comparatively recent times.

We first sought to modify this process, and later to apply it to the winning of the silver also. My first idea was to take these bottoms and cupel them directly with lead. This worked very satisfactorily, but gave a bye-product to be refined. We next tried cupelling the copper direct, as though it were ordinary lead bullion instead of copper. At first this goes on very slowly, but when the bath becomes saturated with cuprous oxide it goes on very rapidly. It differs in no way in principle from the cupellation of lead. We next tried the scorification of copper with silica, and, lastly, we roasted the copper, which, if in thin sheets or if granulated, may be done somewhat slowly, depending, of course, upon the thinness of the sheets or granulations, and this we smelted with silica until the quantity of metallic copper was

sufficiently reduced for refining the gold. This gave the best results of all. None of them provided for the recovery of the silver, which did not remain with the gold, but was lost in the residues. In the class of work in which I have been engaged, a large percentage of copper in the charge is not desirable. The cleanest slags made in Deadwood were made in reverberatory furnaces, and the matte carried only from 3 to 5 per cent. copper. I, of course, made a very large percentage of matte of very low gold and silver contents. This matte was added direct to the blast furnaces and there concentrated. But even in blast furnace work it is desirable, where gold and silver production is the primary object of smelting, that the matte shall not exceed 10 per cent. in copper. Now, one may roast this matte and smelt it with silicious ores until it reaches any desired degree of concentration. We may bring it to the point employed in the copper-bottom process, but while 15 per cent. of reduced copper will free the regulus from gold, the whole of the silver can not be so recovered, no matter what per cent. of copper is so reduced. I may remark that silver reaches its maximum concentration in bottoms, according to Allan Gibb, when 19 per cent. of copper is so separated, but as 42.9 per cent. of the silver may be so recovered, the remaining 81 per cent. of the regulus may be sold to the copper refiners, as the difficulty of sampling is greatly lessened by this treatment, and we have recovered the bulk of our values in the 19 per cent. bottoms, which we may treat ourselves.

Instead of stopping at the point required by the copper-bottom process, we may concentrate the whole of the matte to black copper, which will carry all the gold and silver of the original matte, save that which has been lost in the slags while concentrating it. These rich slags are added, of course, to the ore charge and their values thus recovered. If we now proceed to treat this black copper exactly as we treated the copper-bottoms we shall indeed recover the gold, but the silver will mainly go into the residues, as before, but they now carry the whole of the silver,

with little or no gold, and are either silicate of copper or copper oxide. In either case, the reduction of a small percentage of metallic copper, unlike the bottoms in the Jars process, will carry down the silver. I am not aware that this has been heretofore published. It is, also, fair to state that this has not been done on a working scale, but laboratory tests promise success.

If the copper-bottom process is employed, it may be done as follows, although other methods are known—say ten tons of 65 per cent. matte is placed upon the hearth of a small reverberatory furnace. The doors are left open and the charge fired for six to eight hours, or until a semi-pasty stage is reached. The doors are then closed and the charge melted down. The reaction between the oxide and sulphide, as in the “direct process,” sets free a certain percentage of copper, which Allan Gibb determined to be 14.2 per cent. for best results. The whole charge is now tapped into moulds, and beneath the slag blocks nearest the furnaces will be found sheets of impure copper—or copper “bottoms”—whence the name. We have now concentrated the bulk of the gold into a ton and a half of material for further treatment, which may be returned to the same furnace, roasted in all respects as the original ten tons, again smelted down, the copper oxide slagged off and the copper tapped into sheets or granulated for further treatment upon a copper test or other furnace, where it is again roasted and slagged with silica until sufficiently reduced in quantity to refine the gold with litharge, nitre or other flux.

REFRACTOMETERS AND SOME OF THEIR USES IN
ANALYTICAL CHEMISTRY.

BY W. F. EDWARDS.

SYNOPSIS OF PAPER ON THE DEVELOPMENT OF
PSEUDOMORPHS.

BY HORACE B. PATTON.

DENVER,
PUBLISHED BY THE SOCIETY
MAY, 1903.

REFRACTOMETERS AND SOME OF THEIR USES IN ANALYTICAL CHEMISTRY.

BY W. F. EDWARDS.

Read at the Meeting of the Society, May 2, 1903.

Since the discovery of the law of sines the refraction of light has been a subject of ever-increasing interest and ever-expanding application, until today there is scarcely any field of scientific investigation into which it may not enter as an important, and in many instances, as a determining factor. It is my purpose in this paper to give a brief sketch of the general principles underlying the design of refractometers and to briefly describe a few types, and then call attention to some of their uses in analytical chemistry. I shall omit the interference refractometers altogether, as they are of little practical value to analytical chemists, notwithstanding their high importance as instruments of scientific research. There is nothing new in this paper. I present it with the hope of stimulating interest in the uses of refractometers, as I believe they deserve more interest than they receive.

I shall assume the general law of refraction $M = \sin I / \sin R$, where I is the angle of incidence and R is the angle of refraction and M is the index of refraction and is a constant for the same two media, and greater than unity, the ray of light always supposed as going from the less into the more refracting medium. If the ray passes in the reverse direction, then it is the reciprocal, I becoming the angle of refraction. When I becomes 90 degrees in this case we have the phenomena of total reflection back into the more

highly refracting medium. The angle C at which this takes place is called the critical angle for the media under experiment. In this case we have $M = 1 \sin C$. This critical angle can be determined with a high degree of accuracy and affords a means of determining the index of refraction to a like high degree of accuracy. The more convenient and practical refractometers depend on this determination.

REFRACTOMETERS.

There are two general types of refractometers (omitting interference types): one depending on the measurement of the bending of the ray in passing into or through a medium immersed in another medium, usually air; the other depending on the determination of the critical angle.

The spectrometer of the physical laboratories is the most common instrument belonging to the first type. The usual method is to use the formula $M = \sin(A+d)/2 \div \sin A/2$ and determine the minimum deviation for the light in passing through the prism. This method is capable of universal application to transparent media and is of a high degree of accuracy but has the disadvantage of requiring a prism made of the substance, if a solid, and hollow prisms with windows of glass plates bounded by parallel plane surfaces for fluids. Moreover, the instruments are very expensive, and a long time, comparatively, is required for making the determination. The Abbe instrument, using autocollimation and half prisms, is a modified form of the more general type, which reduces the time required, and the amount of substance and the cost of the instrument. The microscope method, used to some extent in laboratories, for purposes of training, is an illustration of an indirect way of measuring the bending. The Piltschikoff refractometer is an instrument based on this method and one designed for practical use. For various reasons this instrument has not come into practical use.

A class of instruments which may properly be called differ-

ential refractometers have been made in different forms for technical uses in factories and testing laboratories. One of the best of these is that made by Carl Zeiss, of Jena. It consists of two hollow prisms of equal refracting angle placed with their refracting edges in opposite directions and their faces parallel, as shown in Fig. 1. One prism is filled with a standard liquid and the other with the substance under investigation. In the instrument, as made, two of these double prisms are used, one being placed above

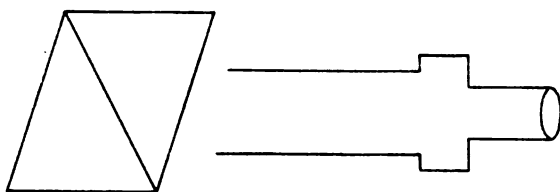


Fig. 1.

the other so that their effects are in opposite directions. These prisms are viewed by an autotelescope with a scale in its focus. This scale is reflected back by a mirror placed behind the prisms. It is a highly practical instrument where quantity of substance is no object and where repeated determinations of the same general substance is desired. By choosing standard fluids, the range of the instrument may be anything we like, and the determinations are accurate to a few units of the fifth decimal place. The instrument, being differential, is very little affected by change of temperature.

The oleo-refractometer of Amajat-Jean is of this same general type, one double prism only being used and a colimator and separate observing telescope being used instead of a scale and autocollimation.

The refractometer of Dupré, constructed for use in the municipal laboratory of Paris in 1885, is a differential instrument of the same general type as the two preceding, but the standard prism is of glass. Instead of autocollimation, the deviation of monochromatic light is measured in much the same way as in the

ordinary spectrometer, the prisms being movable instead of the observing telescope.

Another very ingenious differential refractometer of this same general type is that of Fery'. In this instrument the double prism is so constructed that each prism has a very small refracting angle, the hollow one being of constant angle while the solid one is of variable angle, as shown in Fig. 2. The glass sides of the hollow prism are simply portions of a plano convex cylindrical lens. Consider such a lens (Fig. 3). R is radius of curvature and d is the distance of some point on the surface from the optical axis. $\sin a = d/R$, or, if a is small, $a = d/R$. Now, in case the light passes through the combination (filled with some liquid) without deviation, we have—remembering that a is small— $(m-1)a = (x-1)A/2$ where m is the index of refraction of the glass and a is its refracting angle and x is the index of refraction of the liquid and

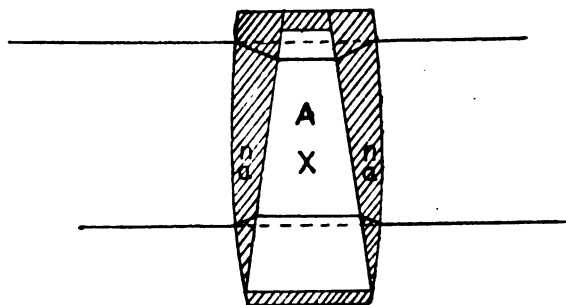


Fig. 2.

A is the refracting angle of the hollow prism containing it. Substitute in this formula for a , its value, d/R , and we have $(m-1)d/R = (x-1)A/2$; or, calling $(x-1) = Kd$, $2(m-1)/AR = K$. Since m , A and R are measured constants of the instrument, x can be determined by simply measuring d the displacement of the point from the optical axis. The prism is mounted between a collimator and observing telescope so as to be capable of movement across their common axis. At some point the image of the collimator slit will fall on the cross wire in the telescope, showing

for that position no deviation of the light in passing through the combination. The amount of displacement is read off on a scale and the index determined from a table or computed from the

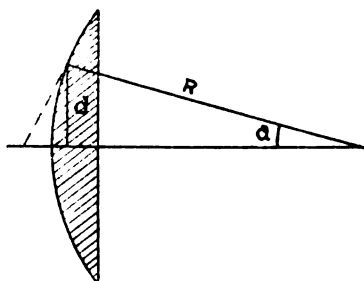


Fig. 3.

formula (the constants of the instrument being furnished by the maker). This instrument has been made with a water-jacket arrangement to control the temperature.

The class of instruments depending on the measurement of

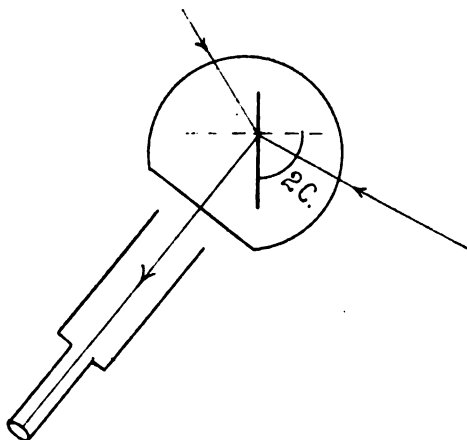


Fig. 4.

the critical angle, and variously known as reflectometers, or total reflectometers, are exemplified in the instruments of Wollaston, Kohlrausch, Abbe and Pulfrich.

Prof. Kohlrausch's instrument is represented diagrammatically in Fig. 4. A is a cylindrical vessel with a window in front of a telescope. In it is suspended a plate of the substance to be investigated. This plate is so placed that it contains the axis of rotation of the graduated circle which measures the amount of rotation. It is surrounded by some highly refracting liquid, such as carbon disulphide. The plate is rotated until the dividing line between the dimmer and brighter illumination is in the line of sight when the reading of the circle is taken. The plate is then rotated in the opposite direction and a like reading taken. The angle through which the plate was rotated is twice the critical angle. The index of refraction is found from the equation. $M_1 = M \sin C$ M being the index of refraction of the liquid in the cylinder, and

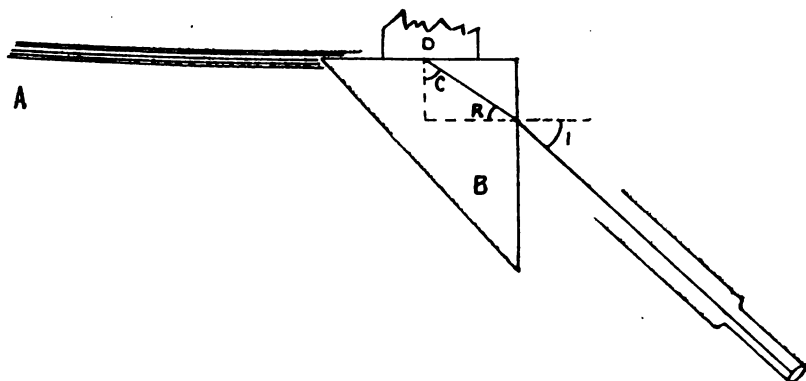


Fig. 5.

M_1 that of the substance under examination. All instruments using an immersion liquid are more or less unsatisfactory on account of the influence of change of temperature.

Instruments based on the original method of Wollaston are the best. This method is sufficiently described in good text-books on physics. I will therefore pass to the instruments without further comment.

Dr. Pulfrich's instrument is a good modern instrument, pat-

turned very closely after the Wollaston instrument, but is very much more convenient and accurate. The instrument is shown diagrammatically in Fig. 5; A is a source of monochromatic light, B is a glass prism of high index of refraction, D is the subject under examination, and T is a telescope for observing the dividing line between the light and dark portion of the field of view. C is the critical angle. The telescope is attached to a vernier arm which moves along a graduated circle which measures the angle of the light coming into the telescope. Calling the index of refraction of the prism M , we have $M \sin C = M_1$; $\sin R = \sin I / M$; $\sin C = \cos R = (1 - \sin^2 I / M^2)^{1/2}$; $M_1 = M(1 - \sin^2 I / M^2)^{1/2} = (M^2 - \sin^2 I)^{1/2}$ from which the table accompanying the instrument is computed. The instrument is made with two prisms, one of hard glass, for liquids, and one of very high index of refraction, for crystals and other solids. It gives results correct to one or two units of the fifth decimal, and can be used quickly and quite accurately.

Abbe's crystal refractometer is very like that of Dr. Pulfrich. A hemisphere of glass is used instead of the prism, and the tele-

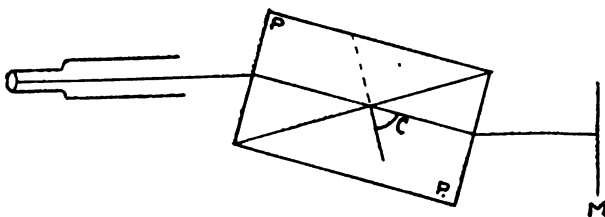


Fig. 6.

scope is connected with a series of prisms so that it has its axis coincide with that of the divided circle, and therefore stationary. It is a very convenient and accurate instrument.

The last instrument to which I wish to call attention is Abbe's refractometer for chemists. It is the most ingenious and convenient instrument of which I have any knowledge. It is designed specially for liquids but can be used for solids. The instrument

is represented diagrammatically in Fig. 6. P and P_1 are two equal highly refracting prisms, M is a mirror or source of light, T a telescope, and C the critical angle. One of the prisms can be removed in order that a drop of the liquid to be examined may be placed between them. This drop of liquid makes a very thin film between them. The prisms, which are attached to a vernier arm which moves along a scale giving direct readings of the index of refraction, are then rotated in front of the telescope until the dividing line in the field of view is in the line of sight when the index of refraction of the liquid is read directly from the instrument to within two units of the fourth decimal place.

If monochromatic light is used with this instrument then the mirror, prisms and the telescope are the only necessary optical parts, but if daylight or ordinary lamplight be used there would be a spectrum in the light portion of the field of view that would seriously interfere with accurate readings of the index. Abbe has overcome this difficulty in a very ingenious way by placing between the telescope and the prisms a pair of Amici prisms of equal refractive and dispersive power, and so constructed that sodium light goes through them without deviation. The prisms are placed with their refracting edges in the same direction and are provided with a drum mounting by which they may be rotated in opposite directions at the same rate, so that in revolving the principal planes of the prisms are always symmetrically inclined to the primitive plane. All dispersion is in the direction of the primitive plane, and may vary between $-2K$ and $+2K$, K being the dispersion of one of the prisms. By this arrangement the dispersive power of the liquid can be counteracted and at the same time we can determine very approximately the dispersive power of the liquid.

Solids can be examined with this instrument, only one prism being used, as shown in Fig. 7, where S is a portion of the solid and B is an attached illuminating prism.

This instrument is put out in the form described and also in

a simple pocket form with a scale in the telescope that may give either the index of refraction or the per cent. of some particular substance in solution (sugar and water, for example). It has also been modified as a salsimeter for determining the salt of sea water. The modification consists in making two little troughs in one of the prisms, in one of which is placed pure water and in the other sea water. In this way both waters are at the same temperature, and the salt can be directly determined to 0.05 per cent. In another modified form, it is known as the butyro-refractometer. In this form the dispersion due to fats is compensated by the form

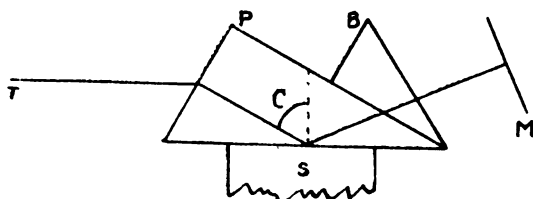


Fig. 7.

of the prisms, so that the amici prisms are not necessary. It is provided with a water-jacket for controlling the temperature.

In going over the literature coming from investigators on the practical application of refractometers one is struck by the many expressions used that show a lack of understanding of the instruments and laws of their construction. For example, one writer who has done a great deal of work with refractometers and who has published considerable as a result of his work, speaks of the prisms in the Abbe refractometers as Nicol prisms. The only thing about them that at all resembles a Nicol prism is their shape, and that there are two of them placed together. Again, angle of refraction is variously confused with index of refraction, some writers even heading tables of indices of refraction with the phrase "angle of refraction." Of course, the index of refraction depends on the angle, but it is a very different thing.

USES IN ANALYTICAL CHEMISTRY.

Wollaston, in describing and reviewing the uses of his total reflection instrument, in a paper published in 1802, wrote:

"For discovering the purity of essential oils such an examination may be of considerable utility, on account of the smallness of the quantity requisite for the trial. In oil of cloves, for instance, I have met with a wide difference. The refractive power of genuine oil of cloves is as high as 1.535, but I have purchased oil by that name which did not exceed 1.498, and which had probably been adulterated by some less refractive oil."

Notwithstanding this suggestion little attention was given to this matter until over half a century had elapsed. In 1857, Beer and Kremers made a report on some work done by them on the halogen salts of some of the alkalies and alkaline earths, in which they gave curves showing the increase in the index of refraction with an increase of concentration in aqueous solutions. In 1865 Landolt published a paper in which he showed that if $(M-1)/D$ is the specific refraction of a mixture and $(m-1)/d$, $(m_1-1)/d_1$, $(m_2-1)/d_2$, etc., were the specific refractions of the components, then $P(M-1)/D = p(m-1)/d + p_1(m_1-1)/d_1 + p_2(m_2-1)/d_2 + \text{etc.}$, where p, p_1, p_2 , etc., are the weights of the components in a weight P of the mixture. If there are only two components the amount of each can be determined if P is known, since $P-p$ may be substituted for the second component p_1 , in which case the equation becomes $P(M-1)/D = p(m-1)/d + (P-p)(m_1-1)/d_1$. d, d_1 , and m and m_1 are supposed known constants for the components. P, M and D can be determined from the mixture and p can be determined from the equation. This formula can then be applied to such mixtures as sugar and water, alcohol and water, glycerine and water, etc., etc.—in fact, any two substances that mix in all proportions in each other.

Wuellner, in the following year, published a paper in which he shows that Landolt's formula does not hold strictly accurate, showing that a difference of three units of the fourth decimal place is necessary to make the difference between calculated and

observed numbers for certain mixtures of glycerine and water which he used for testing the formula.

Landolt's equation is the result of applying Gladstone's empirical formula for specific refraction to mixtures. This same empirical formula has been similarly applied in a somewhat modified form for calculating the specific refraction of mixtures of substances which mix well and have no chemical action on each other. In this case, instead of using weights of the mixture and components volumes are used. Volume, multiplied by the density, gave the mass, but this is only a difference in terms used, inasmuch as the density actually determined is the specific weight.

In 1868, Dr. Karl Hoffman, in a paper on transposition in mixtures of salt solutions of varying degrees of concentration, gives interpolation formulæ to express the index of refraction of solutions of a few solutions of salts.

For analytical purposes, formula and equations have not proved to be of much value in bringing refractometers into use in the practical work of the chemist. What we must really use for this purpose is tables such as was first given for glycerine and water by Dr. Wilhelm Lenz, in 1880. In this year he published a table giving the index of refraction and the specific gravity of mixtures of water and glycerine for each variation of 1 per cent. in content of glycerine.

In 1883 Strohmer published a similar table for mixtures, varying from 50 to 100 per cent. in content of glycerine.

In 1886 Skalweit published a table similar to that of Lenz, but in which the specific gravity and index of refraction were both given for the same temperature of 15°C. The specific gravity used in the other two cases being the numbers of Gerlach.

Table I gives the index of refraction and the specific gravity for mixtures of water and glycerine varying from each other by 5 per cent. in content of glycerine, taken from Skalweit's table. I have introduced a difference column for the index of refraction and specific gravity, and for purposes of comparing other physical

properties, the boiling temperature and the vapor tension. The table is self-explanatory, and requires no further comment.

TABLE I.
SOLUTIONS OF GLYCERINE.

Per Cent Glycerine.	Specific Gravity, at 15°C.—Skatweil.	Difference for 0.5 per cent.	Index of Refraction at 15°C.—Skatweil.	Difference for 0.5 per cent.	Boiling Temp. degrees C. 760 mm. Pressure.—Gerlach.	Tension of Vapor at 100°C.—Gerlach.
100	1.2650	.....	1.4742	.....	290	64
95	1.2525	12.5	1.4670	7.2	164	162
90	1.2395	13.0	1.4595	7.5	138	247
85	1.2260	13.5	1.4520	7.0	127.5	326
80	1.2125	13.5	1.4444	7.6	121	396
75	1.1990	13.0	1.4369	7.5	116.7	450
70	1.1855	13.5	1.4295	7.4	113.6	496
65	1.1715	14.0	1.4220	7.5	111.3	553
60	1.1570	14.5	1.4144	7.6	109.0	565
55	1.1430	14.0	1.4069	7.5	107.5	593
50	1.1290	14.0	1.3996	7.3	106.0	618
45	1.1155	13.5	1.3924	7.2	105.—	638
40	1.1020	13.5	1.3854	7.0	104.	657
35	1.1085	13.5	1.3785	6.9	103.4	675
30	1.0750	13.5	1.3715	7.0	102.8	690
25	1.0620	13.0	1.3647	6.8	102.3	704
20	1.0490	13.0	1.3581	6.6	101.8	717
15	1.0365	12.5	1.3516	6.5	101.4	728
10	1.0240	12.5	1.3452	6.4	100.9	740
5	1.0120	12.0	1.3390	6.2	100.4	750
0	1.0000	12.0	1.3330	6.0	100	760

About ten years ago I made tables for determining the per cent. of hydrochloric acid, sulphuric acid, nitric acid, acetic acid, ammonia and alcohol in aqueous solutions. I will give here a review of the work done on hydrochloric acid, in order to show how the tables were made. Mixtures of the acid and distilled water, of eighteen different per cents of acid were made, and are numbered 1, 2, 3, 4, etc., in the appended table. These solutions were titrated with potassium hydrate solution which had been standardized by oxalic acid dried at 100°C. to constant weight and by freshly crystallized oxalic acid. In titrating the solutions we

used several different solutions of the alkali, in order that several cubic centimeters of the acid could be used in each case.

The refractometer used was a Pulfrich instrument made by Max Wolz, in Bonn. The graduated circle gave readings by vernier to one minute. In the appended table I have given duplicate readings to show that they did not vary more than one minute in any case. This variation makes a variation of from eight to ten units of the fifth decimal in the index of refraction.

The method of determining the index of refraction was as follows: The eighteen glass-stoppered flasks containing the acid were placed with the prism of the refractometer in a large tray through which water from the hydrant circulated freely. When the water had been running until its temperature was approximately constant and the solutions and the prism were of the same temperature as the water, the prism was taken from the water, its upper surface quickly wiped dry, and one of the solutions investigated. The prism was then returned to the water and the operation repeated for another of the solutions. The time required for taking a reading was probably not more than ten seconds from the time the solution was taken from the tray. Sodium light was used in all cases.

TABLE II.
SOLUTIONS OF HYDROCHLORIC ACID.

Number of the Solution.	Specific Gravity at 15°/4°C.	Per Cent of Hydrochloric Acid in the Solution.	First Reading of the Refractometer at 15°C.	Second Reading of the Refractometer at 15°C.	Index of Refraction for the First Reading.	Index of Refraction for the Second Reading.	Average of the Indices of Refraction.
1	1.0111	2.33	64° 40'	64° 40'	1.33834	1.33834	1.33834
2	1.01155	4.51	63° 38'	63° 39'	1.34362	1.34354	1.34358
3	1.0261	5.31	63° 19'	63° 20'	1.34528	1.34518	1.34522
4	1.03315	6.89	62° 38'	62° 38'	1.34886	1.34886	1.34886
5	1.0527	10.62	61° 04'	61° 04'	1.35725	1.35725	1.35725
6	1.05775	11.65	60° 38'	60° 37'	1.35961	1.35971	1.35966
7	1.0708	14.23	59° 38'	59° 39'	1.36576	1.36525	1.36521
8	1.08135	16.55	58° 39'	58° 39'	1.37067	1.37067	1.37067
9	1.0939	18.93	57° 41'	57° 41'	1.37617	1.37617	1.37617
10	1.10395	21.06	56° 45'	56° 45'	1.38155	1.38155	1.38155
11	1.1160	23.28	55° 46'	55° 47'	1.38728	1.38718	1.38723
12	1.12845	25.40	54° 50'	54° 50'	1.39276	1.39276	1.39276
13	1.1410	28.11	53° 57'	53° 57'	1.39799	1.39799	1.39799
14	1.15295	30.45	53° 02'	53° 01'	1.40345	1.40355	1.40350
15	1.1641	32.62	52° 08'	52° 09'	1.40884	1.40874	1.40879
16	1.17615	34.90	51° 20'	51° 19'	1.41365	1.41375	1.41370
17	1.1887	37.17	50° 31'	50° 31'	1.41858	1.41858	1.41858
18	1.19525	38.42	50° 00'	50° 00'	1.42170	1.42170	1.42170

Table III was calculated from the numbers in Table II. The differences in the indices of refraction of numbers 1 and 9 divided by the difference in the per cent. content of acid in these solutions gives an average difference in the index of refraction of 228 units of the fifth decimal for a difference of 1 per cent. in content of acid. In like manner the number 232 is found for a difference of 1 per cent. content between solutions 8 and 18 and 230 for numbers 1 and 18. Again, the index of refraction for water was found to be 1.33311. The difference between this number and those for solutions 5, 10, 14 and 18 gave an average difference of 228, 229, 230 and 231 units of the fifth decimal for a difference of 1 per cent. in content of acid between these numbers respectively. Corresponding numbers for the same solutions at temperatures of 8° and 14°C. agreed very closely with these. From

Table III the content of acid can be determined to within one-tenth per cent. with a good refractometer, and this method does not require more than a minute of time, and will do as well as specific gravity determinations for all ordinary purposes.

TABLE III.
SOLUTIONS OF HYDROCHLORIC ACID.

Per Cent. of Hydrochloric Acid	Index of Refraction for Sodium Light at 16°C.	Per Cent. of Hydrochloric Acid.	Index of Refraction for Sodium Light at 16°C.	Per Cent. of Hydrochloric Acid.	Index of Refraction for Sodium Light at 16°C.	Per Cent. of Hydrochloric Acid.	Index of Refraction for Sodium Light at 16°C.
1	1.33539	11	1.35810	21	1.38111	31	1.40413
2	1.33767	12	1.36039	22	1.38341	32	1.40643
3	1.33996	13	1.36268	23	1.38571	33	1.40815
4	1.34223	14	1.36497	24	1.38801	34	1.41107
5	1.34451	15	1.36726	25	1.39031	35	1.41339
6	1.34679	16	1.36955	26	1.39261	36	1.41571
7	1.34907	17	1.37184	27	1.39491	37	1.41803
8	1.35135	18	1.37413	28	1.39721	38	1.42035
9	1.35363	19	1.37642	29	1.39951	39	1.42267
10	1.35591	20	1.37871	30	1.40181	40	1.42499

In the cases of nitric acid, sulphuric acid, acetic acid and alcohol, tables were made in like manner that were determinative for per cents up to 60, 70, 60 and 40, respectively. Above these per cents the index of refraction is not determinative. In case of nitric acid, while the index increases with increased content of acid above 60 per cent., the increase is not considered fast enough to make it of value in determining the content of acid. In case of the other three there are two per cent. contents corresponding to the same index of refraction for indices for per cents higher than for which the tables were made. For example, a solution of sulphuric acid whose index of refraction is 1.43623, may contain 89.2 or 83 per cent. of acid.

Other useful tables could easily be made, and would be quite as useful as tables of specific gravities. A table giving the index

of refraction for sugar solutions varying from each other by 2 per cent. in content of sugar up to 48 per cent. has been published by Strohmer. This table shows a difference of 13 units of the fourth decimal for a difference of 1 per cent. in content of sugar for solutions up to 6 per cent. content of sugar; 13.5 units for solutions between 6 and 12 per cent. content of sugar; 14 units for those between 12 and 18 per cent. content; 14.5 for those between 18 and 22 per cent.; 15 units for those between 22 and 26 per cent., etc., etc., up to 17.5 units for those between 44 and 48 per cent. content of sugar.

Tables for some of the more common laboratory reagents would be found useful. The ease with which such tables can be made in many cases, is shown by the five numbers given by Schuett for sodium chloride solutions up to approximately 25 per cent. content of the salt for each approximate variation of 5 per cent. in content of sodium chloride. These numbers show a practically constant difference of 177 units of the fifth decimal for each difference of 1 per cent. in content of sodium chloride.

The refractometer is of value in determining the probable purity of many substances, as suggested by Wollaston over an hundred years ago. In the case of the essential oils: Oil of cassia should have an index of refraction of 1.5780, star anise of 1.5496, sassafras of 1.5350, oil of cubebs of 1.4950, oil of lemon of 1.4720, and oil of turpentine of 1.4680 at 22°C. These numbers are not necessarily determinative. In the case of oil of lemon it is not, as oil of orange has practically the same index of refraction, and, also, they have approximately the same specific gravity. The polariscope is the instrument to decide between them, one being leavo- and the other dextro-rotary.

It is unnecessary to name other substances whose purity can be attested by the index of refraction as well as by the specific gravity. Anyone familiar with the tables of Landolt and Boernstein will understand what substances can be attested in this way without further instruction. With a proper refractometer, a drop

of liquid and a minute of time are all that are required for the determination, while in the case of the specific gravity considerable (comparatively) substance and time are required. When sufficient liquid is at hand, of course, specific gravities can be quickly determined by hydrometers and Westphal balances, but one can not depend on the fourth decimal, at all. If the specific gravity is to be of value to the fourth and fifth decimal places some more tedious and accurate method must be used. With the Abbe instrument the index of refraction can be determined to two units of the fourth decimal as quickly and easily as to two units of the third decimal place.

In the case of the fixed oils and fats, a very unfortunate beginning has been made. The Amajat-Jean refractometer is an arbitrary scale instrument; the prisms are arbitrary, the scale is arbitrary and the standard oil is arbitrary (the standard oil sold with the instrument is sheepfoot oil). Abbe's butyro-refractometer is an arbitrary scale instrument. Most of the work done on the fixed oils and fats has been done with these instruments and the results published in terms of the scales of these instruments. In the case of the Amajat-Jean instrument, the numbers mean so many scale divisions to the right or left, and are usually designated plus or minus, and mean more or less refractive than the standard oil used. In the case of Abbe's butyro-refractometer the scale represents a mean variation in the index of refraction of seven units of the fifth decimal place, the scale being of one hundred parts readable to one-tenth part and representing indices from 1.42 to 1.49.

If instrument makers would furnish a table with these arbitrary scale instruments whereby the reading could be used to find the index of refraction, and if investigators would use these tables whenever they had anything to publish, instead of publishing arbitrary numbers, we could hope, I believe, for much more interest in the use of these instruments in the determination of the purity or adulteration of fixed fats and oils.

In factories and other places where refractometers are used on only one kind of substances, the arbitrary scale is all that is necessary, but has little advantage, except in a smaller first cost of the instrument, and this is more than offset, in my opinion, by the limitation of the instrument. Some will say that anyone can be instructed in two minutes to read the arbitrary scale instrument, but the same is true of the other instrument. If all that is required is a number, it can be read from the arc of a circle or from the index of refraction scale as well as from an arbitrary scale.

I believe there will be a very much larger use of refractometers at the end of another decade than obtains at the present time. Our universities are introducing departments of physical chemistry, or molecular physics, as special departments, or as departments within departments. This will bring these instruments more and more to the notice of students of chemistry, and the instruments will ultimately be as much in evidence in laboratories of analytical chemistry as polariscopes and colorimeters.

SYNOPSIS OF PAPER ON THE DEVELOPMENT OF PSEUDOMORPHS.

BY HORACE B. PATTON.

Read at the Meeting of the Society, May 2, 1903.

In presenting this paper, it is not the intention of the author to throw any new light on the various interesting processes that bring about the altered forms of minerals called pseudomorphs, but rather to make clear some of these processes by means of unusually fine illustrative material at his disposal.

More particularly, attention is called to a new occurrence of dolomite incrusting calcite from near Ouray, Colorado. These minerals will be described at the close of the paper.

The development of pseudomorphs is a process that is closely related to that which controls the deposition of many ore deposits, and a discussion of these forms is perhaps of all the greater interest at present, owing to the rather animated discussion that has been going on for a decade over the genesis of ore deposits. The classification of pseudomorphs here given is not intended to be complete, but it presents the more common occurrences.

I. Pseudomorphs with change of molecular structure, but not of composition; called Papamorphs.

Illustration, uralite after pyroxene. Well shown in a specimen from the Calumet Iron Mine, near Salida, Colorado.

II. Pseudomorphs by Chemical Alteration.

(a) By loss of substance.

Illustration, native copper after azurite.

- (b) By addition of substance.
Illustration, anglesite (sulphate of lead) after galena (sulphide of lead).
- (c) By chemical reaction or interchange.
 1. Limonite after siderite (ferrous carbonate loses CO_2 and takes up H_2O).
 2. Limonite after pyrite (FeS_2 loses S and becomes oxidized and hydrated).
 3. Dolomite after calcite (CaCO_3 loses Ca and takes up Mg).
 4. Chalcocite after galena (loses Pb and takes up Cu_2).
 5. Kaolinite after orthoclase (a silicate of Al and K loses all of K by means of CO_2 , also part of the silica and takes up H_2O).

III. Pseudomorphs by Replacement.

- (a) By simple process of solution, producing hollow casts.
Illustration, pyrite is dissolved out of a mass of kaolinite, leaving impressions of pentagonal dodecahedrons.
- (b) By more or less complex replacement.
 1. Filling of cavities that either were dissolved out or preexisted and subsequent removal of the material surrounding the cavities.
Illustration, quartz after coral. See Fig. 1, which is a silicified coral in flint, from limestone, from Joplin, Mo. Natural size.
Illustration, pyrite after a chambered Nautilus, from Baden, Germany. See Fig. 2. Natural size.
 2. Filling of cavities, subsequent removal of the surrounding material and still later filling of the spaces thus produced.
Illustrations, silicified wood, opalized wood.

IV. Pseudomorphs by Incrustation.

- (a) Incrustation followed by dissolution of enveloped mineral.
Illustration, quartz after barite. See Fig. 3 and Fig. 4, from the Yankee Girl Mine, Ouray, Colorado. Fig. 3 represents the outside of the crystals incrustated with quartz crystals; Fig. 4 the reverse side, showing the sharp impressions left by the dissolution of the barite crystals.
- (b) Incrustation and dissolution of enveloped substance, followed by filling in of cavity with the same substance as forms the crusts.

Illustration, calcite incrustated with smithsonite; the calcite afterward partly or entirely dissolved away and replaced by smithsonite. Also, see Fig. 5 and Fig. 6, from the Black Hawk Mine, Rico, Colorado. Fig. 5, natural size, represents a barite crystal incrustated with quartz, then dissolved out and the cavity thus produced lined, but not entirely filled, with quartz crystals; the whole then stained with iron rust. Fig. 6, three-quarters natural size, is similar to Fig. 5, except that the cavities formed by the dissolution of the barite crystals are entirely filled with quartz. This, likewise, is iron-rusted.

V. Pseudomorphs produced by successive application of two or more of the above described processes.

Illustration, a pseudomorph of limonite after an ammonite shell. In the production of this pseudomorph the ammonite is first altered by process III (b), namely, by the filling of the spaces between the partitions with pyrite and the subsequent dissolution of the carbonate of lime shell; secondly, by process II (c), namely, by loss of sulphur and by the oxidation and hydration of the pyrite.

DOLOMITE AND CALCITE CRYSTALS FROM THE CAMP BIRD EXTENSION MINE, OURAY, COLORADO.

Last summer the attention of the author was called to some unusually handsome specimens of dolomite and calcite found lining both sides of a fissure-like pocket in the Camp Bird Extension Mine, near Ouray, Colorado. A visit to the mine was made and the available material secured for the collections of the Colorado School of Mines.

The specimens consist of dogtooth-spar calcite crystals from one to two inches long, incrustated with light cream-colored dolomite. Perched irregularly on the tips and sides of these incrustated crystals are pellucid, whitish calcite crystals in the form of a flat rhombohedron ($-\frac{1}{2}R$) with short prism. The grouping of the dogtooth-spar crystals, their exquisite cream-colored tint, in contrast with the pellucid calcite, and a fine satin-like sheen from the surface of the incrusting dolomite all combine to make these specimens unusually beautiful.

Several interesting features in the formation of minerals are illustrated by these specimens:

First. Two stages in the growth of the dogtooth-spar crystals. On the walls of the cavity were first deposited calcite crystals with flat rhombohedral terminations. At a later stage calcite deposition continued the growth of these crystals which then assumed the shape of dogtooth-spar crystals produced by the development of steep scalenohedral faces.

Second. Dolomite crystals in the form of simple but warped rhombohedrons were deposited in a continuous crust over the surface of the calcite crystals until the crust became about an eighth of an inch thick. These dolomite rhombohedrons arranged themselves in parallel growth so that their symmetry planes correspond with those of the underlying calcite. This parallel growth accounts for the beautiful sheen of the dolomite crust, as all the crystals over a considerable area flash light simultaneously.

Third. During the process of incrustation with dolomite a partial dissolution of the calcite occurred. This seems to have been more effective in the upper portions of the calcite crystals—that is, in the part that assumed the scalenohedral form. In some cases this has resulted in loosening the coherence between the newer and older portions, so that a blow of the hammer has caused a specimen to break along the junction of the two, and has left the older crystal tips exposed. The parting is suggestive of the separation of the newer and the older parts of capped quartzes.

Immediately beneath the dolomite crust a portion of the calcite has been dissolved out in some cases so as to leave a narrow crack in which a few crystals of dolomite have later been deposited, thus showing that the dissolution of the calcite took place, in part at least, simultaneously with the deposition of dolomite.

Fig. 7 affords a view of one of these specimens, and illustrates the distribution of the later calcite crystals on the dolomite crusts. The illustration is five-eighths of the natural size.

ILLUSTRATIONS.

Fig. 1. A silicified coral, in a mass of flint, from limestone at Webb City, Missouri. Natural size. Illustrates the formation of a pseudomorph by filling in of the spaces of the coral and by subsequent dissolution of the carbonate of lime partitions.

Fig. 2. A chambered nautilus altered to pyrite, from the Lias, near Heidelberg, Germany. Natural size. Illustrates the formation of a pseudomorph by filling in of the spaces of the nautilus with pyrite and the subsequent dissolution of the carbonate of lime partitions.

Fig. 3. Pseudomorph of quartz after barite, from the Yankee Girl Mine, Ouray, Colorado. Natural size. Illustrates the formation of a pseudomorph by incrustation.

Fig. 4. The reverse side of the same specimen that is shown in Fig. 3. Natural size. Illustrates the dissolution of the barite crystals and the leaving of their sharp impressions in the surrounding quartz.

Fig. 5. Pseudomorph of quartz after barite, from the Black Hawk Mine, Rico, Colorado. Natural size. Illustrates the formation of a pseudomorph by incrustation with quartz, subsequent dissolution of the original barite and the still later deposition of quartz crystals in the cavity of dissolution.

Fig. 6. Pseudomorph of quartz after barite, from the Black Hawk Mine, Rico, Colorado. Three-fourths natural size. Illustrates the same process as Fig. 5, with the additional fact that the interiors of the cavities of dissolution have been entirely filled with quartz. This is best seen on two of the broken and white-looking parts.

Fig. 7. Dolomite and calcite, from the Camp Bird Extension Mine, Ouray, Colorado. Five-eighths natural size. Illustrates the beginning of pseudomorphism by the incrusting of dogtooth-spar crystals of calcite by a thin crust of dolomite crystals.

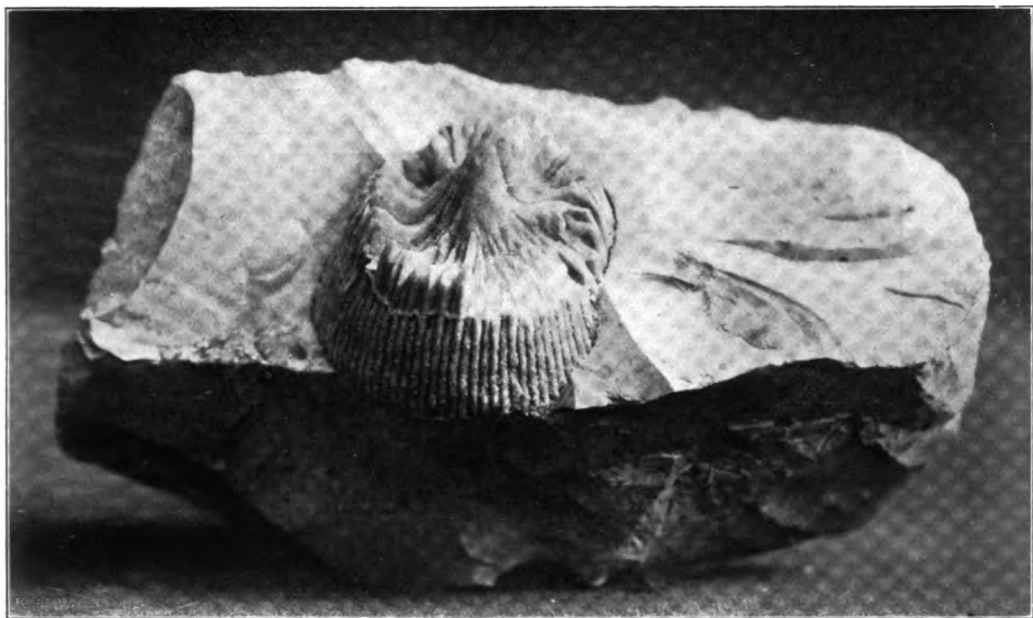


Fig. 1.

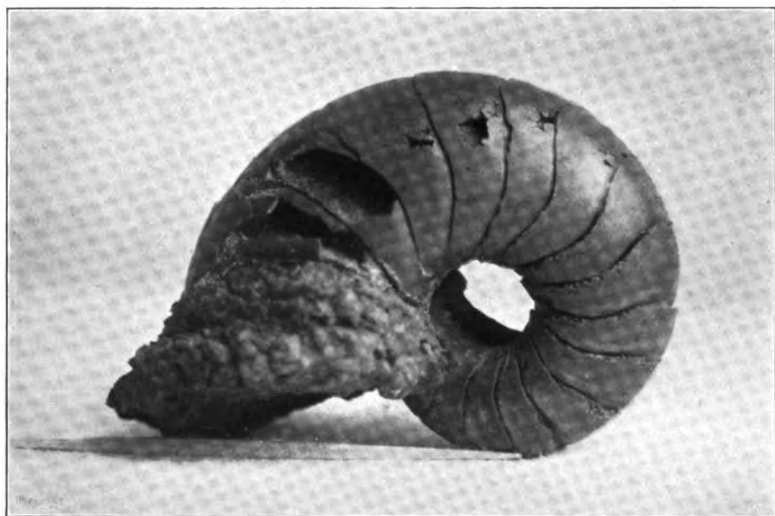


Fig. 2.

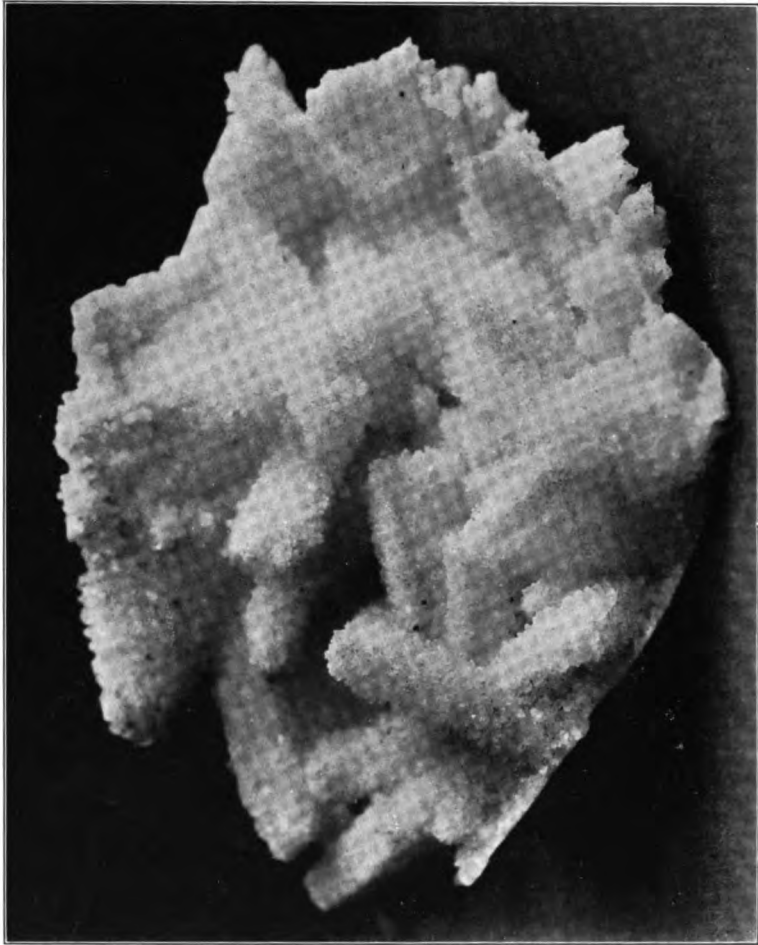


Fig. 3.



Fig. 4.



Fig. 5.



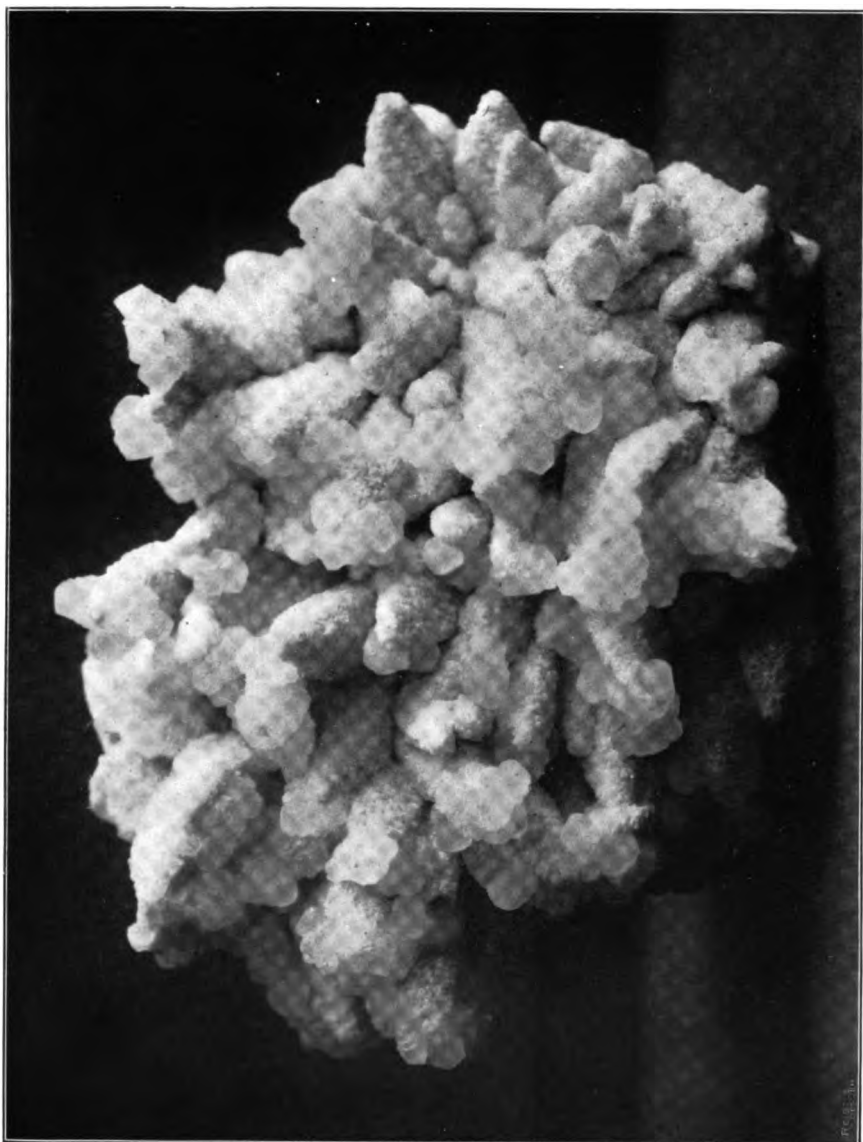


Fig. 7.

THE COMMERCIAL ASSAY OF LEAD ORES.

DISCUSSION.

THE WHITE COUNTRY GRANITE OF WEST SUGAR
LOAF OR BALD MOUNTAIN, BOULDER
COUNTY, COLORADO.

BY CARL D. HENRY, PH.D.

COMMUNICATED BY CHAS. S. PALMER.

DENVER,
PUBLISHED BY THE SOCIETY
JUNE, 1903.

THE COMMERCIAL ASSAY OF LEAD ORES.

Read at the Meeting of the Society, June 6, 1903.

DISCUSSION.

A. W. Warwick—Dr. Johnston, in discussing my note on “The Commercial Assay of Lead Ores,” stigmatizes it as inaccurate, misleading and unscientific. Scientific, in the ordinary sense of that word, it did not pretend to be. My endeavor was merely to point out that the present commercial method of assaying lead ores was *unscientific*. Dr. Johnston, by inference, agrees with this, as he supported me in requesting the Society to appoint a committee to investigate the matter. If the dry assay were scientific there would be nothing to investigate. My note can therefore hardly be called inaccurate and misleading, so far as this point is concerned.

In the discussion a little more was read into my paper than was really said or intended. For example, when I wrote that both chemical and fire assays are used by the smelters, there was no intention to imply that both methods are used in all ores and at all times. Dr. Johnston disputed that both assays were used in this latter sense, but admits that “in some cases of ore containing bismuth, the volumetric assay is used.” This was a case I had in mind when I wrote that both assay methods are used. So, therefore, in this part of my note I was neither inaccurate or misleading.

Dr. Johnston combats the point I made that “the fire assay for lead ores becomes increasingly inaccurate as the ores become complex and low grade.” This is done by making comparisons of

some of the figures given in my paper. It suffices to say that the ores varied so greatly in composition that their comparison was impossible, and any comparisons made would be valueless. The general statement that the assay of lead ores becomes more unreliable as the ore becomes more complex or of lower grade has been too well proven to need defense at my hands.

I note that Dr. Johnston states that my "table of comparative tests of nine samples is too one-sided to be convincing. It proves nothing." My note was written whilst in the mountains, and with no means of amplifying or diversifying the table. Since the discussion, I have obtained, through the kindness of a well-known firm of assayers in Denver, sixteen comparative tests on lead ores by wet and fire assays. The list is not a selected one, but was made up from consecutive entries in the assay book. The similarity of results between my table and the following is remarkable, to say the least:

COMPARATIVE RESULTS OF WET AND FIRE METHODS FOR LEAD.

<i>Nature of Ore.</i>	<i>Wet Per Ct.</i>	<i>Fire Per Ct.</i>
Siliceous	5.5	2.8
Siliceous	3.3	1.5
Iron Pyrites.....	6.2	3.9
Zinc-Iron Pyrites.....	11.0	6.8
Iron Pyrites.....	7.0	5.2
Lime.....	20.5	20.15
Zinc-Lead Pyrites	48.3	44.9
Lime.....	10.89	10.12
Zinc-Iron Pyrites	20.8	19.2
Iron Pyrites.....	24.2	22.3
Lime.....	11.4	10.8
Lime.....	14.0	13.1
Oxidized Iron (Arsenical)	7.95	7.0
Zinc-Iron Pyrites.....	6.2	3.6
Oxidized Iron	1.7	1.3
Lead Iron Concentrates.....	31.4	28.5
	14.40	12.7
Wet.....	14.4	per cent.
Fire.....	12.7	per cent.
Difference.....	1.7	per cent.

In addition to this, I have obtained from a thoroughly reliable assayer who probably makes upwards of 2,000 lead assays a year, the following facts: Over seven hundred (700) samples were tested by fire and wet assays. The ore was of the usual Leadville complex sulphide type, containing 30 per cent. zinc and 10 per cent. lead. The volumetric assay gave results averaging about 2.5 per cent. more than the fire assay.

I trust that, though certainly one-sided, these results will demonstrate that the examples I gave in my note were not unusual or unfair.

I am glad to learn that "the smelters want accurate assay methods." So far as the lead assay is concerned, this desire has not been the cause of any undue haste and has not, up to the present, been sufficiently keen to cause the fire assay to become obsolete as the basis for the purchase of ores.

Possibly the appointment of a representative committee to investigate the assay methods in use may do much to put the commercial assay of lead ores on a satisfactory footing, and I am glad to see that Dr. Johnston has approved of the appointment of such.

THE WHITE COUNTRY GRANITE OF WEST SUGAR
LOAF OR BALD MOUNTAIN, BOULDER
COUNTY, COLORADO.

BY CARL D. HENRY, PH.B.

COMMUNICATED BY CHAS. S. PALMER.

Read at the Meeting of the Society, June 6, 1902.

In the paper presented by Mr. J. C. Blake, in February, 1901, published by the Colorado Scientific Society in April of that year, the abandoned railroad grading leading from Sunset to the sway between Sugar Loaf and West Sugar Loaf Mountains is excellently described.

Half way up this grading occurs the dike of mica-andesite, a specimen of which Mr. Blake analyzed.

On either side of this dike the country rock is of two varieties. One is a dark, greenish schistose rock, carrying fibrolite. This rock has been analyzed in the laboratory (Mr. J. B. Annear); the other is a light-colored, coarse-grained granite, somewhat decomposed. Many outcroppings occur along this grading, and specimens are plentiful over the whole mountain-side. This is the subject of this paper.

THE MEGASCOPIC EXAMINATION.

There is a very slight pinkish color to a freshly-broken surface, and often, in breaking a large piece through a slight crack, a heavy manganese stain will appear which seems not to have been

produced from the rock itself but to have flowed in from another source.

This occurs in the rock, which lies about two-thirds of the way up the grading.

In some places the rock is decomposed so that it may be crushed in the hand, but in general it is very hard and is broken with difficulty and only in very peculiar and irregular pieces.

The specific gravity determined by the heavy solution method is 2.559 at 22 degrees centigrade.

THE MICROSCOPIC EXAMINATION.

The phenocrysts of quartz, muscovite, epidote and labradorite were most easily discerned.

From the examination of nine different fields, the following proportions were computed:

Plagioclase.....	$\frac{1}{2}$ or 50 per cent. of all fields.
Orthoclase.....	$\frac{1}{4}$ or 25 per cent. of all fields.
Quartz.....	$\frac{1}{5}$ or 20 per cent. of all fields.
Mica.....	1 per cent. of all fields.

The following table was made from this result:

	SiO_2	Al_2O_3	CaO	Na_2O	K_2O	H_2O
Computed.....	65.4	21.8	3.0	.75	7.1	1.1
Found	71.434	16.8	.990	3.42	3.48	.85

THE ANALYSIS.

The sample selected for analysis was moderately coarse-grained, hard, clean and white.

"Some Principles and Methods of Rock Analysis," by W. F. Hillebrand, served as a guide to all analyses and is an outline easily filled in, making a complete treatise.

Reprecipitation was resorted to wherever applicable.

Analyses were all done on one-half gram of rock powder.

The finely-ground rock (powder) was mixed with eight or

ten times its volume of sodium and potassium carbonates, and fused in platinum.

After the mass was in fusion over the Bunsen burner, the blast-pipe was applied for ten or fifteen minutes.

The fusion, when cool, was taken up with very little dilute hydrochloric acid and evaporated to dryness over a copper water-bath. This was then ground with a pestle, moistened with strong hydrochloric acid, and again evaporated to absolute dryness in the air bath, and there held at 115 degrees to 120 degrees (C.) for two hours or more.

At a lower temperature than this silica was found even after the fourth group had been precipitated.

The evaporate was then boiled with hydrochloric acid. When only moistened with hydrochloric acid and taken up with hot water and boiled, the silica was slightly soluble and caused further trouble.

After boiling, filtering and igniting, the silica was treated with sulphuric and hydrofluoric acids and to the small remaining residue was added the third group precipitate.

The third group was precipitated at boiling heat by ammonium hydroxide.

After ignition, the total third group was fused with acid potassium sulphate until, after a slow rise in temperature, a complete and quiet fusion ensued.

Then the cool mass was dissolved in dilute sulphuric acid by boiling, and the iron reduced while warm by hydrogen sulphide.

The solution was then boiled in a flask until no hydrogen sulphide could be detected with lead paper, and filtered hot in an atmosphere of carbon dioxide. The cooled solution was titrated for total iron by standard potassium permanganate.

Titanium was here tested for by hydrogen peroxide and by morphine. The latter method is exceedingly delicate, giving a clear ring where hydrogen peroxide gives no trace.

Titanium.—Prepare a fresh solution of morphine in concen-

trated sulphuric acid. Allow this solution to run down the side of a test tube containing a few cubic centimeters of the solution to be tested in such a way that the solution will not mix. A distinct red ring appears at the junction. Allow dilute solutions to stand. Citric and tartaric acids do not interfere, nor do ferrous and ferric iron. This test will show titanium, 1 part in 100,000.

Oxidizers produce the same ring and must not be present.—Whitaker, M.C.

Hydrogen sulphide was run into the filtrate from group three, ammonia was added and the whole allowed to stand over night.

The solution was filtered and the precipitate washed with cold water containing ammonium chloride and sulphide, and then with dilute (1.5) hydrochloric acid containing hydrogen sulphide.

Manganese goes into solution with zinc and cobalt, and nickel with copper are left on the filter.

The second filtrate is evaporated to dryness, ammonium salts are destroyed with a little sodium carbonate solution, and excess of the latter destroyed by hydrochloric acid and sulphurous acid, while manganese is dissolved and reprecipitated by sodium carbonate at boiling heat.

A faint trace of copper was found in the bottom of one of the crucibles, but it probably came from the copper air or water baths. Calcium was precipitated as oxalate and burned to the oxide; magnesium as magnesium-ammonium-phosphate by microcosmic salt and burned to magnesium pyrophosphate.

When manganese ran low, it was a notable fact that calcium and magnesium were high. Instead of allowing the molybdate precipitate with phosphorus to stand, it was boiled and quickly finished, and with less nitric acid in the molybdate solution, led to more uniform results. It was then finished in the regular manner by treatment with "magnesia mixture" and weighing as magnesium pyrophosphate.

Ferrous iron was perhaps the most accurately and easily determined. The rock powder was weighed in a platinum crucible,

hydrofluoric and sulphuric acids added, and the crucible placed in the beaker containing dilute sulphuric acid and immediately titrated with potassium permanganate in presence of carbon dioxide.

The analysis was generally finished under fifteen minutes. The ferric iron was calculated from the total and the ferrous. Carbon dioxide was tested for in the usual manner, as was water also, and both with considerable trouble.

The alkalies were determined by the J. Lawrence Smith method, *i. e.*, potassium as potassium chlor-platinate and the sodium by difference.

Sulphur was tested for in many ways, but none was found.

This was also the case with vanadium.

THE ANALYSIS COLLATED.

Si O ₂	71·434 per cent.
Al ₂ O ₃	16·800 per cent.
Fe ₂ O ₃	1·215 per cent.
FeO	0·157 per cent.
MnO.....	0·218 per cent.
CaO	0·990 per cent.
MgO	1·423 per cent.
K ₂ O	3·48 per cent.
Na ₂ O	3·42 per cent.
H ₂ O	0·85 per cent.
P ₂ O ₅	0·35 per cent.
	<hr/>
	99·337 per cent.

Many thanks are due Dr. Palmer for assistance at all times.

This paper is of the series on "The Eruptive Rocks of Boulder County."

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
Vol. 7, pp. 117-138.

NOTES ON THE SANTA EULALIA MINING DISTRICT,
CHIHUAHUA, MEXICO.

By PHILIP ARGALL.

THE CONTACT, NEVADA, QUAQUAVERSAL.

By CHESTER WELLS PURINGTON.

DENVER,
PUBLISHED BY THE SOCIETY
AUGUST, 1903.

NOTES ON THE SANTA EULALIA MINING DISTRICT, CHIHUAHUA, MEXICO.

BY PHILIP ARGALL.

Read at the Meeting of the Society, August 1, 1903.

Following up the suggestion made at the last meeting of the Society, "that members should present notes on any subject of interest, not necessarily for publication, but rather to form a basis for discussion," I herewith offer some rough notes on the above district, together with my present views on its ore deposits, based on observations made during a hasty visit to Santa Eulalia last January, and subject to change or amplification after a further and fuller examination that I hope to make in the near future.

THE SANTA EULALIA MINING DISTRICT.

About fifteen miles southeast of the City of Chihuahua the Santa Eulalia Mountain rises in a gentle, tuff-capped fold, to a height of about 1,200 feet above the plain. This mountain is massive limestone, and in it occur those rich and extensive deposits of silver-lead ores that for the past 200 years have made the mining district of "Santa Eulalia" one of the most famous in Mexico. Worked by the Spanish and Mexicans in the most primitive manner for 190 years, this district is said to have produced from \$300,000,000.00 to \$600,000,000.00, though these figures cannot be verified and are simply local estimates, the latter doubtless too high. For the 86 years following its discovery in

1703, the total output on which the crown tax was paid is estimated at \$112,000,000.00. During the last decade gasoline hoists, steam engines and railways have to a large extent replaced the malacate, the human ore elevator, and the mule, so that today modern methods of mining may be said to prevail.

Transportation.—The Chihuahua mineral railway (3-foot gauge) connects the small mining town of Santa Eulalia with Chihuahua City, providing cheap and rapid transportation for passengers and minerals.

A narrower-gauge railway (about 30 inches) connects the principal mines with the Chihuahua mineral railway at the town of Santa Eulalia, where ore is transferred from the narrower to the narrow-gauge, and on its arrival in Chihuahua is again transferred to the standard-gauge cars of the Mexican Central railway. The Chihuahua Mining Company, owners of the narrower-gauge railway, carry the ores from their own mines to a point about two miles below Chihuahua, where direct transfer is made to the standard-gauge equipment of the Mexican Central railway.

Geology.—The geology is extremely simple. The Santa Eulalia Mountain is, according to Mr. Walter Harvey Weed, massive cretaceous limestone;* it has approximately east and west axes. The limestone dips gently under the plains along the southern margin, and, so I am informed, on the northern sides also. The mountain would thus appear to be an anticlinal fold in the strata, with the chief ore deposits occurring along fissures mostly at right angles to the main axis. The limestone appears to have been weathered into a series of benches extending from the plain back to the summit, and deeply eroded with narrow valleys, prior to the eruption of the volcanic breccia and tufa which filled up these valleys, covered the benches, and formed the "cap" now covering the greater part of the mineral district. This cap of tuff is usually a light-colored, rather fine-

*Transactions American Institute of Mining Engineers, November, 1901, Mexican meeting.

grained rock, "Cantera" of the natives, passing in the other extreme into a fairly coarse breccia containing limestone fragments.

This cap of volcanic rock forms, with perhaps one exception, the highest peaks, and extends well down towards the plains, rounding off the rough benches of the underlying limestone. Where the tuffs and breccias extend 200 to 300 feet in thickness, very little prospecting has been done until quite recently, hence the earlier maps of the district show large blanks, but in later years these have been pretty well covered with locations. In places deep shafts are now in progress through the cap rock to reach the underlying limestone formation, which unquestionably extends uninterruptedly from the eastern to the western limits of the district.

The richer mines are, at present, The Potosi, San Domingo, Mina Nuevo and Prieto, situated practically in the center of the district, while the western limits have such mines as the Santa Rita, Parcionera and Mina Vieja, all famous for their production, and the eastern limits of the district have the San Antonia, Las Tres Mercedes and San Juliana. All excepting the last are old and famous producers. The San Juliana is a new mine now (January, 1903), shipping largely from a cave recently discovered within 100 feet of the surface.

Porphyry dikes or intrusions are, so far as present developments show, by no means plentiful. The San Antonia mine, on the extreme easterly limits of the district, and practically on the plains, is, however, on a porphyry dike, the ore making in the limestone on either side, often extending to a considerable distance along the bedding planes.

Immediately west of the San Antonia, and along the course of its dike, there is quite an out-flow of porphyry, which assumes a rough, bedded appearance, and has been extensively burrowed by the Mexicans following small seams of ore, which occur irregularly throughout the porphyry, but at times follow the bedding structure somewhat closely.

I am informed that at least one porphyry dike exists in the Mina Vieja, while in the adjoining property I saw some evidence of intrusive porphyry 1,000 feet below the surface. The present development, outside of the San Antonia mine, does not show that intrusive porphyry has had any direct influence on the ore deposition in the district, yet I am led to believe that at greater depths, porphyries will be more plentiful, and that igneous rocks may, to some considerable extent, underlie the ore deposits.

The present proved thickness of the ore-bearing limestone is about 2,500 feet—it will probably exceed 3,000 feet in total thickness. This great limestone uplift appears to be singularly free from faulting. In seven mines which I partially examined, fissures and caves abound, but I did not see a single fault exceeding one foot displacement. The main fissures, often represented by an incipient fracturing, have an approximately north and south strike, and it is along these that the great caves, water courses and ore deposits occur, more particularly where the small cross fissures intersect, a splendid example of which is the great ore deposit on the 1,450 level of the Mina Nuevo on the San Domingo line.

Ores.—The Santa Eulalia ores are lead carbonates containing in places rich bunches of silver chloride, the average ore being of high tenor both in lead and in silver. The main ore masses are oxidized as deep as present development has proven them, though as depth is gained the nodules of galena become more plentiful as do also the branches and veinlets of galena in the walls of the caves. The smaller deposits and branches off the main channels of circulation may, however, contain sulphides quite close to the surface. Much of the ore in the deep caves is an almost pure cerussite, and, taken all together, the oxidized ores very much resemble the Leadville high grade carbonates. The sulphides that I saw, at a depth of 1,400 feet from the surface, in the San Domingo, were principally iron pyrites, and appeared to contain very little zinc and were low in lead.

Ore Deposits.—The fissures connecting some of the great

cave deposits can be traced into the overlying tuffs "cap" rock, carrying ore in both rocks, and in places a small deposit at the contact. If this is the prevailing condition, the fissures and mineralization would appear to be subsequent to the ejection of the breccias and tuffs, and is probably due to a later period of igneous activity.

While my limited observations lead me to adopt this view, I freely admit that it may not be correct; however, proceeding on this hypothesis. I would elaborate it as follows:

First—Volcanic disturbance resulting in the deposition of tuff and breccia.

Second—Second period of igneous activity resulting in the incipient fissuring of the limestone and probable intrusion of porphyry.

Third—Deposition of ore from ascending solutions.

Fourth—Period of oxidation, formation of caves by descending waters.

Fifth—Calcification of the caves sealing up the oxidized ores in their walls.

The miners recognize two classes of ore deposits: the "manto" or blanket form, and the "abras" or fissure partially filled with mineral; they belong, however, to the same system. The small fractures and fissures in the limestone, enlarged by circulating waters, formed the "abras," while the "mantos" are limited to the more soluble beds, or, we might say, certain favorable strata, where replacement of the limestone with ore extended to a considerable distance from the fissures.

From an examination of the smaller cave and watercourse system, I was at first led to the conclusion that the ore was deposited in pre-existing cavities—that is to say, the caves and watercourses were first formed and afterwards filled with mineral. After seeing the extensive "manto" in the "Tres Mercedes" mine, it became clear that here, at least, it was a simple case of replacement between limestone and the sulphides, while a more extensive

examination of the great caves confirmed me in the conclusion that they were formed after the original ores were deposited.

It appears to me that the ores were deposited from ascending solutions which found their way upwards through the more open parts of the incipient fissures and joint planes in the limestone, enlarging them and depositing the ores as sulphides. The more soluble beds were acted upon for considerable distances from the fissures (Fig. 1), and the "mantos" formed by metasomatic action. After the close of this period of ore deposition there followed one of oxidation, probably with reversed currents and descending surface waters, oxidizing the sulphides to sulphates, oxides and resulting carbonates, attacking the limestone above and below the "mantos," forming the great caves (Fig. 2) which today are one of the most wonderful features of this very interesting mining district. During this period of oxidation, the ores near the surface were leached, to a great extent, of their lead and silver values, which were reprecipitated at greater depths, thus enriching the "deeps" at the expense of the shallow deposits; furthermore, mechanical enrichment has also played its part in removing through the large watercourses and fissures, oxidized ores from the caves and fissures near the surface and depositing them in the deeper caverns. Thus we find the shallow caves often empty, or containing only a small floor deposit of impoverished ore, while the caves at 1,400 feet are almost filled to the roof with loose deposits of rich argentiferous lead carbonates. At present the deepest mines in the district may be said to have both the largest deposits and the richest ores. It is quite probable that this will be the general experience with deep mining, at least in the larger ore bodies, due solely to the leaching of the shallow ores and mechanical and chemical enrichment of the deeps, as previously described. With the close of active oxidation the interior of the caves became coated with a beautiful crystalline deposit of calcite, probably while they were yet filled with water, and later stalactites and their counterpart were formed, as in the usual limestone cavern.

I had the good fortune to see two newly-opened caves. The sight was one not easily forgotten. On every side the most delicate crystalline growth covered everything in sight, sparkling in the candle-light like beautiful objects of cut glass, crackling under our feet as if we were walking on thin ice, while here and there huge stalactites hung jauntily from the roof or joined hands with their fellow stalagmites rising in graceful curves from the floor of the cavern. The eyes of the miners, however, were directed to the blemishes in this indescribably beautiful scene, the discolorations on the walls almost too faint to notice in passing, but indicative, nevertheless, of the mineral wealth hidden from view by a few inches of sparkling incrustations.

A word as to the size of these caves: I am credibly informed that some of them reach a width of 300 feet. I saw one 160 feet across and some 300 feet in length. The fissures or joint planes along which the ore deposits occur and the caves are formed are generally mere films outside the caves, and difficult to follow on their strike. The same remarks often apply to the vertical position, though there is usually a system of open cracks and watercourses connecting a given cave (of a series) with the next one below and above it.

In one mine I went from the surface to a vertical depth of 700 feet through natural caves and watercourses—the most unique and inspiring experiences that I have encountered in a rather varied mining career. That trip completed my visit to the deep mines of the Santa Eulalia district, and, had I been then told that twenty million tons of limestone had been dissolved and removed from the mountain by the silent, yet potent influence of circulating carbonated waters, I would not have questioned the statement. Even now, after calm reflection, though lacking data to form more than the crudest estimate, I would not feel like reducing that figure over 50 per cent., assuming the unexplored portion of the district has a similar mineralization and cave system.

The facetious names given to some of the caves and stopes are rather suggestive of their size, as, for example, the batallion stope, in which 200 men were said to have been steadily employed for some years; the Patio de Toros, and such like. In one mine I visited, a roadway had been constructed from the mouth of a cave in the side of a canon, down through a series of immense caves and stopes, until finally the working faces were reached at a vertical depth of 300 feet below surface. At one point in this roadway, connection was made from one cave to another 40 feet below by a spiral roadway shot out of the solid walls of the connecting cave or watercourse—an admirable piece of engineering. By means of this road the festive mules were brought right up to the working faces, so that the ore could be packed out to the surface on the animals' backs—the acme of cheap underground transportation from a Mexican's point of view.

I might here state that the most disappointing thing to me on arriving at the Santa Eulalia Mines was the practical absence of dumps. Not that they are absolutely necessary for profitable mining (they are usually a necessary evil), but one could scarcely conceive that mines had been operated there for a century or more, producing millions of dollars' worth of ore, but only three or four thousand tons of waste, as represented by the surface dumps. When I asked for an explanation it came quickly—"the ore was very rich, the Mexicans smelted everything they took out of the mines." The real cause is the immense cave system in the mines, providing ample room for stowing all the waste, not only that produced from mining the ore, but also from the development work. Practically the only mine dumps are those recently made under modern management, and it is questionable if it would not have been better mining to have used the waste rock to fill up old stopes and caves, as the Mexicans formerly did, instead of hoisting it to the surface.

The Santa Eulalia limestone appears to pass readily into solution. All surface exposures show the flints and fossils stand-

ing out prominently, while many of the joint cracks are enlarged and in places caves are formed which appear to have no relation to the ore deposits and are in all probability of later age. Some of the watercourses connected with the system of ore caves are oval-shaped tubes, devoid of ore and quite smooth except for the insoluble flints that stand out in serrated layers and an occasional bump of silicified limestone.

Another form of deposit is shown in Diagram 3. When solutions ascending a joint plane follow suitable strata to the next joint, ascending along it for a distance and then repeating the phenomenon, replacing in each instance the limestone with ore, as outlined, subsequently a cave may be formed as shown by the broken lines. Fig. 4 is a sketch made at a depth of 1,500 feet from the surface, where solid mixed sulphides can be seen for the first time in that mine. The pyrites and galena appear to be secondary, these ores having been deposited on eroded limestone in what was apparently a watercourse, adjoining and connected with a large cave of oxidized ore. The galena was quite fresh and apparently unaltered; the pyrites was in places oxidized to quite a considerable extent, but the greater part of it appeared to be unaltered. Some native silver occurs in the druses of the mixed sulphides, and the superintendent informed me that he found a loose deposit of native silver on the floor of the watercourse behind the stalagmite shown on the sketch. The mixed sulphides, he told me, assayed about 59 per cent. lead and 80 ounces of silver per ton.

An interesting speculation on the Santa Eulalia deposits is, To what depth will the zone of oxidation extend? and, furthermore, Will the first zone of solid sulphides be enriched by secondary agencies?

These are difficult questions, but, reasoning from analogy, I am inclined to the opinion that the latter will be moderately enriched for a shallow depth—I might possibly call it superficial enrichment. It must be remembered that the oxidized ores are

simply chemical concentrations from the original sulphides, and that the beds of cerussite and bunches of chlorides and bromides of silver contained in the mass of the oxidized ore should account for the greater part, if not all, of the values leached from the original sulphides; consequently, one could not, I think, reasonably expect a zone of heavy sulphide enrichment, nor could even a moderate sulphide enrichment be expected to extend to any great depth in the original sulphides. The depth to which oxidation will reach must naturally vary with the size of the ore bodies. The larger deposits, I take it, should extend in a partially oxidized condition for a considerable distance below the water level of the district. The water level may not be an easy matter to determine. The mines are practically dry at a depth of 1,450 feet, as measured at the San Domingo shaft, and considering the arid nature of the country, it is doubtful if any material amount of flowing water will be encountered. The mines may have, in fact, already reached the ground water level, as a small quantity is being met with. Furthermore, there are strong indications at a depth of 1,500 feet that the sulphide zone appears to be near at hand. The original sulphide ores to be found below the zone of oxidation will, in all probability, be of much lower grade than the oxidized ores, as well as more difficult to treat.

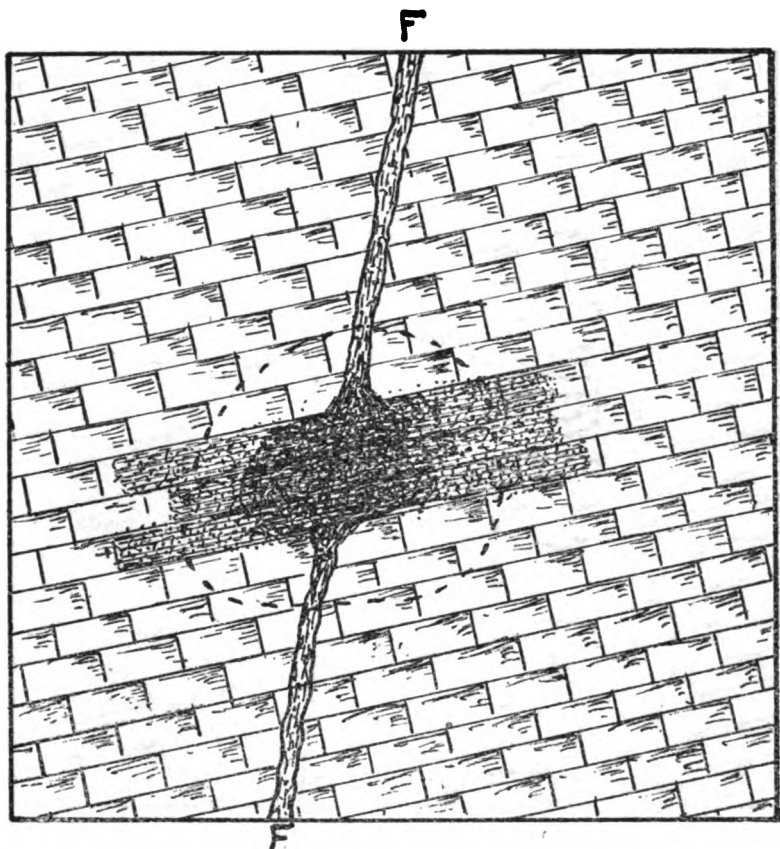


Fig. 1.

F. Fissure.

■ Ore replacing limestone.

--- Cave line.

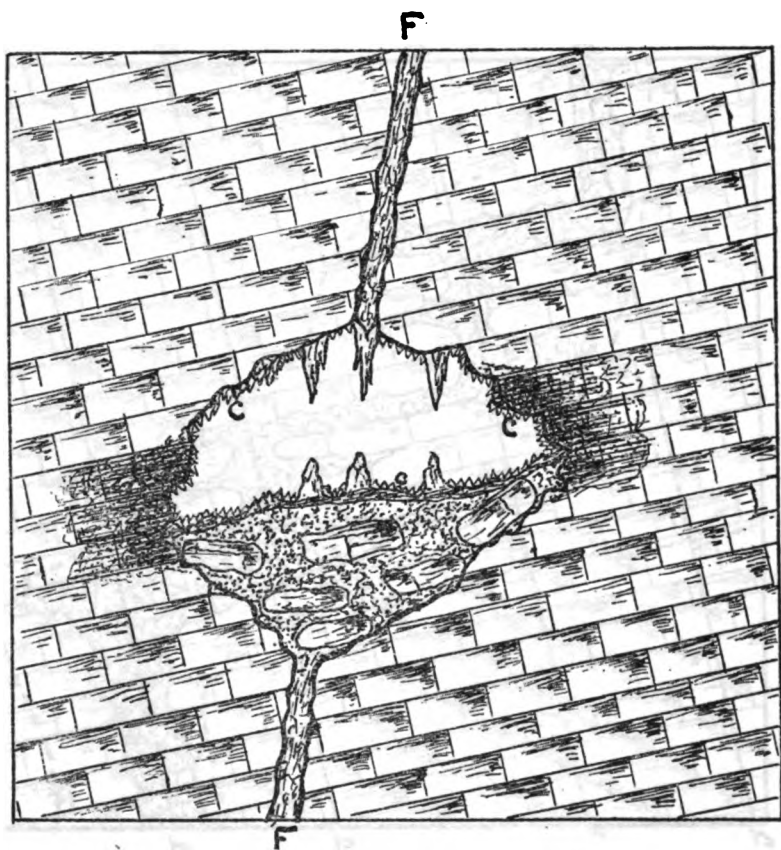


Fig. 2.

F. Fissure.

 **Cave ore.**

 **Ore in place.**

C. Calcite crystals.

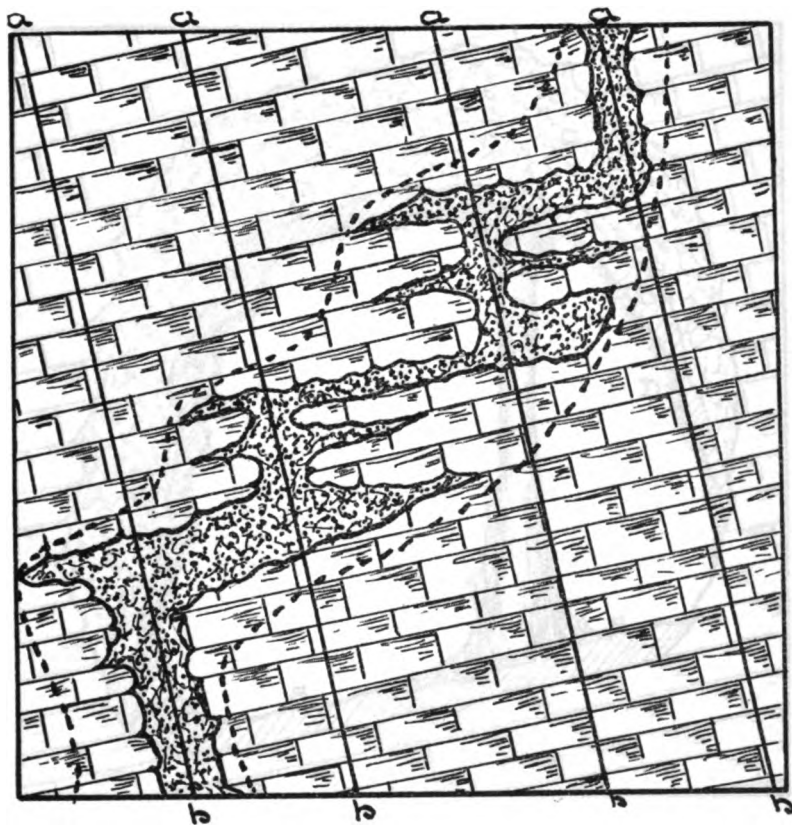


Fig. 3.

 Oxidized ore.

A. B. Joint or Fracture Planes.

THE CONTACT, NEVADA, QUAQUAVERSAL.*

BY CHESTER WELLS PURINGTON.

Read at the Meeting of the Society, August 1, 1903.

The region lying between Wells, Nevada, on the Union Pacific Railway, and Shoshone, Idaho, on the Oregon Short Line, was traversed by a party of which the writer was one, in the early part of June, 1903. The following notes are a result of observations made during that journey. As the time was limited and a stay of only three days made in the vicinity of Contact, at the copper deposits described, nothing more than a geological reconnaissance of the briefest character is attempted. It is hoped that some value may be found in the paper, since the area lies somewhat apart from the path of former geological investigations.

The district with which this paper has principally to deal is situated near the small settlement known as Contact, in Elko County, northeast Nevada, two miles to the west of Salmon River, a tributary of the Snake, and forty miles to the west of the boundary of Utah. The general elevation of this plateau area, in the northern portion of the Great Basin, is 5,000 feet above the sea, and the mountains in which the geological features to be considered are developed rise from 1,500 to 3,000 feet above this general level. The country in the vicinity of the Salmon River, and for distances of more than 100 miles in all directions is, for the most part, a desert, covered with sagebrush, and treeless.

*The journey to this locality was made in company with Mr. Philip Argall, and I am indebted to him for many valuable suggestions in the preparation of the following notes.

The district is one characterized by numerous and broad valleys occupying gentle depressions between the intervening low hills or elevated portions of the plateau. These are, when watered, extremely fertile and suitable for stock grazing. Their filling material is of Quaternary age, probably very recent, and they doubtless form a part of the lake system of which Gilbert's Lake Bonneville is the most notable example. The borders of Lake Bonneville extend, in fact, according to the mapping of Gilbert, to within twenty miles on the east of the Salmon River and the region to be described. I did not see traces of ancient shorelines in the vicinity of the mountains about Contact. The forming of the alluvials now filling the valleys is generally considered as contemporaneous with the glacial period.

In proceeding northward from Wells, Nevada, a station on the Union Pacific Railway, the upland portion of the plateau lying between the flat lake beds, consists of green sand, hardly consolidated, and in the beds of which, exposed on the low hillsides, it is difficult to see stratification. Professor Lester F. Ward* says that at Elko, on the Union Pacific, fossil plants resembling those found at Florissant, in the Green River beds of the Tertiary, have been found. These were found in white calcareous shale, and, although such shale does not occur in the country to the north, it is likely that a widespread formation of white sandstone lying to the north of the (Carboniferous?) green sand area is of Tertiary age.†

The sediments in the vicinity of Contact are limestones and quartzite, and are probably of Carboniferous age. The district of Eureka, 100 miles to the southwest, contains both Cambrian and Algonkian rocks, and the well-known Cambrian fauna of the *Olenellus* beds has been identified there.‡ Of younger sediments

*"Distribution of Fossil Plants;" Lester F. Ward. 8th An. Rept. U. S. Geol. Sur., Part II, p. 919.

†On the maps of the Survey of the Fortieth Parallel, a low divide lying between Thousand Springs Creek on the north, and Wells on the south, is designated as Carboniferous.

‡"Fauna of the *Olenellus* Zone;" C. D. Walcott. 10th Am. Rept. U. S. Geol. Sur., Part I. p. 549.

there appear to be no representatives, up to the white friable sandstones which outcrop in low hills for twenty-five miles to the south of Contact, and which have been referred to.

On Map III of the Fortieth Parallel Survey, the district lying forty miles to the east of Contact, known as the Raft River Mountains exhibits a large outcrop of lower coal measures, overlain by Tertiary beds. A large intrusive granite mass occurs in these mountains.

From a latitude of several miles to the south, flat-topped mesas and low-peaked hills may be seen to the east and west of the main road. As the white sandstones are tilted up on approaching the mountains, it is a possible inference that laccolites of granitic rocks, similar to the one to be described, are responsible for the peaks. The flat-topped mesas, on the other hand, are seen to be formed by outlying masses of basalt—portions of the southern rim of the immense Tertiary basalt flow which has its greatest manifestation in southern Idaho. The basalt has little to do with the geological relations at Contact, and a description of it will be taken up after the main features are described.

The small mining community known as Contact received its name presumably from the fact that it is situated on the approximate junction of a mass of grano-diorite and limestone. A few words are not out of place regarding the unreasoning use of the word "contact" by prospectors, and occasionally by mining industrials of long experience. According to the Standard Dictionary, a contact in mining is the line of delimitation between a metaliferous vein and its wall or country rock; in geology a contact is the junction of an igneous rock and the country rock, and generally of rocks of different ages or kinds. These definitions are perhaps as good as any that can be devised, although the substitution of the word "plane" for the word "line" may be deemed acceptable.

A contact, then, being defined as a plane, cannot have volume, and the name, as applied to a flat-lying ore-body, which applica-

tion it frequently appears to have, is inexcusably wrong. I must frequently make use of this word in the following notes and have entered this mild protest concerning its much-abused significance, in order that no misunderstanding may occur.

At Contact, the limestones, presumably Carboniferous, have been subject to distortion, in the form of an uplift. The Ellen D. mountain, at Contact, and another mountain twenty miles to the east, owe their origin to what I feel justified in calling a laccolite of grano-diorite, of which the central portion, together with the overlying sediments, has been removed by erosion. The definition of laccolite, given by Gilbert, in his "Geology of the Henry Mountains," applies to an intrusive mass of igneous, and necessarily plutonic rock, intercalated between layers of sediments, having a dome-shaped upper surface, and approaching in form a hemisphere. The form assumed by the overlying and distorted sediments must necessarily be that of a quaquaversal flexure, dipping away on all sides from a central point. At Contact the evidence that sediments underlie the grano-diorite mass is lacking, but the assumption is made that sediments similar to those found overlying the plutonic mass lie in place beneath this mass. This seems more probable than that the grano-diorite mass has intruded, in the form of a stock, through the entire mass of the underlying sediments, and that the 1,500 feet of limestone and quartzite overlying the grano-diorite and underlying the capping basalt on Ellen D. mountain, represent the entire geological section at this locality. If the mass be considered as a stock, one must assume that the Cambrian and Algonkian rocks do not exist in this part of Nevada, whereas they are known to exist at Eureka, and Mr. C. D. Walcott states that in parts of Nevada the Algonkian rocks attain a thickness of ten thousand feet.

Of the quaquaversal, at present only the portions of the two legs on the western half remain. These, represented by detached fragments of the original mass, compose Ellen D. mountain, and its neighbor to the east, as represented in the sketch (Fig. 1).

The entire middle portion of the laccolite, with the overlying sediments, has been removed down to a general level of 6,000 feet, leaving the mass of grano-diorite with a low, rough topography. On the northwestern slope of Ellen D. mountain, and on the eastern and easterly-dipping slope of the mountain to the east, a capping of the more recent basalt is found of a thickness not exceeding 500 feet. That this basalt has covered and been partially removed from the region at a time subsequent to the bulk of the erosion of the other rocks, is interestingly shown by Table mountain. This is a small inlyer of basalt directly capping the grano-diorite, two miles to the east of the top of Ellen D. mountain, with an elevation of 7,000 feet.

At the junction of the grano-diorite and the limestone beds on the east slope of Ellen D. mountain, a complicated mingling of the two rocks has occurred. The accompanying section (Fig. 2) taken at a distance of 9,000 feet to the east-southeast of the top of the mountain, illustrates the relations. The grano-diorite itself is of medium grain, with abundant plagioclase and orthoclase feldspar, a sparse amount of quartz, much biotite, and a subordinate amount of hornblende, which is somewhat decomposed to chlorite. The limestone, in blue and white alternating layers, blue predominating, appears with a fair degree of constancy, in three parallel occurrences, as here illustrated. The southeast group of beds shows a thickness of 800 feet, with white limestone lying above the blue. Going up the hill to the west, 500 feet of grano-diorite are succeeded by a layer of white limestone of 300 feet thickness; this is in turn succeeded to the west by 20 feet of white quartzite; 50 feet of grano-diorite intervene, and are succeeded to the west by the main mass of the limestone with a predominating amount of blue beds, and a thickness of 1,500 feet. This upper and main group is capped directly by basalt, conformable in strike and dip, which composes the top of the mountain, 8,000 feet in height. The strike of the series is north 75 degrees

east, and the dip of the main mass of limestone and basalt layers 20 degrees to the northwest.

Although the limestones are, in places, found in fairly fresh and unmetamorphosed condition, fossils were not identified, and thus the age of the beds can be judged only from the physical appearance, and from correlation with other points in the Great Basin. On this ground they are assigned to the Carboniferous horizon.

The structure, as represented in this section, is fairly constant along a strike of about seven miles, although at only a few places toward the east end of the mountain is the dip of the various groups so graphically shown. On the transverse ridge from which the section was drawn, the entirely unconformable dip of groups (3) and (2) was to be seen diagrammatically displayed. If the hypothesis be admitted that the grano-diorite is the eroded relique of an intrusive laccolite, it is an allowable deduction that the two easterly bands of limestone are layers lifted from the underlying sediments by the agency of the viscous plutonic mass at the time of its intrusion. Another explanation is possible, namely, that the intruded layers with unconformable dip have been broken off from the mass to the west and been partially submerged in the cooling mass. A rather uncertain correlation which can be made out between the beds of (1), and of (2) and (3) lends weight to this view. So unusual a phenomenon as the one here displayed is difficult to explain.

At the time of the deformation of the sediments by the laccolite, and slightly subsequent to it, fissuring occurred in both the grano-diorite and the limestone. The main fissuring, which resulted in a marked sheeting of the diorite, was in strike north 5 degrees east, to north 5 degrees west, and vertical. This was so prominently developed in some areas as to have induced a sort of coarse lamination in the grano-diorite. It was not, however, accompanied by a development of open space, in many instances. The subordinate systems were developed, one north 75 degrees east,

following the lines of contact, and one north 45 degrees east, of limited development. This last direction determines the trend of one or two of the veins which have been worked for copper in the northeast part of the area. Dikes of felsite, in all probability of a chemical composition not different from that of the grano-diorite, but of porphyritic habit, penetrate the limestone, following for the most part the nearly north and south fissures. These dikes have generally a width of from two to three feet, but in one instance a dike forty feet in width occurs. At one point there occur two dikes of felsite, each five feet in width, fifty feet apart, with parallel strike north 45 degrees west, crossing the limestone beds of one (1), which dip into the mountain. All the dikes are undoubtedly offshoots from the main laccolite, and their porphyritic form is explainable from the fact of their having cooled under different physical conditions.

It is evident that the rock complex here considered presents five planes of contact. On all of these, but mainly on the east side of (1) band, and (3) band with grano-diorite, the north and south fissures penetrating the rocks have deposited copper ore. Small copper veins in the grano-diorite striking nearly north and south may be seen at numerous points for the entire distance along the east and west direction above referred to. Where these seams cross the contacts, especially when the felsite dikes occur in the immediate vicinity, the ore-bearing solutions appear to have exercised a selective activity of replacement along the adjacent limestone layers. Thus there have been formed ore bodies of an intermittent character, rarely exceeding twenty inches in width, and never, in observed cases, extending over fifty feet laterally from the mineralizing veins or dikes. In one case a fissure, very nearly following in strike and dip the contact of grano-diorite, with (3) has been found to carry copper sulphides to a depth of 300 feet from the surface. Had the grano-diorite been more easily subject to fissuring, and the amount of open space developed been

important, it is likely that extensive ore bodies would have been formed.

It should be noted that, where the north and south fissures cross the beds of limestone at other than right angles both to the strike and dip, it is the down side of the limestone beds which has been the more abundantly replaced by ore. In some cases toward the east end of the mountain, the fissures in the grano-diorite, apart from the limestone, have been worked as copper veins. These veins, carrying glassy quartz as gangue, form outcrops which stand out prominently on the hillsides above the more easily eroded grano-diorite country. The vein outcrops vary in width from one to four feet.

The minerals found in the quartz veins and mineralized beds of limestone carrying copper values are quartz gangue with small amounts of chalcedony, while the only contact mineral identified was garnet.* As ore minerals, chalcopyrite, chalcocite, bornite, cuprite, malachite, azurite and chrysocolla. Molybdenite in small quantity occurs with the ore. In all probability the original sulphide was chalcopyrite, and at a considerable depth an impoverishment of the surface percentage of copper is to be expected. In a nearly rainless country such as the one described, it is not likely that secondary changes have played an important part. The bornite and chalcocite are, in all probability, secondary. Secondary changes would have been aided through the forming of copper salts due to the influence of the limestone.

The occurrence here described presents an instructive feature bearing on the question of mine sampling. It may be seen that the contacts between grano-diorite and limestone are the seat of deposition of small bodies of ore along and to a short distance laterally from the crossing of the north and south fissures, and crossing of the dikes, and generally only under these conditions. The fissures carrying ore in the igneous rock are not regularly dis-

*I would infer that pneumatolytic action in the formation of these copper deposits has been entirely subordinate.

tributed, but may be said to occur at intervals averaging 300 feet apart, for a distance of seven miles from east to west. The ore has no continuous extent across the main fissuring, from one mineralizing vein to another. Openings for development disposed along the north and south veins would show ore throughout the entire drift for considerable distances into the mountain away from the grano-diorite mass. Taking any two of these parallel drifts, it is clear that a possible inference might follow that they showed two sides of a bedded deposit of copper ore. How dangerous this inference would be becomes evident when the geological conditions are considered. The deception is rendered more striking when one of the mineralizing fissures running north 75 degrees east is nearly coincident with the exposed edge of the plane of contact, as illustrated in Fig. 4. Instead of exposing two sides of one wide body of ore, the two parallel drifts are run merely on two narrow shoots of ore, having no connection the one with the other. An east and west drift to connect the two running north and south would at once disprove the existence of continuous ore between.

To treat the copper ores of this district, a 50-ton smelter of waterjacket type was erected some years ago, at a point two miles distant, near the Salmon River. It has not been operated successfully.

During a drive from Contact, 75 miles to the north to the town of Shoshone, Idaho, a portion of the great basalt plateau of southern Idaho was traversed (Fig. 5). At the Shoshone Falls of the Snake River, a section of the basalt and underlying rock, in all about 500 feet, of vertical thickness, was seen. The basalt appears here 250 feet thick, consisting of many separate flows from ten to twenty-five feet in thickness. This lava lies on the top of the rough and apparently denuded surface of andesite,* of which 250 feet thickness was visible. This andesite, with blue

*Mr King, in the Fortieth Parallel Reports, refers to the andesite as a soft trachyte rock of pre-Miocene age.

groundmass and coarse feldspar phenocrysts, bears a strong resemblance to the upper andesite flows of the San Juan region in Colorado.* At a point five miles to the west of Shoshone Falls, a deep incision into the north wall of the Snake River canon, in the shape of an amphitheatre, probably represents one of the sources of the basalt flow. It is 3,000 feet in diameter and 500 feet deep, and contains two small pools of water, tepid in temperature, and sulphur-bearing. These pools, known as the Blue Lakes, are evidently fed by abundant springs, causing a plentiful flow of water which drains into the Snake. The walls of the amphitheatre are steep and crater-like, although the true basaltic columns with fracture faces at 120 degrees, were not recognized in the brief inspection made.

Between the Snake River and Shoshone, in places the surface of the basalt has the ropy and scoriaceous appearance characteristic of fresh lava flows. Long, rope-like ridges, several feet in height, may be seen to the south of Shoshone. Some of the basalt in the region has acquired the name of scorpion rock, from the fact that scorpions make a nest or hiding-place in the vesicles of the lava.

DISCUSSION.

Mr. Argall—I am sure you will all agree with me that the best thanks of the Society are due Mr. Purington for his very able presentation of the geology of a district as interesting as it is difficult to portray.

Having seen the greater part of the mining district described in Mr. Purington's paper, I can add my testimony regarding the large mass of detailed information he has given us as well as to the thoroughness of his examination. Three matters stand out prominently in my mind: First, the very extensive and highly developed shearing in the grano-diorite, and the extensive impregnation of the walls of the shear planes with copper minerals; it is

See description of Shoshone Falls locality by S. F. Emmons; Proc. 5th Sess. Int. Geol. Congress. p. 373; Washington, 1893.

but seldom one sees a wider area of mineralization than that at Contact, Nevada. In the next place, the coloration effect of this wide mineralization is extremely beautiful, and, as is usual in such districts, is liable to lead one to exaggerated ideas of the amount of copper contained in the veins and impregnated rock. Being quite familiar with this tendency of copper to spread over large areas, and having, as I thought, discounted it sufficiently, I was, I must confess, somewhat disappointed at the result of the assays on samples I had taken, more particularly from those quartz veins in the shearing zones that were two and three feet wide, and could be traced in the eroded grano-diorite standing up in bold outline two to four feet above the enclosing rock. Some of these outcrops, though showing a heavy copper stain, yet ran very low in copper value.

Lastly, those immense sheets of limestone standing almost vertical in the grano-diorite are, to say the least, very difficult to explain. I note that Mr. Purington, while showing that they may have been broken off from the main mass now represented by the hill section capped with basalt, yet rather favors the idea that they have been floated up from below. Such occurrences are not unusual, particularly in Leadville, but I have never seen float rocks occupy an almost vertical position in the igneous rock—it usually tends more to the horizontal. Then, on the other hand, I have seen, on the continental divide near Buena Vista, the Carboniferous and Silurian sedimentaries bent over almost at right angles and enclosed in the crystalline schists, a ravine about 600 feet below the summit exposing the limestones at that depth thoroughly marbleized. I would rather favor a similar view in the Contact case—that is to say, that in the orographic phenomena attending the extrusion of the grano-diorite, a fold of the limestone was caught in the mass of the igneous rock and subsequently eroded to the outlines of the section. The correlation of the sedimentaries, in both positions on the section, would, I believe,

lend weight to this view, more particularly as at some points the grano-diorite separating the limestone is not present.

It appears to me that this tongue of limestone extending into the mass of the grano-diorite is worth prospecting, especially in the neighborhood of the more prominent shear zone veins.

SCALE - 1 INCH = 4 MILES
Below broken line show direction of flowing
- False Ditch.

Grano-Diorite.

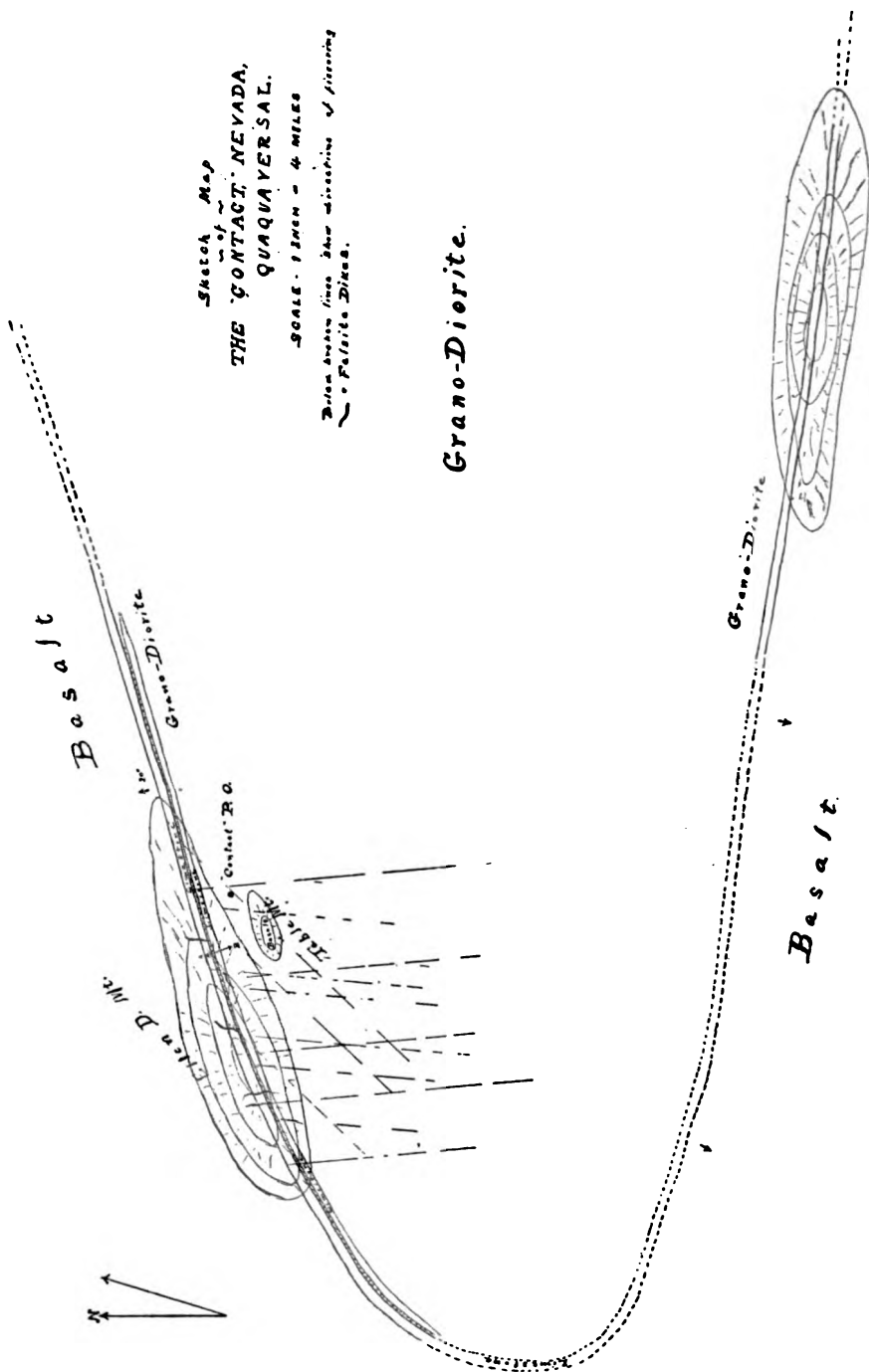


Fig. 1.

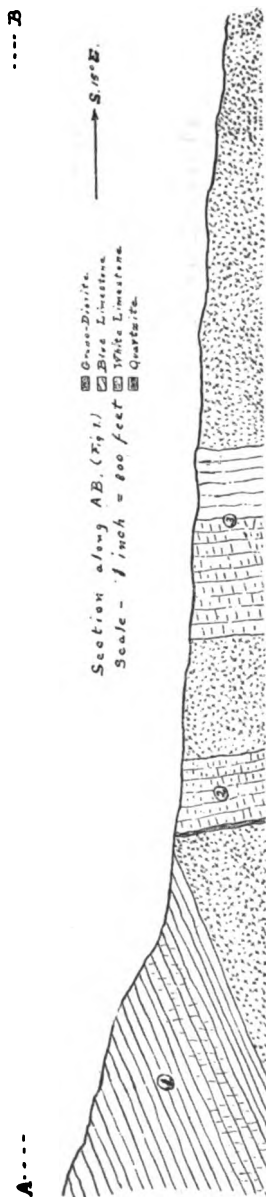


Fig. 2.



Fig. 3. Limestone bed stained with copper carbonates, near contact with grano-diorite; Contact, Nevada.

Photograph taken by Mr. Philip Argall.

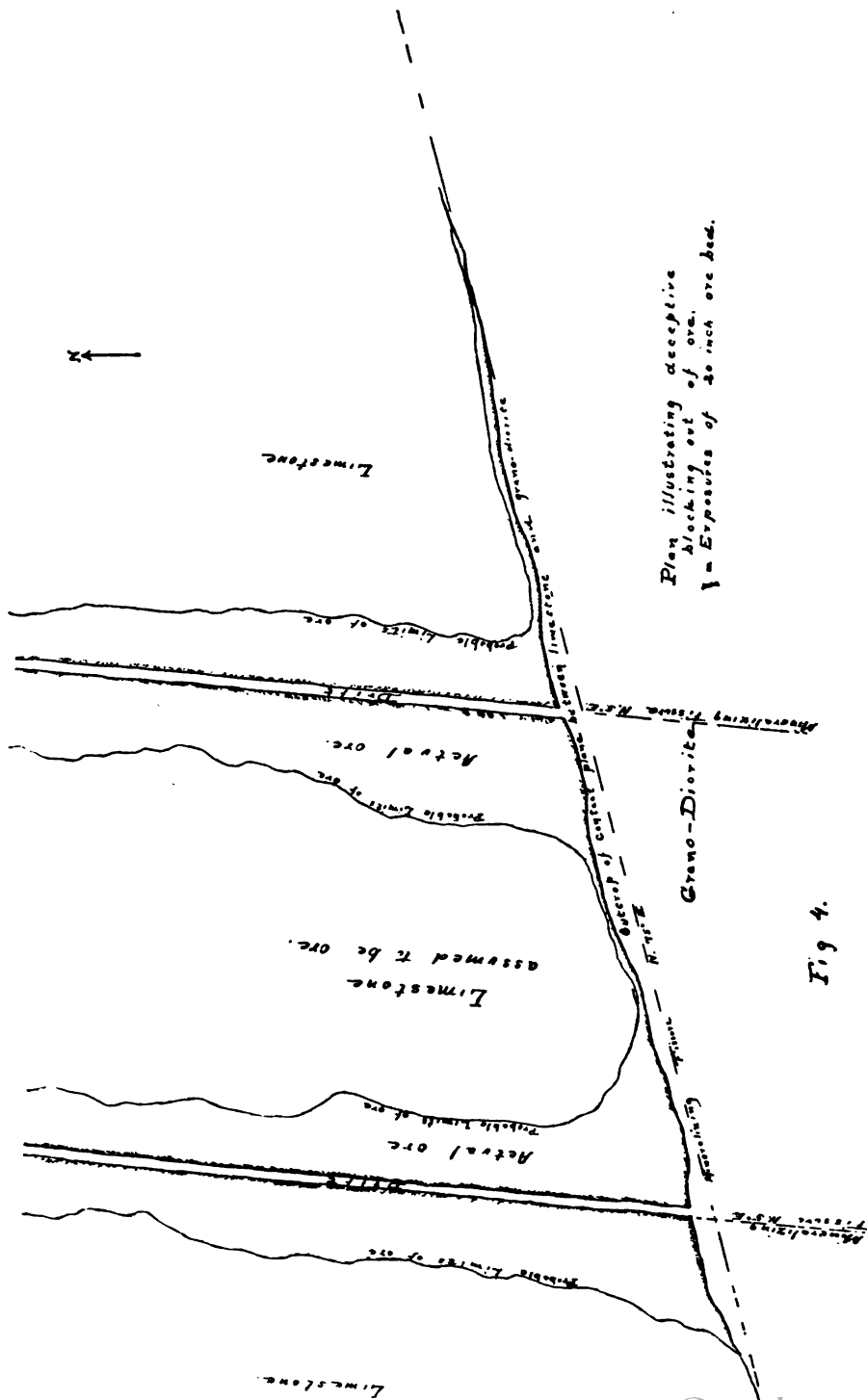


Fig 4.

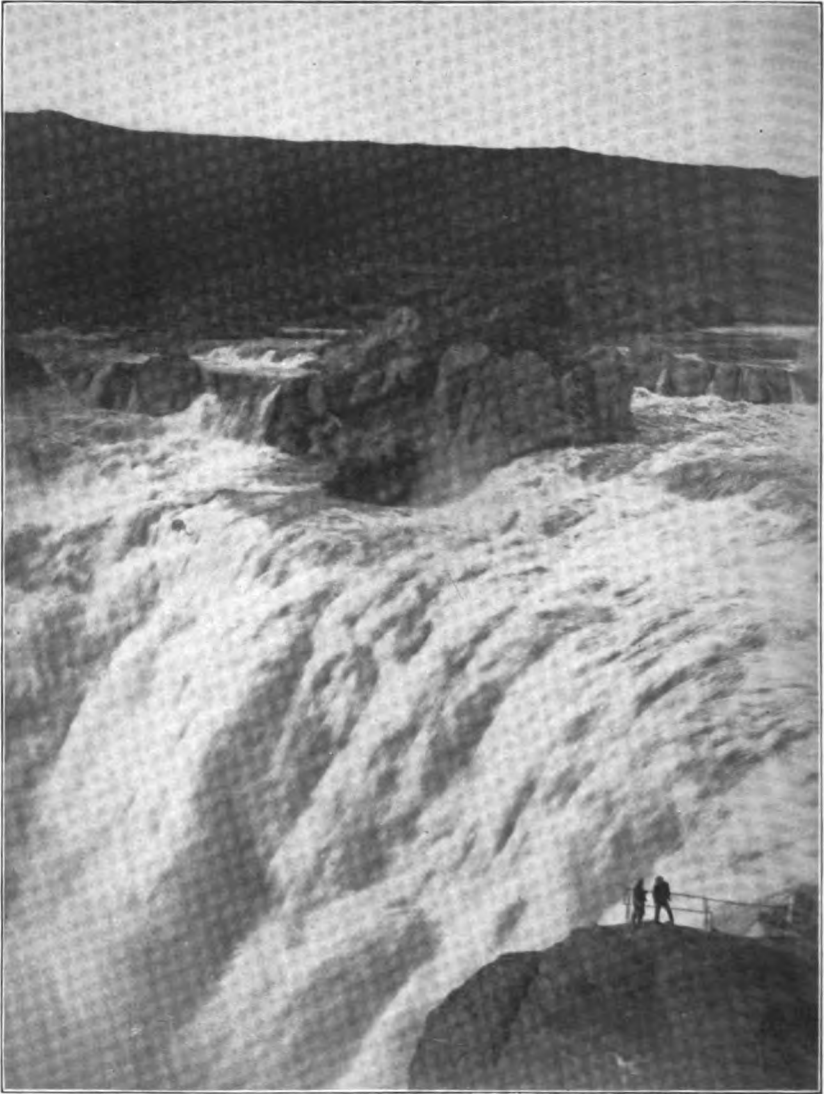


Fig. 5. The Shoshone Falls of the Snake River, Idaho. Height, 212 feet.

Photograph taken by Mr. Philip Argall.

139-150.

NOTES ON AN OCCURRENCE OF MICA IN BOULDER
COUNTY.

By T. E. SCHWARZ.

MINERALOGICAL NOTES.

By W. P. HEADDEN.

DENVER,
PUBLISHED BY THE SOCIETY
SEPTEMBER, 1903.

NOTES ON AN OCCURRENCE OF MICA IN BOULDER COUNTY.

BY T. E. SCHWARZ.

Read at the Meeting of the Society, September 5, 1903.

Some ten miles west from Boulder, Colorado, on the south side of Left Hand Creek, a short distance below the little town of Glendale, occurs an interesting development of mica.

The country rock is hornblende-mica schist. There are several places on the mountain side where there occur apparent segregations of white quartz, usually accompanied with more or less orthoclase feldspar and mica, in small crystals. The most extensive occurrence is, however, associated with what appears to be a white quartz vein 5 feet to 10 feet wide, traceable 150 feet, and probably more were the slide-rock removed, in a northeasterly direction.

Lying directly above this vein of quartz and dipping slightly to the northwest, under the dark gneiss schists, is a body of orthoclase feldspar 3 feet to 4 feet thick, interspersed with the crystals and aggregations of muscovite in various sizes. The mica is best developed in and near the contact between the quartz and feldspar, filling the contact with coarse crystals. From the contact the most defined and probably the largest books make down into the underlying quartz at intervals, and are 8 inches to 10 inches in diameter.

The striking features of the occurrence are that the face of white quartz, some 10 feet deep by 5 feet wide, shows no mica

except at the top adjoining the contact, and no feldspar except an included mass at bottom of cut. The overlying feldspar, however, is full of mica, but shows little or no quartz, except with depth, where bunches of quartz occur, and the whole takes the appearance more of a pegmatite dike, the mica crystals being smaller. The specimens presented to the Society are an average of the larger sheets.

The Society has in its collection some specimens from the Dake mica mine, in North Carolina, which produces, apparently, a better grade of mica than occurs in this Boulder county instance, but the gangue minerals, quartz and feldspar, are of the same character. The country rock, however, in North Carolina, is more distinctly a mica schist than that of Boulder. None of the accessory minerals often occurring in such veins were observed.

The question as to whether such occurrences as I have described should be termed veins or dikes, is referred to by Kemp*, as follows:

"Especially in regions of granite intrusions and of extensive metamorphism, veins or dikes — it is an open question which is the more correct term — are met formed of very coarsely crystalline aggregates of the same minerals that constitute granite. These are called pegmatite, and in them is the home of graphic granite, a curious intergrowth of quartz and feldspar, such that a cross-fracture of the blades of quartz suggests cuneiform characters. Garnet, tourmaline, beryl and minerals involving the rare earths, are often found in pegmatites, and they supply the feldspar and mica of commerce. The outcrops may be two hundred feet broad, or more, and again the same aggregates are found as small lenses, or "Augen," in metamorphic rocks. In regard to the larger veins or dikes, it seems improbable that true igneous fusion could have afforded such coarsely crystalline aggregates, and so we were forced to assume such abundance of steam and other vapors, *i. e.*, mineralizers, as to almost, if not quite, imply solution."

T. Sterry Hunt† classes them as "endogenous granitic veins," in his admirable chapter on "Granites and Granitic Veinstones." He plainly refers them to aqueous origin, as does W. C. Kerr‡, in describing the mica deposits of North Carolina.

*J. F. Kemp: "A Handbook of Rocks," p. 31.

†Chemical and Geological Essays, p. 191-203.

‡Trans. A. I. M. E., Vol. VIII, p. 457

MINERALOGICAL NOTES.

By W. P. HEADDEN.

Read at the Meeting of the Society, September 5, 1908.

NATIVE TELLURIUM, GUNNISON COUNTY, COLORADO.

Through the kindness of the Hon. Harry A. Lee, ex-Commissioner of Mines, and of Mr. J. C. Langley, Chief Clerk of the Bureau of Mines, I was fortunate enough to obtain a quantity of interesting material from the Goodhope Mine, Gunnison County. The specimens consist of native tellurium, associated with iron pyrites, arsenopyrite, tellurite, etc.

I will consider the sample of native tellurium from this locality first, because it is the most typical sample of this material in my possession.

The native tellurium occurs in streaks up to an inch in thickness, but usually about one-fourth of this thickness. It is highly crystalline, showing eminent cleavage in two directions, suggestive of an orthorhombic, rather than hexagonal, form. The seemingly more perfect cleavage being parallel to the macropinacoid, the less perfect parallel to the prism surfaces. The form, however, is hexagonal, as given in Dana's System, and not orthorhombic, as here suggested; the cleavage form is simply suggestive of the latter. The enclosing rock, such as is attached to the fragments of the tellurium, is a chloritic schist. I have no information relative to the quantity in which this occurs, but as there was rather more than thirty pounds of the material, from which I sorted out

the specimens described in this article, I infer that the occurrence is not confined to one bunch; indeed, the flat and thin pieces indicate seams of extraordinary size and of unusual length. This sample gave the following analysis:

Te	99.45
Fe	0.11
Se	0.40
	<hr/>
	99.96

The selenium is given as obtained by adding hydrochloric acid to the solution of potassic cyanid after precipitating the tellurium by drawing a current of air through it for some time after it had become colorless. Notwithstanding the care that was taken to get the whole of the tellurium thrown down from the potassic cyanid solution, I am in doubt whether the precipitate contained more than a trace of selenium.

The manner of occurrence, form and composition of this sample is entirely different from the Boulder County samples that I have seen, especially from those that I have analyzed, as the following samples from the Valley Forge Mine, Boulder County, will show.

NATIVE TELLURIUM, BOULDER COUNTY, COLORADO.

Sample No. 1. This sample consists of a mass of quartz, such as is common in the veins of Boulder County, in the mass of which occur flakes, seams and bunches of tellurium. One side of it is covered rather thickly with a mass of tellurium, which is not solid, but is composed of irregular bunches showing cleavage, but no crystal forms. This coating is, in places, close to one-quarter of an inch in thickness. The associated minerals are pyrite, chalcopyrite and quartz deposited in and upon the irregular masses of tellurium. It was absolutely impossible to select pure material. The analysis gave:

Quartz	20.00				<i>Calculating Te and Au to 100</i>
Te	76.94	Te	99.51		
Au	0.38	Au	0.49		
FeS ₂ { Fe	1.23				
{ S	1.41				
	<hr/>				
	99.96				100.00

Sample No. 2. Also from the Valley Forge Mine. The material composing this sample was designated as the rich streak, and had the following composition:

Quartz	34.54				<i>Calculating Te, Au and Ni to 100</i>
Te	54.76	Te	88.75		
Au	1.72	Au	2.79		
Ni	5.22	Ni	8.46		
FeS ₂ { Fe	1.57				
{ S	1.79				
	<hr/>				
	99.80				100.00

Assuming the Ni to be present as melonite, Ni₃Te₂, and the gold as calaverite, though it may be present as free gold, we would have—

Melonite	Ni ₃ Te ₂	35.54
Calaverite	AuTe ₂	6.40
Native tellurium	Te	58.06
		<hr/>
		100.00

Sample No. 3. from the Valley Forge Mine. This sample has a very dark gray color, metallic lustre, a subconchoidal to an irregular fracture, with no definitely recognizable cleavage surfaces. The irregular little masses of tellurid are covered with a thin coating of quartz and are often penetrated by the same mineral. The hand specimen showed only a few particles of pyrites or chalcopryrite. While the mass of tellurides is doubtlessly mixed, it appears to be quite uniform in character, even when examined with the aid of a good magnifier. The only thing suggestive of any lack of uniformity is the occasional appearance of what seemed to be cleavage surfaces. This sample does not

resemble native tellurium in any manner, and appears to be pretty homogeneous even when examined with a magnifier, except that in a strong light a very thin film may be detected covering the small masses. This film is so thin that I am not sure that it ought to be considered as more than a tarnish due to the action of the air on the sample which has been in my possession for some years. The presence in Sample No. 2 of a fine-grained, pinkish to brown, somewhat iridescent mineral in greater abundance, while the analysis leads us to conclude that over 35 per cent. of the sample is melonite, suggests that the coating on Sample No. 3, observable only in a good light, may be this mineral, *i. e.*, the tellurid of nickel or melonite. The analysis of this sample gave:

			Calculated to 100
Quartz	27.12	Te	83.88
Te	58.26	Au	1.44
Au	1.00	Ag	Trace
Ag	Trace	Hg	6.08
Hg	4.22	Ni	1.38
Ni	0.96	Fe	3.81
Fe	2.65	S	3.41
S	2.37		
On gentle heating in			
CO ₂ *	3.18		
	<u>99.76</u>		<u>100.00</u>

Assuming this to be a mixture of known minerals, and basing our calculations on accepted formulas, we have the following for the sample:

Coloradoite	HgTe	9.96
Melonite	Ni ₂ Te ₃	5.88
Calaverite	AuTe ₂	3.31
Tellurium	Native	76.63
Pyrite		6.38
Iron, probably in combination with tellurium		0.84
Silver, probably contained in the calaverite		Trace
		<u>100.00</u>

*The sample was heated in a glass tube in an atmosphere of CO₂ under such conditions that any loss of S or Hg would have been detected.

NATIVE TELLURIUM, GUNNISON COUNTY, COLORADO.

Goodhope Sample No. 2. The first sample discussed was taken up before the last three, because of its being a very pure and typical specimen of the native tellurium. The following samples are from the same locality, the Goodhope Mine, Gunnison County, Colorado, and differ entirely from the Boulder County samples in their physical qualities and manner of occurrence. The following specimens seem to be the most common type of occurrence in this locality. These samples were sorted out of a quantity of material kindly placed at my disposal, but I can tell nothing about the occurrence of the different samples, and consequently nothing of the relation which the different forms of tellurium may bear to one another. In this sample, however, the pure tellurium, with characteristic color and cleavage, forms a part of the sample, so the fine-grained gray material constituting the greater part of it is probably deposited in the form here found and is not an alteration product. The specific gravity of this sample is 5.3142, temperature 79°F. Some smaller pieces showed even a lower specific gravity, 4.8125 to 4.9474. There is no sign of cleavage, hardness 2.5 to 3, color steel gray, streak is dark gray inclining to brown, and upon examination with a lens it sometimes shows a brown portion. The analysis shows that the material is not homogeneous, though it appears so to the naked eye, and even upon examination with a magnifier. The composition of this mass is as follows:

	<i>Per Cent.</i>
Insoluble in aqua regia	15.98
Fe	10.24
Te	66.96
Loss on ignition in CO ₂ (H ₂ O)	3.83
Loss on ignition in H (O).....	2.88
	<hr/> 99.89

If we could accept, without any misgivings, the results of this analysis as correct, we could offer a satisfactory explanation of them, *i. e.*, if the portion insoluble in aqua regia were gangue, and the iron were present as ferric hydrate, we would then have a

sample of native tellurium, mixed with the decomposition products of the chloritic schist, which I infer from the specimens themselves, constitutes the inclosing rock. The composition of the native tellurium would then become tellurium 96.03, iron 4.97 per cent., all of which is consistent with known facts, but I have some cause to doubt the correctness of this interpretation, for after reduction in hydrogen gas the portion insoluble in acids was perceptibly less, besides the hydrochloric acid solution showed the presence of a very considerable portion of ferrous salts.

The physical characteristics of this sample, together with these inconsistencies, lead me to doubt the interpretation offered, though it is the best—in fact the only one—that I have to offer.

The existence of a tellurid of iron was suggested by Prof. F. A. Genth, Sr., years ago. The frequent presence of iron in the tellurium minerals would lead us to expect to find a tellurid of iron, and, judging by the physical properties and preliminary tests, I hoped that we had such a combination in this specimen, but my conclusion is that we have not.

NATIVE TELLURIUM, ASSOCIATED WITH ARSENOPYRITE, GUNNISON COUNTY,
COLORADO.

Goodhope Sample No. 3. This consists of a mass of radiating crystals of a dark gray color, metallic lustre, and uneven fracture. The cleavage is probably parallel to the columnar faces of the radiating mass of crystals. The specific gravity is 5.4376.

In the outer portion of the mass and in the less pure fragments one can detect the presence of other minerals between the radiating columnar crystals. Some native tellurium can be detected by its color and cleavage, and the tellurid of copper by its brilliantly iridescent hues, but in the purer portions no lack of uniformity can be detected. This sample was picked out of a mass of materials as were the others, and the details of this occurrence are lost, so far as my knowledge goes.

The composition of this mass is:

	<i>Per Cent.</i>
Insoluble.....	7.45
Loss on ignition in CO ₂	0.23
Loss on ignition in H	1.37
Te	14.67
Fe	28.95
S	16.08
As	29.36
Cu	0.77
Bi	0.37
Ni	Trace
	<hr/> 99.29

Some of the loss is undoubtedly due to loss of arsenic as the reduction was effected by sulfurous acid in an hydrochloric acid solution. Basing our calculations on the composition of already known minerals, we obtain for this mass the following:

		<i>Per Cent.</i>
Rickardite	CuTe.....	2.31
Tetradymite	Bi ₂ Te ₃	0.71
Native tellurium.....	Te	13.02
Arsenopyrite	FeAsS	72.74
Oxid of iron, ignition and loss		11.22
		<hr/> 100.00

While I hoped that I could find some other ratios for this mineral, as I could scarcely believe that I had here to do with an arsenopyrite, the results obtained by eliminating the tellurium, bismuth, oxid of iron, etc., and calculating the remaining iron, sulfur and arsenic to 100, we obtain:

	<i>Per Cent.</i>	<i>At. Equiv.</i>		
Fe	36.33.....	6.4.....	6.4	1
As	41.15.....	5.4.....	}	12.4
S	22.52.....	7.0.....		
	<hr/> 100.00			

These percentages are so close to those required by the formula FeAsS that there can scarcely be any doubt but that it is correct.

The ratios are not perfect, but they are so nearly so that we are justified in assuming them to be correct and that the tellurium has not replaced, to any appreciable extent, either the sulfur or the arsenic, and we have a mixture of native tellurium with other minerals.

TELLURITE, GUNNISON COUNTY, COLORADO.

This mineral occurs in the specimens from the Goodhope Mine as coatings, and interspersed through the masses, especially in those specimens in which the native tellurium fills in the interstices between pyrite crystals, as it does in portions of some of them. In the latter case it is usually white. It is sometimes translucent and lustrous, at others it is not. It occurs as a white coating on the native tellurium, sometimes nearly an eighth of an inch in thickness when it possesses the properties described in the manuals, but I have been unable to detect any signs of crystallization.

I did not recognize this mineral in the crystallized form in any of the specimens at my disposal, but on treating some refuse, trimmings, etc., with nitric acid, I observed a brownish yellow powder which, on being washed out, proved to be a crystalline powder composed of small quadratic crystals, showing the surfaces of the pyramid in combination with those of the prism of the second order, or 111 and 100. The surface 100 sometimes showed only a slight development, when the crystal appeared like an orthorhombic crystal, presenting a combination of pyramid and basal pinacoid. I think, however, that they are quadratic forms, as stated.

The fact that the mass had been treated with moderately strong nitric acid, and the forms being apparently quadratic, suggested the possibility of their being artificial. The form of the artificial crystals is quadratic, but the size of these crystals, and the conditions under which they were found, the acid solution being in excess, and of only moderate strength, did not support this suggestion, but it at first appealed strongly to my fears. An

examination of the sand washed off of the crystalline powder fortunately set aside these misgivings, for here I found grains of quartz and other gangue matter showing crystals attached to them, and some of the larger fragments showed clefts containing crystals. Some of the grains, both large and small ones, fail to show the crystals, while others show them in considerable numbers. I am convinced that the crystals were derived from one of the more strongly decomposed and granular masses, and constitute a sample of tellurite which is well crystallized.

The color in mass is brownish yellow to light brown; the individual crystals vary from colorless to brownish yellow. The most of them are translucent. No attempt was made to determine the specific gravity.

The composition of the mass, as obtained, was:

	<i>Per Cent.</i>
Insoluble in HCl	1.04
Bi ₂ O ₃	Trace
Fe ₂ O ₃	0.70
Te	78.68
O by difference.....	(19.58)
	<hr/> 100.00

Calculating the tellurium and oxygen to 100, we have:

		<i>At. Equiv.</i>	<i>Ratio.</i>
Te	80.072.....	6.166	1
O	19.928.....	12.237	2
	<hr/> 100.000		

As the crystals have not yet been subjected to measurement, the form can only be given tentatively as quadratic.

CUPRODESCLOIZITE, ARIZONA.

This sample was given me by Mr. A. B. Frenzel, of Denver. It came from near Nogales, Arizona, and forms layers up to half an inch in thickness. It was enclosed in crystalline calcite, and presumably formed thin layers in this material. The color is

reddish chestnut brown; the structure is fibrous. One surface is quite smooth, the other either bears the impressions of calcite crystals or is covered by a well-marked crystalline coating, composed of indistinct crystals of the mineral itself, which, under the microscope, have a beautiful amber color, and are transparent. The specific gravity is 6.176, streak bright orange yellow, powder not so bright. Composition of the fibrous mass:

	<i>Per Cent.</i>
V ₂ O ₅	19.014
As ₂ O ₅	3.842
PbO	52.954
CuO	8.508
ZnO	12.450
Fe ₂ O ₃	0.200
MnO	Trace
H ₂ O	2.650
Insoluble	0.350
	<hr/> 99.996

There is no phosphoric acid or chlorine. The ratios given by this analysis are as follows:

	<i>At. Equiv.</i>			<i>At. Ratio.</i>	
V.....	0.10675.....	20.85	} 24.19.....	2.04	2
As.....	0.02506.....	3.34			
H.....	0.00297.....	29.40	29.40.....	2.45	2
Pb.....	0.49152.....	23.76	23.76.....	1.98	2
Zn.....	0.10003.....	13.76	} 24.44.....	2.04	2
Cu.....	0.06798.....	10.68			
O.....	0.19987.....	124.91	124.91.....	10.40	10

The atomic ratio is fairly good. A little doubt might be entertained relative to the hydrogen and oxygen, but as the moisture was determined by ignition after having treated it for several hours at 120°C., a slight error might easily have been made, and would account for the fraction of an atom in these ratios. I feel entirely justified in rejecting it in both cases, and the ratio becomes the one accepted for this mineral, with the formula $R_4V_2O_5$, $R(OH)_2$. Where we have Pb:Zn as 1:1, in which five-twelfths of the zinc have been replaced by copper, or the ratio of Zn:Cu is 7:5.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
Vol. 7, pp. 151-162.

ECONOMY IN MILL WATER.

By JESSE SCOBAY.

DENVER,
PUBLISHED BY THE SOCIETY
JANUARY, 1904.

ECONOMY IN MILL WATER.

By JESSE SCOBEE.

Read at the Meeting of the Society, December 5, 1903.

With no running or surface water in sight, or available, nine Wilfley tables were operated during the year 1902, at Washington, Arizona, subsidiary in treatment to a plant of 100 tons per day requiring a 150 horse-power steam equipment.

A water supply was accumulated in a large storage tank before starting the plant, and this, when the plant was running, was in constant circulation, being alternately fouled and cleaned of both slimes and acid. The least consumption over the normal allowance was vital, as in summation it would eventually close the mill. The reserve supply generally sustained the minor internal losses, and only on a few occasions was it necessary to shut down from an actual lack of water.

The final improvements, bred of experience, gave a saving of 97 per cent. of the water in circulation, and in view of the 20 per cent. loss admitted to be made in the South Africa cyanide plants, this loss of only 3 per cent. may well be reviewed. The comparison in no way criticises the South Africa plants, as the widely different treatments account in a large way for the discrepancy. Mr. Denny, in a recent paper, says the discharged tailings retain only 10 per cent. water, and in this he means the sands only, else, of course, he would not have the 20 per cent. loss. This construction puts the entire penalty upon the separation of the slimes, as, in my saving of 97 per cent., the sands carried 25 per cent water. The

stamp mill practice necessitated more slimes made than did our roll mill, both from the manner of crushing and the method of screening, using in the stamps 30-mesh, and on the trommels for the rolls a 12-mesh cloth.

That the 20 per cent. loss is excessive is admitted, when it is proposed to reduce this to 10 per cent. by a better system for saving the slimed water, in the use of 20-foot circular vats, which step is, to my mind, the proper one. So far the system proposed is weak in the vital point of discharge, which must be over the entire periphery and must not be drawn from one point.

The entire water supply at Washington was obtained by sinking a well from which was run a drift across and under an arroyo draining an extensive watershed. Tests showed that this well would supply 7,500 gallons per day in the dry season — of course more in the wet season — but that did not affect the problem. This amount was considered ample when properly used, and a small boiler and pump were installed with a two-inch pipe line to deliver this water to the plant, some one and one-half miles distant.

At the time I took charge of the plant, all machines were in place, and the design of the building was such that they must be connected up as they stood. In brief outline, the ore carrying copper, lead and zinc in a silicious gangue heavy with garnet, was crushed in rolls to 12-mesh and roasted. After cooling it was treated magnetically, and about 20 per cent. of the ore was lifted as a copper concentrate that was reduced in a reverberatory furnace to copper matte. The remaining lead, zinc and garnet tails were submerged and treated on tables to a lead-zinc concentrate, a zinc-garnet middling, and tailings. Each of the two metallic products were redressed on two tables to shipping lead and zinc suitable for drying and subsequent magnetic cleaning. The nine tables for this work required, in feed and wash water, 900 tons of water per day, or 216,000 gallons.

The table floor was well laid in hydraulic cement, draining to the center, through which ran an open cement launder that car-

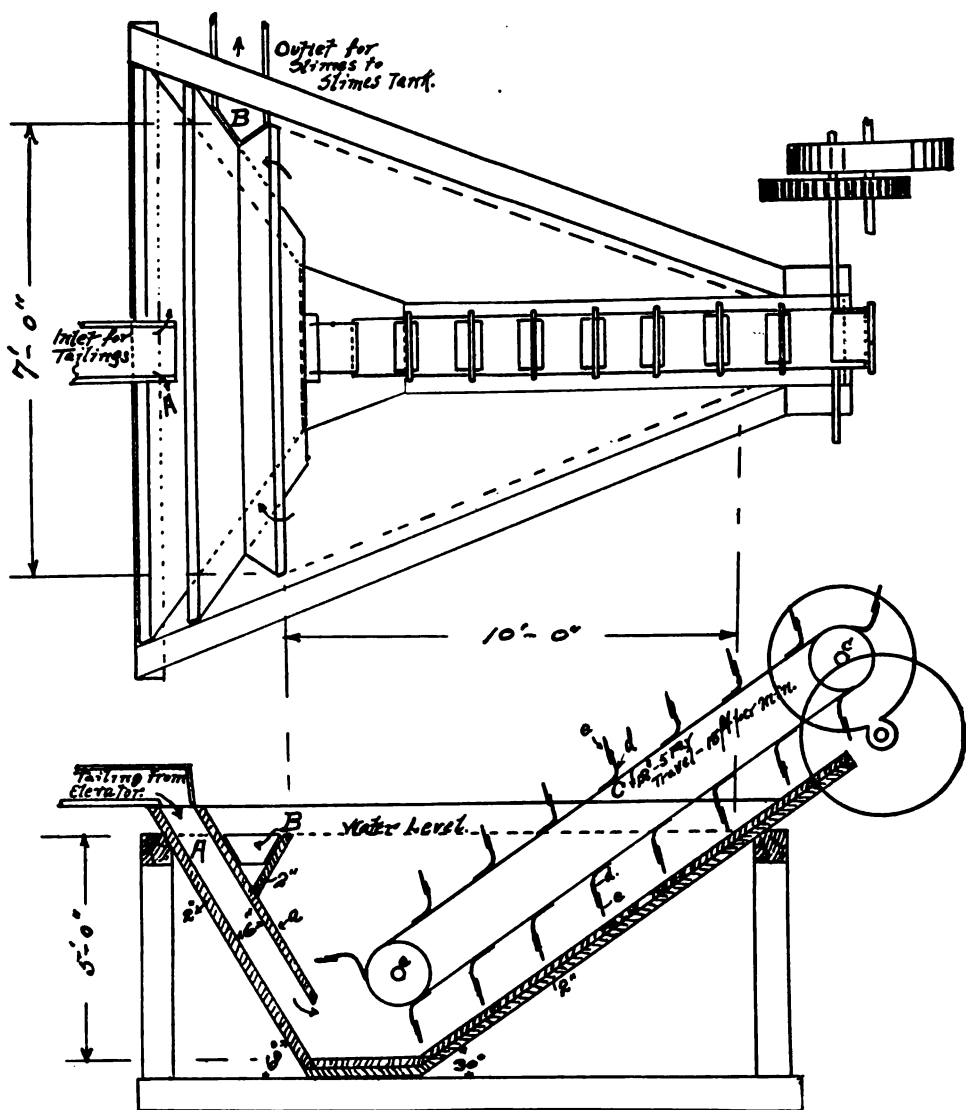
ried the tailings from the first five tables and the waste water from the four dressing tables. About 5 per cent. of the ore was taken out as a lead concentrate, which was collected in special boxes from which the overflow water was discharged, after passing under and over baffle boards, on the cement floor from which it drained into the main artery. The concentrates were shoveled from the boxes into hemp sacks, and when first sacked would contain 25 per cent. moisture; these drained to 15 per cent. moisture in standing before being finally removed to the shipping platform. The 15 per cent. moisture in five tons of lead concentrates made a loss of .75 ton, or 180 gallons per 24-hour day.

The zinc dressing tables gave about 15 per cent. of the ore as material to be dried for final magnetic work. This was collected from the tables to an automatic drag, similar to the one about to be described, in which the sands were separated, giving waste water to the tailings launder, and the zinc with 25 per cent. water, to the drier, where the water was lost in evaporation. The 25 per cent. moisture in 15 tons of zinc concentrates made a loss of water of 3.75 tons, or 900 gallons per day. This, with the loss in the lead, left 214,900 gallons discharging through the main launder, with the recovery of which we were mainly concerned.

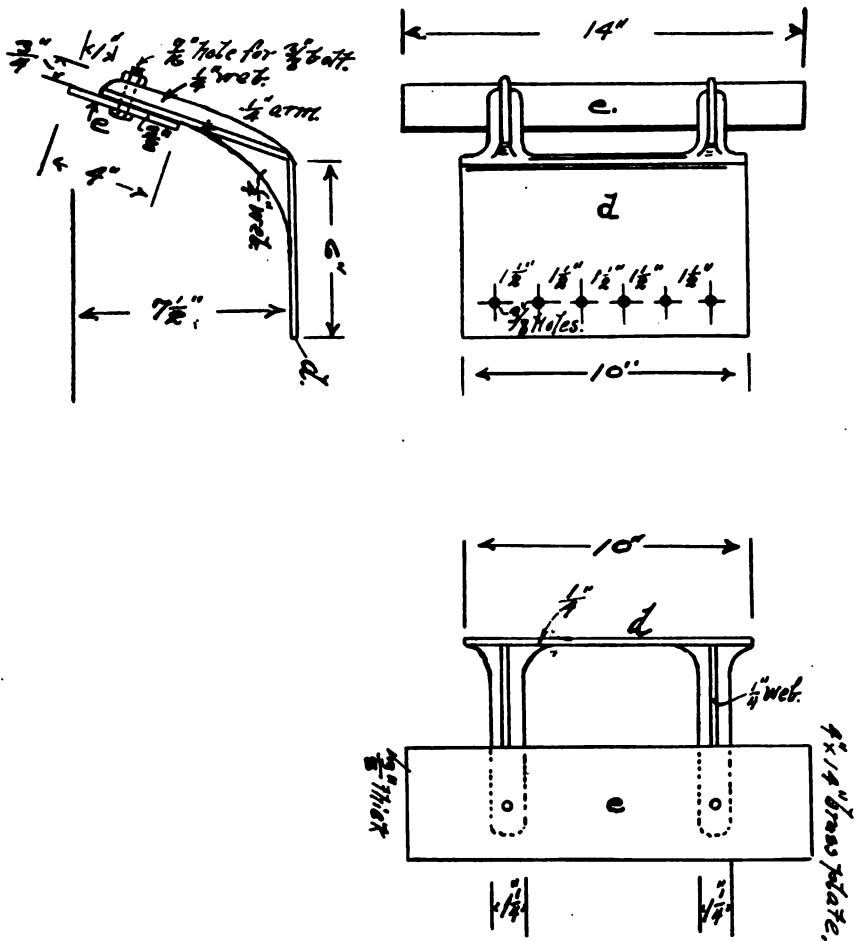
The extraction of copper, lead and zinc left about 60 per cent. of the crude ore to be carried in suspension by this water to a cement pit, from which it was raised twenty feet—a head sufficient to allow the sands being drawn off and the cleared water returned by gravity to the head tank which supplied the tables.

The sketch shows the means of accomplishing the separation of the sands from the slime water.

The sand box is in the form of a truncated pyramid, inverted with the larger triangle at the top, having a 7-foot base and 10-foot altitude. A 5-foot depth of water filled the box to within four inches of the top. All sides of the box slope at an angle of 60° toward the bottom of the box, or toward the edge up which the sands are dragged, at an angle of 30°. In this way all material



Sand Box for automatically cleaning mill tailings of coarse sands.



Detail of Drag Bracket (d) and Plate (e) for belt in Sand Box.

settled in the box is deposited under the drag belt. When full, the settling area of the surface of the water is 35 square feet.

The tailings from the elevator are discharged into the sand box at "A," where the false back "a" extends across the box and to within 18 inches of the bottom, allowing a 6-inch space for the full width of the back, which conducts the sand and water to the bottom of the pyramid, where it is practically entered at the apex and under the bottom pulley, around which the drags are carried. The rising current is thus subjected to an enlarging area, increasing as the square of the distance ascended, which accordingly reduces the velocity in like proportion and effectually drops the sand.

From the surface the overflow water and the slimes are taken from the box by the 7-foot weir "B," over the edge away from or opposite the sand discharge. This wide discharge materially reduces any tendency to form currents.

The drag belt "C" is 12-inch, 5-ply rubber, traveling 15 feet per minute over the foot pulley "c" and the head pulley "c." The head shaft is in fixed bearings to accommodate the gearing necessary to drive at the slow speed, while the foot shaft is held loosely in its position by wooden bearings, as is the practice in the Joplin mills. These bearings are in the water at the bottom of the box and are in no way protected. They consist simply of a half-round cut in the end of a 4 x 4-inch hard-wood block. These pieces are held in place, each with two bolts in slotted holes in the hickory, with just sufficient tension to keep the belt taut, and at the same time enabling it to be taken up by slightly tapping the block down with a sledge. Our experience with this kind of bearing in such a place, or in the foot of wet elevators, has been to prove its superiority over all iron and babbitt bearings arranged either bridged or overhanging. It is much easier to admit that sand is going to get into your bearing and design the box accordingly than to make fruitless efforts to keep it out. Under the

above apparently severe test, the wear on either the shaft or the bearing was immaterial after a six-months' continuous running.

A hole closed with a plug in the bottom of the box, from which the contents can be drawn, is convenient in case of clogging or breakage.

The belt was equipped with brackets "d," bolted 14-inches, "c" to "c," to which the drags proper "e," were bolted with slotted holes in the plate, for taking up, reversal or renewal, without changing the more costly bracket, upon which there is little wear. The drag was constructed especially to leave a space between the belt and the plate, so that when leaving the water the current could escape over as well as around the sides, thus lessening any tendency to wash away the sand carried on the drag. From leaving the lower pulley until discharging the gathered sand at the top, the edge of the plate was resting on the floor of the edge of the pyramid, up which it traveled, protected by a 2x12-inch plank that could be renewed. Acid water necessitated the bracket and drag, as well as all elevator cups and metal exposed to the water to be made of copper, consequently we put the burden of the wear on the wood, which lasted about two months.

All the sands of the tailings were thus dragged over the point of the box and some two feet beyond the surface of the water, allowing the sands to drain, after which they were discharged, invariably containing 25 per cent. moisture, to a small accumulating bin to be taken to the dump in wheelbarrows. We failed in an effort to handle this mass by a belt conveyor, as it would cling to the belt, fouling the rollers and bearings and quickly destroying the belt.

The water delivered from the sand box carried about 10 per cent. of the crude ore treated in slimes, while the sand delivered was 50 per cent. of the ore. The loss of 25 per cent. moisture in the sands going to the dump amounted to 12.5 tons of water, or 3,000 gallons per day. This loss now reduced the quantity going

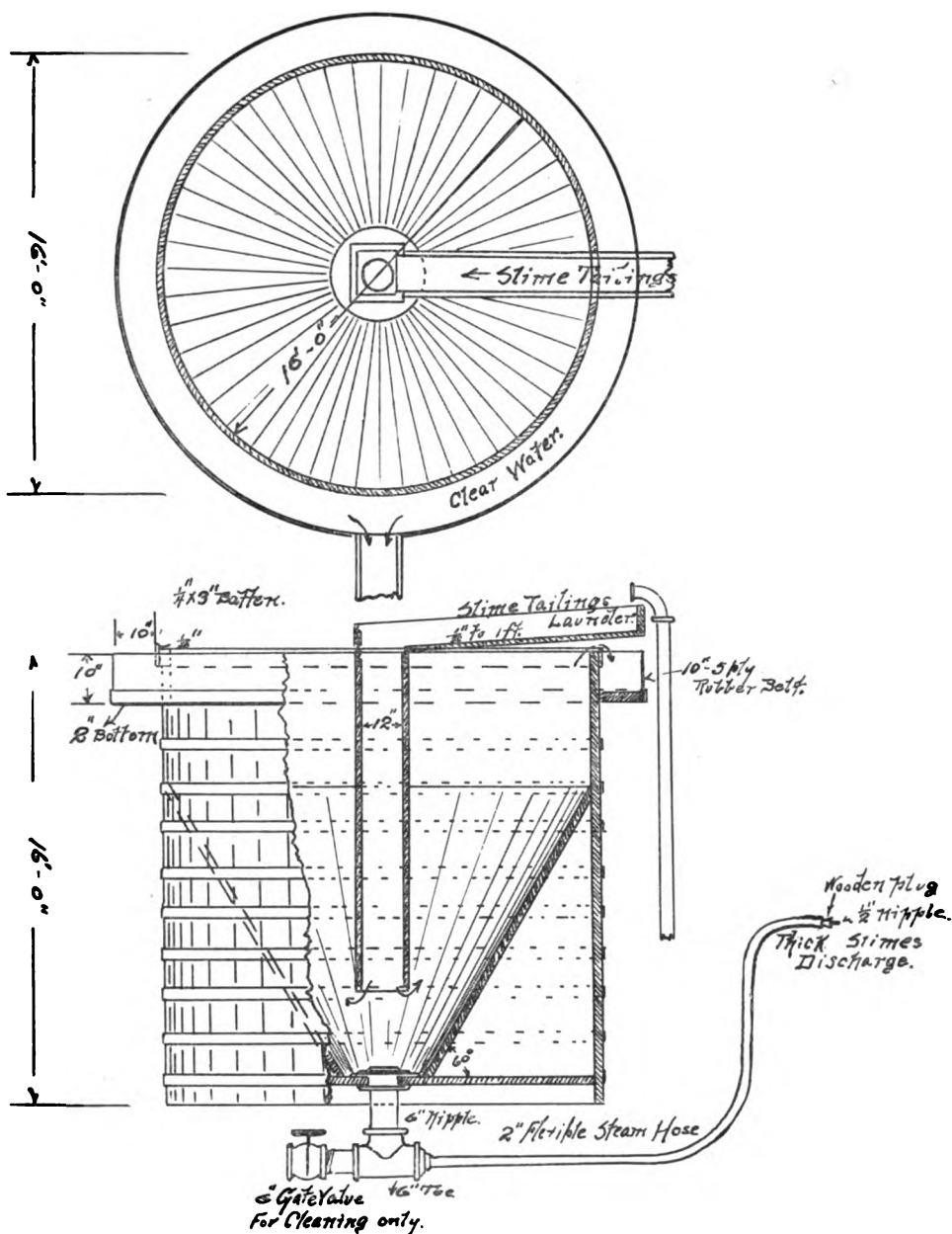
to the slimes tank to 211,900 gallons contaminated by ten tons of fine slimes.

Sketch No. 3 shows the tank in question, which may be understood simply as a 16-foot by 16-foot standard round tank, to which has been added a false lining that gives the interior the appearance of an inverted cone, with sides 60° from the horizontal, truncated at the bottom of the tank in a circle of 2 feet diameter. This lining is essential, as otherwise the settled slimes would not feed regularly to the discharge. No especial care is needed in putting in this lining, as it is supposed to fill behind with water and eventually with slimes.

Around the upper rim of the tank, about 10 inches down, is fitted a 10-inch circular launder enclosing the whole circumference. This was most expeditiously made by forming the bottom of the launder from sections sawed from a 2-inch plank to fit the outside of the tank, and after securing these in place temporarily the outside of the launder was formed by tacking to the 2-inch bottom the lower edge of a 10-inch 6-ply rubber belt, which was easily formed around the tank in one piece. This was quite stiff enough to maintain itself erect, especially when now the whole was incased by an ordinary hoop band with draw nuts, which was so placed as to draw the belt against the 2-inch bottom and the whole securely against the tank.

As has now been surmised, it is essential to have the overflow water drawn evenly over the top of the tank from all parts of the circumference, and as the tops of the staves are irregular and hard to dress to a plane, this is facilitated by nailing around the top a half-inch batten on edge, so that about one-half of its width stands above the ends of the staves. This thin strip is easily bent around the tank, and its upper edge can be easily planed down to an exact level when the tank is filled with water; also, any uneven settling can be easily remedied.

In the center of the bottom of the tank is cut a 6-inch hole, to which, on the under side, is bolted a 6-inch Tee, to one leg of



Slimes Settling or De-watering Tank for continuous discharge of both thick slimes and clear water.

which is attached a gate valve that can be opened in emergencies and to the other, by reducers, a 2-inch hose, which is carried out past the chime and raised some eight feet, where the end is closed with a wooden plug, in the center of which is a half-inch nipple.

Supported vertically in the center of the tank is a long tube or box, open at both ends, 12 x 12 inches in section, extending from above the water-level down to within two feet of the bottom, and directly over the 6-inch slimes outlet. Into the upper end of this tube the slime and water from the sand tank is introduced. It is delivered at the bottom at the apex of the cone, whence it rises evenly without irregular currents, with the velocity decreasing as the square of the ascension. The slimes are gradually dropped and are drawn continuously from the half-inch nipple.

The velocity of discharge and consequently the amount or quantity of pulp drawn from the bottom of the tank, can be accurately gauged to suit the needs or requirements by raising or lowering the discharge end of the hose, and thus decreasing or increasing the head under which it works. This is an important and pretty detail, as no valve or jig gate can be set to a small discharge of slimes without sooner or later causing a disastrous stoppage that blocks the whole system. In our case we found an 8-foot head to give us a desired regular discharge of thick slimes of about the consistency of molasses.

Under this head, and with a half-inch orifice, clear water would have been discharged at a rate of 12,367 gallons per 24 hours, using the coefficient of discharge of 0.61. In our case, the friction of the thickened slimes through the 2-inch hose and small orifice reduced the discharge to 6,500 gallons per day of slimes, with two parts of water to one of solid matter.

These slimes are dryer than those recorded by Mr. Denny in his practice as 4 to 1 from the first operation, and I think this is mainly due to the use of the hose discharge. We anticipated discharging our slimes with the proportion of 2 to 1, but as there were more slimes than anticipated, it led to the discovery that

when reduced to this thickness they settled and gave a covering of clear water in time incomparable to their former obstinacy. Accordingly we were led to re-treat them, which should have been done by the same system, but, being driven to act quickly, we made a 6x8x6-foot V box, which, taking so small a stream of pulp, discharged clear water, and settled slimes in the bottom as a thick mud, from where it was drawn intermittently by an attendant who took this as one of his miscellaneous duties.

Ten tons of slime tailings were thus discharged here that would average about one part water to one of solid matter, which caused a loss of ten tons of water, or 2,400 gallons per day. In summation these are:

5 tons of lead concentrates.....	180 gallons
15 " zinc "	900 "
50 " coarse tailings.....	3000 "
10 " slime "	2400 "
Total	<u>6480</u> gallons

In such a climate the evaporation may be considered, but it is not as much as is generally supposed, and in our case we estimated as nearly as possible that we were losing 6,500 gallons per day, distributed as above. With 216,000 gallons in circulation, this loss of 6,500 gallons represents a loss of only 3 per cent.

Various attempts have been made to claim a saving equal to this* by the use of huge and cumbersome V boxes, as, notably at Cananae, but from a casual observation it could hardly be credited.

I have noticed that where apparently muddy water was flowing over a wide weir, that there was generally a thin film of clear water on the surface. Whether this is due to any property of the surface of water peculiar to the surface only, as in the capillary attraction shown on the sides of the vessel of water, or on the bead over the gauger's hook, I do not know, but to draw clear water from a light slime it is necessary to so reduce the velocity of discharge, by extending the cross-section of discharge to its

limit of breadth, that the depth of the cross-section reduces the water to a practical film, which brings us to the same thing.

In the case of our 16-foot tank, the loss of 6,500 gallons left 209,500 gallons in circulation which was cleared in twenty-four hours. As our discharge was over the entire circumference of the upper rim of the tank, this was equivalent to discharging over a 50-foot weir. Such a quantity of water discharging in this time over a 50-foot weir would flow with a depth or head of only 3-16ths of an inch, according to standard hydraulic formulae. This was the depth of our film, as near as it was practical to measure. Similar formulae will show that from a head of 3-16ths of an inch in the above conditions, we will have a velocity of approach of .42 feet per second, or 1,500 feet per hour.

These figures I consider important for a justifiable anticipation of good work. I know that the tank would do nothing like the same work if the discharge were drawn from a 12-inch opening at any one point of the rim. If this should be done we would have a 12-inch weir, which, to discharge the above amount of water in the same time, would require a depth or head of 2.4 inches, which not alone would draw from below what I would call the safe film, but would also create a velocity of 1.6 feet per second, or 5,760 feet per hour.

In this latter case, the depth over the weir would be thirteen times as great, and the velocity of approach would be four times as great, which would again seem to accentuate the charge that the depth of discharge from the tank is of more importance than the velocity.

GASES IN METALLIFEROUS MINES.

By HARRY A. LEE.

DEATH GULCH.

By F. W. TRAPHAGEN.

DENVER,
PUBLISHED BY THE SOCIETY
FEBRUARY, 1904.

GASES IN METALLIFEROUS MINES.

BY HARRY A. LEE.

Read at the Meeting of the Society, December 5, 1903.

I trust that all the members of the Society who were present at our last meeting have remembered the announcement made at that time and have come prepared to enlighten us upon the subject of Gases in Metalliferous Mines, and that all present tonight will relate their individual experiences and give the Society the benefit of their conclusions.

As then stated, my remarks tonight will be almost wholly confined to a description of an occurrence of nitrogen recently encountered, and will be more in the line of an interrogation than a paper upon mine gases. It is hoped, however, that the presentation of these notes will provoke discussion, the relating by others of similar experiences, and may be eventually the indirect cause of investigation that will prove both interesting and valuable.

Gases in our metalliferous mines are generally spoken of as "bad air." The term "bad air," as used by the miner, does not include the explosive gases common to coal mines. Neither does the term, as generally used, accurately define the condition of the air. It is a term applied to air obnoxious to the sense of smell, to the gases or smoke following the discharge of explosives, and to air depleted, to a greater or less extent, of oxygen.

The latter is the condition most commonly referred to when the expression "bad air" is used. The term itself, however, conveys no idea of the actual condition of the air.

Another common expression, when the air is low in oxygen, is to speak of it as being "warm" or "hot."

Although the "hard rock" miner has no means to accurately determine the percentage of oxygen present, there is an almost universal method of measuring or determining a condition of the air that it is deemed safe or unsafe to work in, viz., combustion. If an ordinary candle will not burn freely when held in a vertical position, the air is said to be "bad," but if the candle burns freely enough to afford light when placed upon its side, work continues.

If one candle refuses to burn when placed upon its side, combustion is often aided by the addition of another candle, so adjusted that the two flames join. This condition is likewise termed "bad" and considered near the danger point.

If two or more candles refuse to burn and a light can not be thus maintained, it is considered both "bad" and dangerous if exposure be long continued.

When candles can not be used, a torch burning kerosene is often resorted to and utilized for short periods of exposure. This condition is also spoken of as "bad air." Likewise when a torch refuses to burn, it is called "bad air," but the latter condition is considered dangerous, and is generally described by the miner in such a forceful manner as to convey a fair idea of the actual condition of the air.

To form an opinion, therefore, of the "bad air" existing in any part of a metalliferous mine, one must learn the manner of testing it.

So far as I know, there have been no actual determinations made in the State of the percentage of oxygen present in the air when one, two or more candles or a kerosene torch will not burn in a drift, heading or stope.

The view is generally advanced that an atmosphere that will not support combustion is unsafe and must not be ventured into, and there is little doubt that this belief has prevented many acts of rescue in cases of mine accidents. It has been demonstrated many times, however, that men can live for hours in air that will not support the combustion of candles or even a kerosene torch. Some physiologists claim that air containing 10 per cent. oxygen is not only respirable but may be breathed by healthy persons for long periods of time without permanent injury. This percentage of oxygen is doubtless 4 or 5 per cent. below what will support the combustion of an ordinary candle, and it must also be below what is required for a kerosene torch. The miner's measure of "bad air" is, therefore, a safe one, provided the atmosphere be only depleted of oxygen, and poisonous gases do not exist in dangerous quantities. The percentage of oxygen may, however, be sufficient to support combustion and the atmosphere be absolutely unsafe to human life.

Beyond mere mention, these matters will not at this time be further entered into.

During a somewhat recent visit at the Happy Thought Mine, near Creede, Colorado, in company with Mr. J. W. Finch, a very interesting occurrence of nitrogen gas, or so-called "bad air," was encountered. Prior to coming in direct contact with it, so many varying accounts were related of its erratic occurrence, recurrence and general characteristics, that serious doubt was entertained as to its existence. This doubt was strengthened by the complete absence of "bad air" in a number of places in the mine visited, and also by a casual inspection of the underground working map. This map showed a main working shaft about 1,400 feet deep, with drifts run on the vein each way from the shaft at intervals of about 100 feet. The bottom of the shaft and the 1,000-foot level were connected with surface by tunnels, and the 500-foot level by a shaft. In addition to these surface connections, the various levels were connected with each other on both sides of the shaft by stoped territory, winzes or upraises, the whole presenting a con-

dition almost ideal for perfect ventilation and one in which the presence of "bad air" would not be anticipated.

Notwithstanding the apparent favorable conditions for good ventilation, the presence of gas was later freely admitted. Some of the characteristics are jotted down in my note book, as follows:

"Extinguishes candle or torch immediately.

"When drift or stope is only partly filled, is found at the top portions.

"Lighter than air.

"Is colorless.

"When encountered in concentrated form, appears to have a sweetish taste and brackish odor.

"Miners can sink a winze but can not make an upraise.

"Mine working appears warm.

"Exposure to gas in concentrated form produces a choking sensation, dizziness, and increases heart action.

"Ill effects from exposure soon pass away upon return to good air.

"Finds exit through open crevices and coarse brecciated areas in and near breast of drifts."

Two samples of this gas were taken in well-stoppered bottles. The place selected for the samples was a shallow upraise from a drift that acted as a reservoir and which was apparently filled with the pure gas from a near-by crevice in the vein wall. These were first filled with water, which was carefully poured out while held well up in the reservoir and the gas permitted to enter. Both of these samples were later submitted to Dr. W. F. Edwards for analysis who made the following return:

DENVER, Colo., Sept. 9, 1903.

Substance analyzed, Gas

Received from Lee & Finch.

Amount, one liter (2 half liter bottles).

<i>Elements Determined.</i>	<i>Per Cent. Vol.</i>	<i>Remarks.</i>
Carbon dioxide.....	.....
Carbon monoxide.....	.....
Nitrogen.....	96.08	By difference.
Nitric oxide.....	.....
Oxygen.....	3.92	By pyro absorption.
Hydrogen.....	.....
Ethylene.....	.....
Methane.....	.....

GENERAL STATEMENT.

Nothing absorbed by KOH, CuCl, KMnO₄, Br in H₂O, and no explosive or combustible substance found.

(Signed) W. F. EDWARDS.

Upon entering a drift or stope charged in part with nitrogen, nothing but a large-sized kerosene torch could be used with any satisfaction. Carrying the torch in the hand in the ordinary way, say about even with the waist, was also a practice soon stopped. At that height the air might be good, while near the top of a drift it was quite bad, and soon produced a "groggy" feeling.

Walking through a drift thus charged would disturb, put the gas in motion, and appear to separate it into waves. These waves were very noticeable upon the torch, which burned brightly or dimly as a wave of gas was succeeded by a wave of comparatively good air.

If this stirring up of the air were continued for some little time, the waves of gas appeared to be broken up in smaller volumes and would eventually drive one from the drift, and usually in the dark, the torch refusing to burn.

One noticeable feature of this condition was the ability to breathe this mechanical mixture of air and nitrogen with but comparatively little inconvenience when at rest, and for a period of ten minutes' time or more, after it was impossible to keep the

torch burning. Very little physical exertion, however, in such condition of the air caused profuse perspiration and made the breathing and heart action harder than climbing up a heavy grade at the summit of Pike's Peak.

The slowness with which the air and gas diffused was well shown by an attempt to displace, mix or force back the gas from the breast of a drift with a stream of air from a compressor.

Before turning in the fresh air, a lamp would burn well as high as two and a half feet above the floor of the drift. The hose from the air pipe was carried to within about eight feet of the breast of the drift and the air-cock turned wide open. Our lights were almost immediately extinguished and we were compelled to return to the main shaft.

One hour, two hours and three hours later attempts were made to reach the breast. The last effort was successful, but without a light—the air valve was closed, and we retired vanquished. When the last effort was made the gas near the breast had been partially displaced, but not sufficiently to support combustion.

It was found that "parlor matches" were absolutely useless in what appeared to be comparatively good air, and that the old-style sulphur match would burn sufficiently well to light a torch in air in which the "parlor match" would barely make a spark.

The presence or absence of nitrogen in the mine workings appeared to anticipate weather conditions, *i. e.*, it was partially or wholly absent in fair weather and present in abundance in stormy weather.

This gas evidently exists in great volume, and appears and disappears in the mine workings at comparatively short intervals of time.

Now as to surrounding conditions:

The Happy Thought Mine embraces a part of the great fault-fissure vein upon which is located the Commodore, Bachelor, New York, Chance and Amethyst Mines, and lies immediately north of

and adjoining the latter. This great fissure occurs in an eruptive rock, locally called trachyte. Although the rock mass differs in appearance locally, it is mainly rhyolitic in structure. Among the striking features of the mine are the smooth, highly polished walls, and the apparent post-mineral faulting. The wall-rocks are very hard, and, while well-polished, are generally but little grooved. However, the striae are, as a rule, sufficiently distinct to determine the general direction of the movement to have been at right angles to the strike, or with the dip, of the vein. No attempt was made to determine the throw produced by faulting. Locally, however, the displacement appeared to have been considerable, and also to indicate repeated post-mineral movement.

The results produced by this continued series of movements have been variable. This is well shown by the extensive mine developments upon the vein. The ribbon-structure common to fissure veins is entirely obliterated, and in the mineralized portions or ore shoots the vein presents a complex mixture of ore and brecciated country more or less tightly packed in the variable fault clays. The vein width between walls varies from six to twenty feet or more. The general conditions may be summarized as follows: Immediately adjoining the hanging wall, a band of dark blue fault clay varying in width from a knife-blade seam to two feet or more; adjoining this, the complex mixture of ore and country varying from a few inches to twenty feet or more in width; then a band of trachyte breccia a few inches to four feet in width, and finally another band of clay, light-colored and filled with fine brecciated material, varying from a few inches to four feet in width. The clays throughout contain fragments of sulphide ores to a greater or less extent, and even the finely ground and compact clay bands are often filled with minerals in such a finely divided state as to not be observable to the naked eye.

At different points along the strike of the vein the conditions differ. The vein at places presents an appearance of rather solid and compact sulphide ore bodies; at others a vein of compact and

impervious clays, and at others a loose mass of brecciated country and ore, from which the clays have been wholly or partially removed by water, if they ever existed.

The last mentioned condition is the apparent fountain-head of the nitrogen gas. In two levels driven north from the shaft, about 150 feet apart, on the dip of the vein, they have passed from the compact sulphide ores into a section of clays, and finally into the coarse brecciated ore and country, which appears to act as a gas reservoir. This reservoir is doubtless of considerable extent, and the area of open space in the coarse breccia of ore and country between the vein walls amounts to thousands of cubic feet of space. Until penetrated by the mine levels, the gas appeared to have been enveloped in this reservoir by the surrounding clays, which were practically impervious and formed a secure casing. Since the opening of this reservoir by the two mine drifts the gas enters the mine workings and returns to the reservoir at irregular intervals of time. These changes appear to accord, to some extent, at least, with barometric variations.

Upon one visit to the breast of one of these levels the air was particularly good. At that time the breast showed only a small portion of loose boulders of ore and country, and there was practically but one free opening into the gas reservoirs. In size this opening would average about five inches wide by nine inches long. Holding a lighted candle in a vertical position before or practically in this orifice, the air current *from* the drift *into* the reservoir was strong enough to draw the candle flame to almost a right angle. This escaping air also produced very distinct sounds of different kinds. A soft moaning or sighing sound would be followed by that produced by distant water rushing over a rough stream bed; then the sighing of a gentle breeze, to that of the whistling or moaning of a rather heavy wind. The sound-changes were ample to account for some of the "spook" stories related about the mine. They also indicate a somewhat extensive section of open territory

in the vein. The extent of this territory was not determinable, but it is certainly extensive.

About five hours after my visit to the breast of the tenth level, above-mentioned, the air current was reversed, and the gas poured into the mine in such volume that work was impossible, and all who were in that part of the mine had to crawl to the main shaft on hands and knees. Even near the shaft a torch-light could be maintained only with difficulty. That the gas reservoir had sufficient capacity to fill several thousand feet of drifts and stopes in a very short interval of time was, however, thoroughly demonstrated.

When the gas discharges into the mine, a large portion of it reaches the main working shaft, and is carried to surface by the strong upcast air current. The remainder hangs in the drifts and stopes in that part of the mine for irregular intervals of time, and is then again forced back into the reservoir, leaving the mine workings charged with good air.

Previous to the completion of the Nelson Tunnel and the Humphreys Tunnel (the latter being an extension of the former) to the Happy Thought territory, about three years ago, this section was thoroughly saturated with water, and mining could only be prosecuted by the use of large pumping plants. At the present time it is thoroughly drained to the bottom of the shaft, or the tunnel level. In fact, the mine is so thoroughly dry above the tunnel as to produce a "dry rot" in the mine timbers, the air absorbing the water necessary to prevent oxidation of the timbers.

The apparent volume of gas present in this mine is great. The main working shaft of the mine has a very strong upcast air current, and when the gas is emitted into the mine workings a large volume reaches the shaft and is carried to surface, thereby largely depleting the available amount in storage. Notwithstanding the almost daily discharge of gas into the mine, and loss certainly sustained by being carried to surface for an observed

period of over three weeks, there was no apparent diminution in supply.

The predominating minerals present in the vein where the drifts or levels tap what I have designated as the gas reservoir, are lead and zinc in sulphide form. Iron pyrites occur, but in unusually restricted amount, as compared with the lead and zinc sulphides present. With this exception and the condition of ores as they exist, due to post-mineral faulting, no other characteristics uncommon to sulphide ore deposits were observed.

It is barely possible that more careful research would disclose the presence of gases other than nitrogen, and that the samples taken and analyzed by Dr. Edwards did not fairly represent the gases as a whole. As before described, these samples were taken near the top of a shallow upraise, where the nitrogen would naturally concentrate, and perhaps be more or less compressed and condensed.

As previously stated the mine, in this portion, appeared to be warm, or warmer than in portions where the gas did not occur, or in other mines upon the same vein. I am unable to state whether this be fact or not. The depleted air, or lack of oxygen, might make it seem warmer, and especially so when under physical exertion. It was the intention to measure the temperature, but doing so was postponed from day to day and finally neglected.

Again, I am not positive that the gas present has either odor or taste. I did, however, have several different persons test it, and each and every one confirmed my own finding. However, it is doubtful if the judgment, taste or smell of anyone can be trusted after indulging in a few good breaths of this concentrated gas.

The above is a brief description of conditions as found. Such a volume of nitrogen gas is certainly uncommon, at least as far as my experience with gases in metalliferous mines is concerned. What I have designated as the gas reservoir in this mine must have immense capacity, since the amount of gas lost daily appeared to have been inappreciable, or else nitrogen, and perhaps accom-

panying gases, are generated with unusual rapidity. While the abstraction of oxygen by the decomposition of sulphides will account for nitrogen on a small scale, the gas works of the Happy Thought mine appear to have a "secret process," and to make a commercial saving of at least 120 per cent. of the material at hand. Should any number of the Society feel inclined to investigate this matter further, I will take pains to supply the needed gas, mine water or vein material deemed essential for such investigation.

No reference is herein made to the gases more commonly found in the metalliferous mines, but it is hoped that these notes together with those presented in discussion, will arouse interest sufficient to lead to careful and systematic investigation of mine gases, and indirectly produce beneficial results.

DISCUSSION.

George E. Collins.—I assisted my brother, the late Arthur L. Collins, in the observations which he records in his paper. The barometrical readings there referred to were repeated in other cases, and found to be an invaluable guide in mining work where emanations of carbonic acid gas were probable.

This gas occurs more or less in a great number of mines, mostly situated in what might be termed the southeast section of the main Gilpin County district—in fact its presence may be looked for in any vein throughout an area bounded by the Colorado & Southern Railroad on the north, Willis and Russell Gulches on the south, and the Gilpin Tramway on the west.

Personally I have observed no other noxious gas underground in Gilpin County, and doubt whether the loss of life in the Sleepy Hollow, referred to by Mr. Lee, was due to any other gas but carbonic acid. Certainly this mine is within the area where carbonic acid may be looked for.

It is singular that this gas should be so abundant in the archæan gneiss of Gilpin County, where calcite is practically or entirely unknown. The only carbonate mineral known to me in

this area is chalybite, which occurs as a vein mineral in the Running Lode Mine and elsewhere.

A. W. Warwick.—Mr. Lee has brought to the attention of the Society a condition of affairs that is, no doubt, a common one. It is a fact that very few analyses have been made of the air in metalliferous mines. Most of our information is derived from the conditions as they exist in coal mines, and this bears no sort of relationship to conditions in metal mines. Such analyses as are available for comparison are anomalous cases. The whole subject is one well worthy of investigation, and Mr. Lee's paper will no doubt stimulate interest in mine air and mine gases generally.

In 1896 I had an experience with gas in the Minah Mine, Wickes, Montana, which was ordinarily well ventilated. In company with the foreman, an inspection was being made of a drift from the bottom of a winze. Three men were working at or near the face. No difficulty was experienced in keeping the candles alight. After being under ground for a few minutes, the three miners fell unconscious, without any warning—one, indeed, whilst speaking of his work and in the middle of a sentence. The foreman and myself carried these men to the bottom of the winze, from whence they were hoisted by bucket to the tunnel level and to the open air. The unconscious men had a ghastly pallor, and were revived with great difficulty. The symptoms resembled very closely a case which I once witnessed of the recovery of a man overcome by carbon monoxide gas (CO). I do not doubt but the gas encountered in the Minah was carbon monoxide. The gas appeared to come from the diabase country, and the face of the drift being in a fault plane, it may have come from a great distance. In 1899, when the mine was operated by sub-lessees, three men lost their lives in the main tunnel opposite the winze, thus confirming the idea that the gas, whatever it was, came as, in Mr. Lee's example, from the vein or country, and was not due to imperfect detonation of dynamite.

Recently a Royal Commission was appointed by the Transvaal Government for the purpose of investigating the causes of

miners' phthisis in the Johannesburg mines. During the investigation, which was quite thorough, analyses were made of the mine air at different times. The analyses were as follows:

	<i>Mine Air.</i>		<i>Compressor Air.</i>	<i>Pure Air</i>
	<i>Normal</i>	<i>After Blasting</i>		
	<i>Average of Six Samples.</i>	<i>Average of Seven Samples.</i>	<i>Average of Three Samples.</i>	
O	20·38	19·90	20·76	20·96
CO ₂	0·11	1·59	0·05	0·03
CO	0·13	0·39	0·08	.....
H	0·48	0·32	.....	.....
N	78·88	77·57	79·12	79·00
NO	0·0004	0·0078	.....	.....

The remarkable percentage of CO, even in normal cases, points out, beyond question, the unsanitary nature of the ordinary mine atmosphere. It is an old-time joke that a miner is one who can keep his candle alight and an eye on the boss.

The bad atmosphere of the ordinary mine, as shown by the Johannesburg analyses, is not conducive to energetic work. Most miners are subject to anaemia, a disease I believe rare to adults engaged in other occupations. An anaemic subject cannot, in the nature of things, be any too energetic. The subject of mine air and the removal of gases is but a branch of sanitary science, a science which is almost entirely neglected around the average mine—as witness, for example, the ordinary bunk-house. The recent severe outbreaks of ankylostomiasis (due to a parasite widely referred to as the “germ” of laziness) in Germany and Cornwall, is directly attributed by medical authorities to the enervating conditions of the mine air and the unsanitary condition of the mine workings generally. The nomadic instincts of the miner tends to spread the diseases peculiar to his calling, and, although no outbreak of the specific disease referred to has been recorded in our Western mines, yet it may occur at any time.

There is no question that pneumonia, the Western miner's most deadly complaint, is due as much to impurities in the mine

air as to the rapid changes of temperatures to which he is subjected. The effect of dust, nitrous fumes and carbon monoxide in the air is such as to predispose miners to that dreaded complaint.

Mr. Lee, by calling attention to the question of mine gases in general, has indirectly called attention to the necessity of giving more thought to mine sanitation. He deserves our best thanks for the very interesting paper he has read.

W. F. Edwards.—This paper originates in a request by Mr. Lee that I offer some discussion of his paper on "Gases in Metalliferous Mines." Instead of a discussion or commentary in any way on that paper, it is rather an addition, and devoted to two points brought out in Mr. Lee's paper: (1) that there is no adequate simple chemical means of testing gases in the mine; and (2) that the deleterious gas may be nearly, if not quite, all nitrogen.

I have nothing new to offer, but hope that putting some well known facts and processes before you may lead, as suggested by Mr. Lee, to some more definite knowledge of the gases met with in the metalliferous mines of Colorado and the whole Rocky Mountain region.

Doubtless our mine superintendents would furnish us more definite information concerning the kind of gases met with in these mines if they had some simple means of determining the kind of deleterious gases met with. Unfortunately, of the three most common gases naturally occurring in mines—carbon dioxide, nitrogen and methane—only one, the first, is amenable to any simple definite chemical test. To eliminate doubt concerning carbon dioxide is one step in the right direction, and to this end I would call your attention to a very simple apparatus that may be used with suitable chemicals, not only for the detection of this gas, but by a little practice, also, for roughly determining its quantity.

An ordinary $6 \times \frac{3}{4}$ -inch test tube is fitted with a number three rubber stopper (a perforated cork is all that is required). Through one hole is passed a close-fitting glass tube which reaches to the

bottom of the test tube. Above the stopper the tube is bent to a right angle, and the end is fitted with an ordinary flexible rubber bulb having a valve in one end.

Ten cubic centimeters of a saturated solution of calcic hydrate diluted with an equal volume of water is placed in the test tube. The rubber stopper is put in place when the apparatus is ready for use for detecting the presence of carbon dioxide, it being only necessary to pass the polluted air through the solution by means of the rubber bulb.

Our physiological chemists tell us that the expired air from the lungs of a man of my age, size and shape contains about 4 per cent. by volume of carbon dioxide. This bulb will deliver about twenty-five cubic centimeters of gas for each compression of the bulb. One bulb full of my breath should produce a distinct cloudiness in this solution, if I can manage to get even twenty cubic centimeters of breath into it. In this case, only the equivalent of ten cubic centimeters would be forced through the solution, as the bulb holds about twice as much as it will deliver.

Knowing that ten cubic centimeters of a gas carrying 4 per cent. of carbon dioxide, but otherwise indifferent to the solution, will produce a cloudiness in the solution, we can roughly approximate the condition of the air as to carbon dioxide by simply noting the number of bulbs full of air required to form a distinct cloudiness in the solution. The first bulb full is always rejected as it is presumed to be good air.

Another way that has been used somewhat for the approximation of carbon dioxide is better whenever the polluted air contains considerable of this gas. The only change is that of putting two or three drops of phenolphthalein indicator in the solution in the test tube. The indicator is made by putting one gram of phenolphthalein powder into a tenth-liter of 50 per cent. alcohol. This indicator colors the solution red as long as there is calcic hydrate left in it. When the last of the hydrate has been used in making calcic carbonate by the carbon dioxide the solution be-

comes colorless. Gas is pumped through the solution until the color is discharged.

Twenty-two parts by weight of carbon dioxide are required to neutralize thirty-seven parts by weight of calcic hydrate. A liter of carbon dioxide weighs approximately two grams and ten cubic centimeters of a saturated solution of calcic hydrate contains approximately fourteen milligrams of the hydrate. Ten cubic centimeters of a saturated solution of calcic hydrate require, then, about eight and one-third milligrams of carbon dioxide to neutralize it and discharge the color of the indicator. This would be the amount of carbon dioxide in one hundred cubic centimeters of air carrying 4 per cent. by volume of this gas.

If in any case the color is discharged, and there is no accompanying cloudiness or precipitate the cause should be investigated.

A chemist in his laboratory would probably use one of the two color-indicators if he desired accurate results. This indicator is given here because it can be used by the inexperienced, and is quite accurate enough for this approximation. As a rule it will be best to omit the indicator till the presence of the gas is established.

This same apparatus can be used with a solution of potassium permanganate in dilute sulphuric acid for detecting the presence of such gases as nitrogen dioxide, nitrogen trioxide, nitrogen tetroxide, sulphur dioxide and hydrogen sulphide, but give no indication of which one, except in the case of hydrogen sulphide, which, if unmixed, needs no better means of detection than good olfactory nerves. The oxides of nitrogen are converted into nitric acid, and the sulphur dioxide is converted into sulphuric acid the oxygen being taken from the permanganate. The permanganate should not be concentrated enough to prevent reading through the test tube when filled with it. The color of the permanganate is discharged by passing sufficient quantities of the named gases through it.

The apparatus can be used with various other solutions for detecting other gases, but it is not my purpose to tell the uses of

this simple apparatus, except in so far as it may be of service in detecting gases in mines, and I have exceeded this already.

Marsh gas, methene, is, so I believe, much more common than is generally supposed in metalliferous mine. It has been met with in iron mines, salt mines (common), lead mines, tin mines, copper mines, mercury mines, and gold and silver mines, and, as everybody knows, in abundance in coal mines and natural gas. It is an ever present component of the products of the dry distillation of organic matter and of the products of the slow decay of organic substances in ponds and marshes. Thus it will be understood that this gas is very common. In most cases where the flame indicates a combustible gas the gas will prove to be marsh gas.

Marsh gas occurs sometimes practically unmixed with other gases, as in the case of the mud volcanoes of the Crimea, the gases of which were analyzed by no less an authority than Bunsen, and pronounced to be pure methane—but much more often it is mixed with various other gases. In coal mines and marshes and ponds it is frequently, and perhaps always, accompanied by nitrogen. Graham's analysis of the firedamp in Killingsworth colliery showed eighty-two and five-tenths volumes of methane and sixteen and five-tenths volumes of nitrogen in every hundred volumes of the gas. Bunsen found in the gases from a pond in the Botanical Gardens of Marburg methane forty-eight and five-tenths volumes and nitrogen fifty-one and five-tenths volumes after the carbon dioxide had been removed from the gas. Noyes found in the natural gas at New Lisbon, Ohio, methane 67 per cent. and nitrogen 19.8 per cent. Other natural gases have been found having no nitrogen at all, and methane as high as 95 per cent.

I realize that I am digressing from the real subject of my paper, but perhaps I may be pardoned if I call attention to the variation of methane in the same well in a Pennsylvania district. The gas from the same well was analyzed at intervals of two months and gave the following in the order of the analyses: Me-

thane, 72.18, 65.25, 60.70, and 49.58; hydrogen, 22.02, 26.16, 29.03, and 35.92; ethane, 3.60, 5.50, 7.92, and 12.30. The gas of this well contained no nitrogen.

This gas may be formed in considerable quantity wherever large quantities of organic matter undergo decomposition under water; more especially if there is considerable cellulose (hard woods contain from 40 to 50 per cent., soft woods from 55 to 65 per cent., and wheat and barley straw about 50 per cent. of cellulose). I investigated a case some years ago in which a company had been formed for the purpose of boring wells for gas. They had bored a couple of wells and in both cases got a nice flow of water at a depth of about one thousand feet. They became suspicious of the enterprise and concluded to have a little investigation before going further. A learned professor who had traveled much and had a large collection of mineral specimens and curios, had discovered, while fishing in a river, for his health, that bubbles of gas came up through the water in considerable quantity whenever he rowed his boat through a certain place in the river. He took barrels and so floated them that they collected the gas and permitted the burning of it. This was the only place in the river where the gas could be found, and it was therefore concluded that the gas must come up through the ground at that point. As a matter of fact there was a considerable bend in the river at this point and large quantities of sticks and leaves had accumulated there and were undergoing decomposition. Just above this place a large area of land had been formed in what had been a marsh. Here the gas could be found in the wet places among the willows. One of the wells was driven on this mud flat.

The flame test is the only test for this gas that can well be used in mines. The alcohol or hydrogen flame is best. A portable safety lamp burning oil or hydrogen at the will of the operator has been invented for this purpose. Another having a detachable alcohol reservoir so that alcohol or oil may be used at the will of the operator has been successfully used. Some experience with the flames in gases of known composition would be of value to users.

A gas that cannot be proved to be any other gas is nitrogen is the best description of an analytical test for nitrogen that I am able to give. This involves the determination of oxygen as well as other gases. Testing for oxygen or nitrogen is not suited to the mines. In all cases where accuracy is desired the gas should be sent to the laboratory for analysis. If the analysis is to be a complete quantitative one the sample should be as large as convenient, as the use of considerable quantities may be required for the determination of constituents occurring in small proportions.

Hydrogen and carbon monoxide can not be conveniently determined in the mine and whenever they are suspected, very seldom naturally occurring, I believe, in metalliferous mines, they should be determined in the laboratory by competent persons.

While there are but few simple qualitative tests for gases yet there is no adequate excuse for not knowing the character and composition of gases in mines. The quantitative determination of gases may fairly be placed among the exact sciences and the cost of apparatus and the requisite skill are not such as to prohibit or even hinder the general determination of the composition of gases in mines.

As to the second point, that the deleterious gas may be nitrogen, I may say that while it is my belief that nitrogen in small proportion is common in the gases coming from rocks, I know of but three cases where analysis has proved nitrogen to be among the polluting gases. In the Strinesdale Tunnel in England the workmen were troubled with a gas which made them dizzy and finally gave semi-paralysis of the limbs. This gas was analyzed and found to be made up of ninety-two volumes of nitrogen and eight volumes of oxygen with a trace of carbon dioxide. In another case somewhere in Australia, I believe, a gas was analyzed and found to be by volume nitrogen 31.44, methane 61.49, oxygen 6.33 and carbon dioxide 0.74 per cent.

The Strinesdale Tunnel case shows a gas similar to that met with in the case described by Mr. Lee; i. e., the gas was practically all oxygen and nitrogen, and differed from ordinary air in having a too high proportion of nitrogen.

Assuming that the oxygen found in the three cases represented that of good air supposed to be made up of four volumes of nitrogen and one of oxygen, we have for the Strinesdale Tunnel gas forty volumes of air and sixty volumes of nitrogen coming from the rocks. In the case described by Mr. Lee, the proportion of nitrogen is higher, the gas being made up of twenty volumes of air and eighty volumes of nitrogen. In the other case there would be, under the assumption, 31.65 volumes of air, 6.12 volumes of nitrogen, and 61.49 volumes of methane coming from the rocks, ignoring the carbon dioxide which may come, in part, from the air.

The presence of nitrogen in rocks has not been explained, so far as I know. I will, therefore, offer the following suggestions, not so much as an explanation as that they may lead to definite proof of some kind.

Percolating water, charged with gases and organic substances, and various other substances, including substances containing nitrogen, as is well established, is a ubiquitous and active agent in making subterranean changes in rocks. As rain water it reaches the surface, carrying varying proportions of oxygen, nitrogen, carbon dioxide, and very small quantities of various other gases. An average of a large number of analyses of rain water gave the proportion of oxygen, nitrogen and carbon dioxide by volume as 33.76; 64.47 and 1.77, respectively.

The numbers for oxygen and nitrogen agree well with the numbers for the theoretical absorption of these gases, their coefficients of absorption being 0.041 and 0.02, and their partial pressures being practically 0.2 and 0.8, respectively. These numbers agree also with the numbers found by Bunsen, when distilled water was shaken with air, his numbers being: oxygen 34.9, nitrogen 65.1.

The number for carbon dioxide is not two-thirds high enough for theoretical absorption corresponding to a partial pressure of four ten-thousandths, which is the average for a large number of analyses of air. This is what might be expected, since the time element is one that cannot be ignored.

Rain water, on reaching the earth's surface, may be considered, then, as saturated with oxygen and nitrogen, but not saturated with carbon dioxide.

At the earth's surface this water takes up various organic compounds, as already pointed out. This organic matter is constantly undergoing decomposition, and produces varying amounts of methane and carbon dioxide, according to conditions not well understood. The various, probably complicated, go-between products of the decomposition is not yet understood by chemists, all of the very numerous attempts to follow the process chemically having failed of any definite result, on account of the very unstable character of these compounds. The process is not a spontaneous one, nor is it merely the result of slow oxidation by the oxygen of the air, but at and near the earth's surface is very largely due to bacterial fermentation. Organic matter undergoes decomposition by contact with some metallic oxides, as evidenced by the destruction of cotton and linen fabrics by rust spots.

Carried underground, these organic compounds—called altogether, sometimes, by the term humus—may produce the reduction of sulphates and oxides. An example of the first is that of the pyritous coating of coal seams, and of the latter is that of the native copper sometimes formed on the props of mines. A notable example of this kind is said to have occurred in the Ducktown Copper Mines of Tennessee. These mines were closed during the civil war. When they were opened afterwards, stalactites of native copper were found hanging to some of the timbers of the mine.

This reduction has had much to do with the widely distributed coloration of rocks by iron and copper compounds, as well as with the occurrence of hydrogen sulphide in springs. The carbon dioxide formed, attacks limestone, and the water carrying acid calcium carbonate attacks many other rocks that are practically permanent in the presence of pure water. Bischoff pointed out, years ago, in his *Chemical Geology*, that almost any rock near the earth's surface would show effervescence when treated with a min-

eral acid. It is doubtless due, to a considerable extent, to the action of these carbonated waters resulting from the decomposition of organic matter.

At the earth's surface, and in the presence of easily reduced metallic oxides, the product of this decomposition is finally very largely carbon dioxide, as well illustrated by the analysis of gases in the Thames. Gases taken from the water at Kingston gave the proportions for oxygen, nitrogen and carbon dioxide, respectively: 7.4, 15.0 and 30.3. From the waters taken at Greenwich the proportions were in the same order: 0.25, 15.4 and 55.6. The water taken at Kingston contained the oxygen and nitrogen in nearly the proportions found in rain water, but by the time it had moved to Greenwich the oxygen was practically all used up, and the carbon dioxide had increased very much, while the nitrogen remained about the same.

When the decomposition takes place under water, where there are no easily reduced oxygen compounds, the product is finally methane, as evidenced by the case already cited and by the gases from the mud lumps at the mouth of the Mississippi River.

As the water goes into the earth the oxygen is probably all used up in chemical action, in the decomposition of organic matter, if it is present, and in oxidizing such substances as sulphides, when the organic matter is wanting. The carbon dioxide accompanying it usually finds combination, but may not in certain classes of rocks, but the nitrogen and methane, if it is once formed, do not easily change or attack other substances; indeed, the nitrogen may be considered inert under nearly any condition.

Various conditions may obtain so that the water will be unable to hold the nitrogen taken in at the surface. The water may become warmer; it may be partly used up in processes involving hydration; it may dissolve substances that materially affect the co-efficient of absorption of nitrogen, etc. Any of these conditions would force the nitrogen to find a place in the rocks or an escape from them.

The well proved fact that crystalline minerals are seldom free from vesicular cavities which are often filled with gas, which gas is almost always nitrogen with traces of oxygen and carbon dioxide would seem to support this view.

A portion of the excess of nitrogen in mines could come from the absorption of oxygen from the air entering the mine as already suggested, but that the quantities occurring could all come from this source without some very marked evidence of the oxidation, such as could not fail to be noticed by casual observation, seems to me highly improbable. It also seems inconsistent with the fact, mentioned by Mr. Lee and also mentioned in the case of the Strinesdale Tunnel, that the gas escapes from the rocks with force enough to blow out a candle placed several inches from the rock from which the gas is escaping. It also seems inconsistent with the variation (apparent, at least,) of the escape of the gas, depending on the variation of the barometric pressure (Scott and Galloway called attention to this variation in the case of methane several years ago).

I do not know that the nitrogen carried into the earth by percolating waters has anything to do with the excess of nitrogen found in mines but it certainly would be interesting to know what becomes of it. It does not seem possible that it can escape by a return passage through the rocks, unless there were some very free passage open for it. Some data as to gases in the waters of deep wells and springs would be interesting and might be of service in the solution. Unless some extraordinary accumulation of nitrogen, such as mentioned, obtained, it probably would pass unnoticed.

F. W. Traphagen.—Mr. Lee's paper has brought to our attention a phenomenon of very great interest. With your permission, I wish to add a few words on the physiological side of the discussion, which I believe has not yet been considered.

So far as respiration is concerned, nitrogen, the principal constituent of the gas described by Mr. Lee, is inert, so that in the consideration of the gas in question we have to deal only with the effect of a deficiency in oxygen.

In respiration, the accession of oxygen by the blood, and the elimination of carbon dioxide, is a mechanical process which consists in osmosis, or the passage of gases through the pulmonary cell walls. The tendency in this gaseous diffusion is to establish a uniformity in composition on the opposite sides of the separating septum. The greatest motion, then, is from the side containing the greater percentage of any gas to the side containing less, and this ordinarily continues until equilibrium is established.

Blood, in passing through the lungs, takes up a variable proportion of oxygen—from eight to twelve volumes per hundred. This oxygen, however, is, to a very large extent, present in a weak form of chemical combination, forming oxyhaemoglobin, the coloring matter of arterial blood. This removal of oxygen by the blood is the method nature uses to prevent the equilibrium ever being established under normal conditions.

In man, respired air contains about 16 per cent. of oxygen. In the lung cells, however, the proportion of oxygen must be less than this, since the expired air consists of tidal air mixed by diffusion with the stationary air.

At the sea-level pressure of 760 millimeters, 16 per cent. is equivalent to a partial pressure of 122 millimeters. A very important question is, What is the minimum amount, or partial pressure, of oxygen which can be tolerated by man? So far as results are concerned, the same effect would be produced if oxygen alone were present. When the atmospheric pressure is reduced to 300 mm., the partial pressure of the oxygen sinks to 6 mm., or, when the oxygen percentage is reduced one-half, loss of oxygen from oxyhaemoglobin occurs, and the blood begins to lose its power as an oxygen absorbent and carrier.

In man, when oxygen is gradually diminished without other changes in the air, difficulty in breathing does not make its appearance until the oxygen sinks to about 10 per cent. in the inspired air, and therefore must be less than this in the lung cells.

At an elevation of 17,000 feet, the atmospheric pressure is 300 mm., and breathing is especially difficult.

The composition of air is as follows:

	<i>Oxygen. Per Cent.</i>	<i>Nitrogen. Per Cent.</i>	<i>Carbonic Acid. Per Cent.</i>
Inspired air	20·81	79·15	0·04
Expired air	16·033	79·587	4·38

When the breath is held for some time, the carbonic acid in respired air reaches 7 or 8 per cent.

It will be noticed that in respiration the nitrogen remains practically constant, while the oxygen and carbonic acid vary considerably.

In respiration there are two kinds of diffusion. First, the mixing of the inspired air with the residual air of the lungs; and, second, the osmotic passage of the oxygen into the blood, and the corresponding elimination of the carbon dioxide. The average amount of air passing into the lungs at each inspiration is about 500 cubic centimeters, or 30 cubic inches. This is followed by the expiration of an almost equal quantity of air, containing about 22 ccm. carbon dioxide, which gives, at the normal breathing rate of 17 a minute, 500,000 ccm. per day.

Actual experiments show 800 grms., or 406,000 ccm., to be actually given off in a day. These 800 grms. contain 582 grms. oxygen, and it has been found that 700 grms. of oxygen are actually required daily.

In actual experiments the variation was:

CO ₂	686 to 1285 grms.
O	594 to 1072 grms.

"When an animal is made to breathe an atmosphere containing nitrogen only, the exit of carbonic acid by diffusion is not affected, and the blood, as proved by actual analysis, contains no excess of carbonic acid. Yet all the phenomena of dyspnoea are present, and if the experiment be continued convulsions ensue, and the animal dies in asphyxia.

"In this case the result can only be attributed to the deficiency of oxygen.

"On the other hand, if an animal be made to breathe an atmosphere rich in carbonic acid, but at the same time containing an abundance of oxygen, though the breathing becomes markedly deeper and somewhat more frequent, there is no culmination in a convulsive asphyxia, even when the quantity of carbonic acid in the blood, as shown by direct analysis, is very largely increased. On the contrary, the increase in the respiratory movements may,

after awhile, pass off, the animal becoming unconscious, and appearing to be suffering rather from a narcotic poison than from simple dyspnoea; the excess of carbonic acid in the blood appears to affect other parts of the central nervous system, and especially portions of the brain, more profoundly than it does the respiratory center. It is obvious, however, that a lack of oxygen, and an excess of carbonic acid, affect the respiratory center in very different ways, and that in ordinary cases of interference with the interchange in the lungs, as in deficient aeration, it is the lack of oxygen which plays the principal part in developing the abnormal respiratory movements.*

The fact that when the gas in the mine was bad, work was impossible, was simply because the amount of oxygen required is in direct proportion to the work done, a minimum amount being required to keep up the vital processes. And this amount, in the case of the depleted mine air, was insufficient to do more than keep up ordinary actions.

Assuming that the availability of the oxygen in air is in direct proportion to its percentage, which is by no means true, it would require five times the volume of air to supply the oxygen where this mine gas was breathed, as would be needed with pure air. This would make the breathing rate 85 to 9 per minute. As a matter of fact, far more mine air than this amount would be required, for the elimination of oxygen in respiration is far from complete.

There are gases, of course, which produce death by their own direct action, and prominent among these are carbon monoxide and hydrogen sulphide, which interfere with the oxygenation of the blood by forming more stable compounds with the haemoglobin than that formed with oxygen, and which are difficult to break up. Of these gases, minute amounts are sufficient to produce fatal results. One per cent. of the former, or 1-10 per cent. of the latter in the air, are followed quickly by the death of those breathing it. The frequent fatal results following the breathing of water gas and the unfortunate affair at the Colorado School of Mines, are examples illustrating the poisonous character of these gases.

*Foster: Text Book of Philosophy; Part II. page 632, 6th edition. McMillan & Co.

DEATH GULCH.

BY F. W. TRAPHAGEN.

Read at the Meeting of the Society, January 16, 1904.

It is very certain that nowhere, within a like area, can be found so many natural features of great interest as those to be seen in the Yellowstone National Park.

Not the least of these is Death Gulch, discovered in 1888 by Walter Harvey Weed of the United States Geological Survey. Mr. Weed's description of his discovery appears in *Science*, February 15, 1889, and contains information concerning geological features, comparisons with Death Valley of Java, and many other matters of general interest.

At this time, bodies of five bears, one elk, many small mammals in various stages of decomposition, and numerous insects, were found. None of the animals showing any sign of violence, the discoverer concluded that death was caused by poisonous gas.

In 1897, Dr. T. A. Jaggar, Jr.,* visited the Gulch, finding the carcasses of seven grizzlies and one cinnamon bear. Tests made at various places along the bottom of the gulch failed to show sufficient gas to extinguish the flames of burning matches. About a year or two later, Captain H. M. Chittenden visited the Gulch and found no animal remains nor any evidence of noxious gases.† This experience caused him to express considerable doubt as to the authenticity of the previous accounts.

*Pop. Sci. Mo., Feb., 1889.

†Yellowstone National Park. 4th ed., page 335.

As both Weed and Jaggar have indicated, the Gulch is of such a nature that it is almost certain to be cleaned out periodically by freshets, resulting from the melting of snow or from heavy rains.

Quoting from the journal of the Corporal in charge of the the Soda Butte Station, the following extracts need no comment:

"MAY 3, 1897.—Lieutenant Lindsley and Corporal Herb left station for Cache (creek). Followed trail to Death Gulch. Crossed Cache Creek at Death Gulch and patrolled two gulches to find the one in which supposed skeletons were to be found. Ran into a bear track, and, in following it, came to Death Gulch. Corporal Herb went into it to the bottom and counted seven bear—brown, silver-tip and one grizzly. Part of gulch covered with snow. Signs of bear abundantly on both sides. The smell is that prevalent through the sulphur regions of the Park. On being in the bottom of the Gulch the sensation experienced was that of dizziness, leaving a headache behind."

"MAY 28, 1898.—Privates Root, McDonald and Edwards mounted to Death Gulch. Counted carcasses of seven bear, one fox; saw fresh signs of large bear on east side of gulch."

"AUG 10, 1898.—Private Wilson, from station to Death Gulch, found carcass of bear having just recently died—probably within 24 hours."

I have visited Death Gulch three different times. The first was in 1900, when, returning from Hoodoo Basin, our party camped near the mouth of Cache Creek, and went to the Gulch. On this occasion we counted the carcasses of four large bears and the remains of many other animals, represented by bones mainly, with occasional tufts of hair. Believing in the preservative effect of the gas of the gulch, I supposed at first that the bear discovered by Private Wilson was the one I found the following June, but I learned later that the former was a large bear from which the claws were taken by the soldier, while the latter was a small bear and still retained the claws. On my first visit the smell of sulphuretted hydrogen was noticeable, and I then determined on some further occasion to learn the composition of the gas of the gulch. With this end in view, I went to the Park last June with apparatus for the analysis of gases. Upon reaching Soda Butte Creek, however, I found the water too high to permit safe fording with the wagon, and had to be content with a horseback ride over to the Gulch, without apparatus, and found the only fresh animal

remains were those of a small bear, which I thought was the bear Wilson of Soda Butte Station found the preceding fall. The smell of sulphuretted hydrogen was very strong, and later I noticed the silver coins I had in my trousers pocket while in the Gulch were very much tarnished.

In August we succeeded in getting our apparatus to the Gulch.

The wind was blowing at a fair rate during all the time we were in the Gulch, and occasional showers also took place. Notwithstanding the extremely favorable conditions for rapid diffusion of gases, the air from near the bottom of the gulch showed the presence of more than 11 per cent. of carbon dioxide and strong traces of sulphuretted hydrogen. A search for the outlets of the gas showed fissures on the *sides* of the gulch from which the gas literally poured.

One crevice in particular—an opening about fourteen inches long by four inches high—furnished so much gas we decided to analyze it first, and found 1 per cent. of sulphuretted hydrogen and more than 50 per cent. of carbon dioxide, and have every reason to believe the percentage of these gases was even higher than these figures, for there were several ways in which the air constituting the remainder of the sample might have entered.

But these results show how, upon still days, when gaseous diffusion is not very active, a sufficient percentage of gases to cause death might remain, mixed with the air along the bottom of the Gulch.

The question of sulphuretted hydrogen poisoning has not been very carefully studied, and it is difficult to obtain any reliable data concerning it.

The following translation gives some information on this point:*

“Lehman states that when the proportion of sulphuretted hydrogen in the atmosphere reaches one to three parts per thousand, animals die in it in ten minutes with apoplectic symptoms and great difficulty in breathing.

*Toxikologie für Thierärzte. Eugen Fröhner. 2nd ed., pp. 146, 147.

"An atmosphere containing one part per thousand sulphuretted hydrogen produces death with cramps and oedemic inflammation of the lungs. It further produces rhinitis, conjunctivitis and laryngitis. It may be characterized as a blood poison which decomposes the oxyhaemoglobin in the body to sulphmetahaemoglobin."

It may be conceded, then, that about one-tenth per cent. in air is a sufficient amount to produce fatal results. This percentage would be reached by the dilution of the gas issuing from the fissure to ten volumes, which, considering the large volume of gas coming from this and similar fissures, would require a very large amount of fresh air. This dilution would reduce the carbon dioxide to 5 per cent., which would be not generally considered a dangerous quantity. Another point in connection with the poisonous effects of sulphuretted hydrogen gas, is that concerning its effect when associated with large amounts of carbon dioxide. Would it not, for several reasons, be more dangerous when associated with 5 per cent. of carbon dioxide? This phase of the question deserves more careful investigation.

In conclusion, it should be said that these investigations were carried out under the auspices of the Montana State College, Bozeman, Mont.



PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
Vol. 7, pp. 193-252.

THE CIRCULATION OF UNDERGROUND AQUEOUS
SOLUTIONS AND THE DEPOSITION
OF LODE ORES.

By JOHN W. FINCH.

DENVER,
PUBLISHED BY THE SOCIETY
MARCH, 1904.

THE CIRCULATION OF UNDERGROUND AQUEOUS SOLUTIONS AND THE DEPOSITION OF LODE ORES.

BY JOHN W. FINCH.

Read at the Meeting of the Society, April 4, 1903.

The materials of this paper have accumulated in long intervals of observation in many of the mines of Cripple Creek and other districts in several States and Territories of the west. The paper is, however, rather a summary of the deductions made from the phenomena observed than an extended account of the phenomena themselves, it being deemed best to first present a working hypothesis, with only such corroboration in detail as seems to be essential, reserving for a later date the detailed discussion of the physical conditions upon which the paper is mostly based.

The attempt has been made to restrict the paper to matters bearing directly upon the deposition of ores—meaning, by ores, metallic mineral deposits of the commercial category in distinction from vein deposits in general—which, unless affected by special processes of segregation and concentration in nature, are not of economic value, although they may be of great scientific interest, and may, indeed, be regarded in certain instances as potential or intermediate stages in the deposition of productive deposits. Only to that extent will they be considered, and the word ore in this paper will be construed as meaning only valuable deposits.

The conclusions reached are also intended to apply, as will appear, not only to those particular deposits of gold and silver

which have been the subject of much special study by writers on ore deposits, but to all metallic deposits in fissure veins or resulting from the alterations of such deposits, since the application of the principles and hypotheses considered is believed to be general to all such ores.

THE AGENTS OF ORE ACCUMULATION.

The Physical Agents.—(1). Meteoric water accumulated in the form of rain, snow or atmospheric vapor, gathers in the soil, and, except in arid climates, by various means and intricate routes, gradually sinks to considerable depth in the earth. Underground water is the universal vehicle of migrating mineral material near the surface of the earth, and the medium of the majority of physical and chemical changes. The main effort of this paper will be to correlate certain phenomena which are conspicuously dependent upon the activities of underground water of meteoric origin, and, though not assuming that these are the exclusive agents of ore deposition, yet, to formulate the effects as tangible and known factors which, when articulated into a system, may be of practical utility to the professional economic geologist and mining engineer.

(2). The impelling force of all circulating underground water concerned in the processes of ore deposition is gravitation. No other influence seems to be required for the flowage of water at the depths herein considered,* although certain exceptional phenomena of deep ore deposition involve other factors which contribute, to an important degree, to the efficiency of the gravitative agent.

Chemical Agents.—(1). The free solvents of the atmosphere and soil may have an independent function in the alteration and preparation of superficial materials for downward transportation by water. Water is itself the most universal solvent, and the greatest efficiency of the other solvents depends upon their solution and circulation in water, which not only co-operates thereby with the others, but also serves as a means of bringing them into

*VanHise: *Genesis of Ore Deposits*, A. I. M. E., 1901, p. 302.

contact by circulation with a maximum field of-attack. Van Hise says water is a million times more important than independent vapors or gases, and that, as a chemical factor, it (1) takes all minerals into solution, especially at high temperatures and pressures; (2) at low pressures or temperatures it deposits; (3) acts as the water of hydration; (4) may give up hydrogen to be replaced by other bases.

Other solvents are derived from the atmosphere, the superficial country rock, and from the vein itself. Not to attempt an enumeration of the full list, the more important are: oxygen, organic acids, chlorine, bromine, iodine, ferric chlorides, hydrobromic acid, sulphurous and sulphuric, hydrochloric and hydrofluoric acids, silicic acid and the sulphates of the metals. Hydrochloric and carbonic acids are the most universal near the surface. Organic matter, by its decay and disintegration, contributes carbonic and oxalic acids; also in its processes of food assimilation when living, develops the humic acids. Chlorine, the familiar solvent for gold, may be produced by action of hydrochloric acid on the high oxides of manganese, or of sulphuric acid on the same minerals in the presence of chlorides.* The oxidation of pyrite, the classic example, yields ferric sulphate and sulphurous or sulphuric acid. The latter, acting on the chloride salts which are almost always present in mine waters, liberates hydrochloric acid. Dr. Don,† who has accomplished some valuable work in the analyses of mine waters of Australia, has failed to find water containing free acid in which there was not also a large percentage of ferric salts, which indicates their mode of production. Such solutions would be effective in the attack upon most metals. In Cripple Creek this reaction has been prominent. Aside from the pyritous ores occurring as original materials in the veins, the volcanic rocks are characterized by a large constituent of indigenous

*John R. Don: *The Genesis of Certain Auriferous Lodes*. *Trans. A. I. M. E.*, Vol. XXVII, p. 598-9.

†Op. cit.

pyrite.* The latter, in some sections, has been thoroughly removed, leaving the andesites and phonolites porous in texture because of the solution cavities, or filled and stained with the iron oxides disseminated through the rocks or pseudomorphic in the pyrite matrix. Conspicuous marks of reactions so effective in producing solvents, would of itself suggest notable secondary enrichment in the ores of the district, and such has been the fact developed in mining.

I have had occasion to obtain analyses of Cripple Creek mine waters for various purposes, and find invariably appreciable amounts of the common solvents, varying, of course, between different mines and at different depths. The waters of the Gold Coin vein contain sulphuric, hydrochloric, and probably some silicic acids. The mine is entirely in the granite-gneiss area south of the volcanic complex. Water from the drill-holes into the unaltered granite west of the vein at the same depth, about 750 feet, contained chiefly sulphates of lime and magnesia in small amounts. This contrasts with the water entering the east wall of the Elkton vein, which is the underground drainage of the large andesite area of Raven Hill, a region strikingly marked by disseminated pyrite in the country rock. This water contains a considerable amount of sulphuric acid.

The opportunity to test mine water for any differences of content at different horizons is somewhat rare, since by the depression of water level due to pumping, the water ordinarily obtained at any deep level is not representative of that depth, but may be normally native to a horizon many hundred feet higher. In some cases, a long drift on a vein at a great depth, entering a territory not drained for a long distance above by other drifts, may, as the heading progresses, supply water which, on analysis, will afford information to the point. Determination of pressure (head) should be made at some place of free and maximum flow to enable calculations of the height of water standing in the rocks above the point where the sample is taken. If the head is small the analysis will not have great significance, except in showing the contents of

*Whitman Cross: XVI Ann. Rept., U. S. Geol. Surv., Pt. II, p. 52,

water of the superficial horizon. Investigations along this line have not given reliable results.

Returning to the question of solvents, the superficial waters of Beacon Hill flowing through the Standard Tunnel, at a depth of 400 to 500 feet from the surface, showed marked amounts of sulphuric, hydrochloric and considerable silicic acid two years ago. The city water supply of Victor, accumulated from the springs on the southwest slopes of Pikes Peak, contained three to five grains of chlorine per gallon. This water was derived from the ancient crystalline rocks remote from artificial contamination. Given the factor time, this would be an effective solvent, possibly even of gold.

The mine waters of the San Juan show, in many cases, remarkable acid and metallic contents. Ransome finds in the waters of a spring near the Guston Mine, on Red Mountain, silica 75 to 80 parts per million; sulphuric acid, "very much"; alumina, 214 parts; iron and calcium, "much"; and a little zinc and copper. The zinc and copper were gathered by the oxygenated surface waters passing downward through blende and chalcopyrite.*

In the Geyser Mine, Custer County, Colorado, Emmons found waters highly charged with carbonic acid gas and containing considerable quantities of the metals.†

From my own observation, the waters in the Virginus vein are highly charged with acid which decomposes timbers and destroys iron pipes. This is superficial water artificially depressed to a deep region, 2,500 feet, but its opportunity for solution is abnormally enhanced by its great distance of passage through the materials of the vein under oxidizing conditions. The presence of solvents in mine waters everywhere needs little comment to miners, since their universal occurrence is recognized.

Precipitants.—The most important precipitants are encountered by the downward-moving solutions in the vein itself, as

*F. L. Ransome: Bull. No. 182, U. S. Geol. Surv., p. 114.

†The Mines of Custer County, Colo., Ann. 17. U. S. G. S., Part II., pp. 456-466.

minerals already existing there, notably the sulphides of the metals. Another effective means of precipitation is the mingling of solutions from various parts of the vein, or of solutions from the wall rocks with those in the vein, in either case the contents differing to some marked extent. Water from the wall rocks may contain precipitants, and thus effect deposition, or the mere mixture of the various solutions may result in saturation with reference to some ore-building material contained. This factor of deposition is emphasized and thoroughly discussed by Van Hise.* Even though dilute, solutions mingling may form a combined solution saturated as to the least soluble substances contained or formed by combination.

Organic matter, and some of the compounds derived from it, serve as reducing agents, and thus precipitate the products of oxidation. Dr. Don illustrates this by detecting gold in old mine timbers. Bituminous sedimentary beds have been discussed fully in this relation by Dr. Jenny, in recent "Transactions of the American Institute of Mining Engineers." There is, however, some doubt as to the general applicability of his conclusions. In Cripple Creek, at least, carbonaceous matter associated with certain veins does not produce the effects described by Dr. Jenny.

Deposition may also possibly be accomplished by physical means, such as the retardation of flow or local cooling of solutions in a high state of saturation; underground evaporation with consequent saturation, and other similar causes.

THE FLOWAGE OF UNDERGROUND WATER.

Water is such a conspicuous and universal solvent, and its rôle as a transporting agent is so extremely important, that its activities merit the closest possible attention, as has been recognized by the host of writers now working on this subject.

As already noted, gravitation is the motive force in flowing water. This is true even in convection, when a water body develops

*The Genesis of Ore Deposits, A. I. M. E., 1901, p. 324.

currents within itself due to local differences of density from any cause. The phenomenon of convection is, however, of relatively small importance in water circulation, it is believed, as it normally operates. The water probably moves very much as surface streams move—in channels—following, as a mass, the direction imposed by gravitation and the physical interferences to direct routes.

Ideal Directions of Movement.—Near the surface, wherever conditions are such that water may enter the ground, the direction is downward, and, as nearly as possible, vertical. At a certain depth, varying with different regions and with various local conditions, given sufficient precipitation of water on the surface, proper relations of topography, texture and structure of surface formations, etc., the rock crevices become permanently filled and porous formations are saturated with water. The top limit of this condition of saturation is “water level,” as the miner uses the term. At this depth, water may approximate a horizontal direction of movement, if it has an outlet. With no outlet, the water will seek a level, and be subject to very little movement. In mountainous regions, however, outlets always exist through the crevices of the rocks to the slopes, canyons, valleys or plains at lower altitudes.

Passages Through the Rocks.—Near the surface, the movement of water downward is easily accomplished through the abundant spaces existing in the surface soil and the underlying disintegrated rocks. As depth increases and disintegration becomes less marked, the joints and cracks of the rocks become the easiest avenues of movement, and conduct the greater part of the flowing water. To a moderate depth, also, but varying with different regions and with different rocks, seepage through the body of the rocks may form a prominent feature of water flowage by means of interstices existing between the minerals of the rock. Such spaces are developed chiefly by the secular release of pressure attending the degradation of the surface by the processes of erosion. Joints and cracks are enlarged and probably many of them are originated

by the same means. The marked diminution of such openings in deep mine cross-cuts through the country rock and their abundance near the surface would seem to support such a view. Any such openings, once formed, are greatly enlarged by the various activities of water passing through them, until, when any given rock body is finally exposed at the surface, its transformation to loose soil has been already instituted by the processes which began the work while the rock was still buried at considerable depth in the earth.

At great depth rocks are so compact that the water which the miner encounters is found to flow, at least in appreciable amount, only through the prominent crevices, such as the faults and fissures. Joints and cracks may still exist but much less prominently and usually discontinuous and disconnected, therefore not capable of conducting flowing water.

The circulation of underground water closely resembles the venous flow of blood in the body, from the capillary extremities into the veins and finally into one great vein which conducts it back to the heart. The water of innumerable openings at the surface is gathered in the network of joints and cracks at moderate depth and by these is contributed to the more prominent channels at greater depth, through which it is finally returned to the surface at lower altitude.

Barriers to Flow.—As influencing the activities of underground water in its relation to the segregation and localization of ore bodies, the barriers to flow interposed in the routes of water movement have an importance second only to the channels of flow themselves. The barrier may be only a means of checking or retarding the flowage, or it may be a practically impassable obstacle acting as a bar or dam. This will be considered more fully in connection with some of the processes of ore deposition.

Barriers may be local bodies of impervious rock, as beds, layers, dikes, sheets, or any extensive mass which can for a long distance resist the passage of water and bar it from the direction it would naturally choose. A barrier may be merely a mass of rock lacking the fissured condition of the surrounding rocks. A

rock body to be effective as a barrier need not be perfectly impervious. All forms of rock known may in time probably become saturated with water. Many rocks, however, although penetrable to the extent stated, will yet be, when saturated, impervious to the flow of water through them, particularly if there is any other route which may be followed. Water, like the electric current, will seek the easiest route. It will choose an open conduit up to the limit of its capacity, and up to this point the more difficult medium will be avoided as if impenetrable. If, however, the capacity of the more favorable conduit be overtaxed, the other may offer a difficult, yet possible, passage under pressure. In the matter of water flowage it will be one of the aims of this paper to set forth reasons for the belief that the latter condition is exceptional in the majority of mining regions and that the flow of water through continuous open passages, such as fissures of capillary width and greater, constitutes the important form of underground circulation as observed in mining.

The movement of water in vein channels is rendered irregular by the many variations in vein filling or the inequalities in size of the crevices themselves. The vein may contain a continuous but circuitous open water course, and at the same time be sealed in many places to the free passage of water.

THE ZONAL DISPOSITION OF UNDERGROUND WATER.

Classification is clarifying only in so far as it simplifies the conception of the relations of the things classified. It is hoped that the following zonal classification of underground circulation may serve such a purpose. It is developed on the basis of the vertical change in physical conditions affecting the movement of water at various depths. With this a correlation is afterward attempted of certain phenomena of ore occurrence which appear to exhibit a genetic relation to such disposition of water in zones.

Zone I, the Gathering Zone.—As already noted, waters which enter the ground are accumulated in the loose rocks of the surface, from these supplied to the cracks and joints, which in turn convey

them to the fissures and larger openings. Zone I includes all depths near the surface in which water is accumulated and conducted to a saturated zone, in all localities where a saturated zone exists. This is named by Van Hise the "Belt of Weathering."

The water routes in this zone are essentially the same in veins and country rock, though they may differ in degree of conductivity.

The depth of Zone I varies with the topography, rainfall and the nature of the rocks. In low topographic areas it may be zero, in areas of extreme relief it may be hundreds of feet; in arid climates it may be shallow or exceedingly deep according to the character of the rock exposures and the interpretation given certain exceptional features to be discussed later. If the saturated zone be lacking, Zone I may be conceived as terminating with the cessation of downward percolation.

Zone II, the Zone of Discharge.—In all regions studied by the writer where there exists a condition of saturation at a certain depth, particularly in the mountains and where deep mining has revealed the state of the water bodies, there is a certain upper portion of the belt of saturation in which there is flowage of a well-marked character, and it is believed that this certain part of the belt of saturation merits special investigation, and, because of its well defined limits and its apparently notable significance as related to ore deposition, a separate classification. Between those important bodies of ore known as the secondary sulphides, and to some degree the oxidized ores, and the limits of this zone, there is a significant correspondence of position.

The zone, as it will be described, has been observed mainly in the high regions of the Rocky Mountains, but, though extremely variable in extent and importance in different localities, it is believed that it can be distinguished in any region of rock saturation and sufficient topographic relief. It is, therefore, discussed as a general feature of all such mining regions.

Zone II embraces that part of the belt of saturation, in any region, which has a means of horizontal escape and discharge.

The means of discharge establishes a continuous condition of gravitational flow.

The routes of flowage are the prominent fissures traversing the country rock. To effect a considerable movement, the open fissures must aggregate continuity. A series of fissures connecting or intersecting may thus lead the water to the surface at a lower altitude.

The water of flowage is acquired from the numerous crevices of Zone I. The massive unfissured rocks of Zone II may become saturated, though not necessarily; but, if so, the movement in them is infinitesimal, except in loose sands and gravels.

The upper limit of Zone II, which is the upper limit of rock saturation, or "water level," is exceedingly variable. Besides the several factors mentioned under Zone I as affecting the depth at which saturation is found, it varies also as the facility of movement to the place of discharge. The latter is governed by distance to be traveled and the degree of conductivity of the passages through intervening rocks. In configuration the upper limit of Zone II may be undulatory, approaching the topography of the region, especially in humid regions, or it may approach a horizontal plane where water supply is meagre or the distance to outlet great and movement consequently slow. In the semi-arid regions the latter is likely to be the case. In any locality characterized by rock saturation, water level changes with the seasons and any irregularity of rainfall.

The bottom of Zone II is the lowest limit of notable movement of water. It is controlled by the lowest limit of discharge. If barriers intervene, the bottom of the zone may be the crest of the barrier, and much higher than the apparent line of lowest escape. The altitude of the bottom of Zone II, more strictly, ranges from the highest point to the lowest point along the deepest avenue of discharge, and may be much higher in the midst of a mountain mass than near its borders.

In the great plains Zone II may approach zero in width, and it may be absent, except locally, where minor features of topography

admit its restricted development. Such conditions are usually remote from mining regions. Water is not infinitely mobile nor does it flow with perfect freedom through restricted passages. A gradient is therefore established which may indeed approach the horizontal, but never reach it except with total cessation of flow. The exceedingly low slope of the continental areas outside the mountain regions may not, therefore, be sufficient to cause underground flowage except in a local and superficial way. Water gradient is the resultant of the viscosity of the water, the resistance by friction, the volume under motion, and head. The first two are sufficient to determine a water gradient from Pueblo to the Gulf of Mexico of higher inclination than the slope of the continental surface. The altitude of the bottom of Zone II for the Pikes Peak region is then, at least, above the level of Pueblo, and it is believed that it will later appear that it is considerably higher.

Figure 1 is a diagrammatic representation of the land profile from Pikes Peak to the sea. It also shows the general relations of Zones I and II to the topography. Line $a-b$ is the mountain profile, $a-s$ is the plains profile, $m-s$ is a horizontal line. Angle x is the gradient of flow of underground water, z is the slope of the ground surface, y is the difference between x and z . Water will discharge to the surface if y is negative but not if it is positive.

The rate of flow in Zone II is ordinarily much greater at the top than at the bottom. It also moves at a grade which varies as the depth. Near the top of the zone the channels are usually much larger, more numerous and better connected than at the bottom, and the normal gradient at the top is therefore much steeper than at the bottom. In Cripple Creek, waters from Bull Hill and Battle Mountain, before pumping was begun, found outlet into West Beaver and Wilson creeks and into their tributary gulches, but for water below the bed of either at any point it was necessary to move farther down stream to escape, until at a certain depth the channels of Cripple Creek, Ute Creek or Beaver Creek, at a distance of three to five miles, were the nearest points of discharge. Water at a depth of 2,500 or 3,000 feet, if any water

exist at such depth, must travel to the edge of the valley of the Arkansas or to its deep-cut tributary canyons, a distance of seven to twelve miles. Although the lower layers in the water zone may exist under head, they move slower than the upper layers, both because of the increased chance of obstruction with greater distance to discharge, and because of the diminishing openness of structure in the rocks as depth is attained.

Such conditions may locally exist as to greatly modify or completely reverse the normal downward decrease of flowage as set forth above. Pervious layers near the bottom of the zone may accommodate the circulation sufficiently to leave little movement in the upper part of the zone except downward.

Artesian flow is anomalous. Water is confined by an impervious cover in such a manner as to develop head by accumulation, but is static until artificially released. Lacking means of natural discharge, artesian water bodies do not belong to Zone II.

In the ideal conditions of uniform permeability for extensive regions, flow in Zone II has no vertical component except that of its gradient. It is therefore characterized by downward movement, but in special cases there may be upward movement. Any source of heat in the pathway of the water of the zone, as vulcanism and dynamism, may divert its currents upward. Geysers and certain hot springs are the extreme instances.

Zone II may be entirely absent. It depends upon Zone I for supply, hence any peculiar condition in the latter or of precipitation at the surface which renders the supply of water moving through Zone I insufficient to saturate the rocks and form a "continuous underground sea" of considerable extent by the perpetual accumulation of such waters, may preclude the existence of Zone II. Such conditions may be observed in the great desert regions.

The desert exhibits, particularly at points of low altitude, as in Yuma County, Arizona, and in the desert of California, two classes of surface rocks, as affecting the imbibition of water, viz.: the sand plains, or "washes," and the massive outcrops of

the hills and mountain ranges. With increased altitude, as in northern Arizona on the "Painted Desert," erosive agents are essentially of the transporting order, and almost the entire surface is a bare exposure of indurated rocks.

The limited precipitation in these regions would yet be sufficient to supply extensive or even generally prevailing bodies of underground water it may be, if the rainfall were more evenly distributed. But, occurring in violent concentrated downpours at long intervals, it is ineffective in saturating the ground, chiefly because of the immediate and nearly complete "run-off." In 1900 the Gila river, tributary to the Colorado in southwestern Arizona, ranged in flow from zero for the entire month of July and part of August to a maximum of 3,460 second feet within a very short interval, and in a period of 28 days in September varied from a maximum of 6,630 to 30 second feet.* This affords a good illustration of the characteristic manner of rapid dissipation of precipitated waters in such a region.

In the great interior basin, where drainage cannot escape to the sea, it flows into sinks, and even in these it is evaporated before it descends deeply into the ground.

The rainfall upon the desert, therefore, excepting a very small percentage, does not escape beyond the reach of the sun's heat, which is usually intense immediately after a storm, as at any other time. The surface rocks, prior to rainfall, are in a state of extreme desiccation. It is a familiar principle of physics that dry capillary passages are difficult water routes because of surface tension.

In *Figure 2*, *x-y* represents the cross-section of a single capillary in the intricate system of passages existing near the surface, magnified to illustrate conditions in the soil or in any porous rock exposure immediately following a violent rainfall. This tube may be made up of the continuous chain of spaces between the constituent grains of rock as represented, or it may be a crevice of

*Water Supply Paper No. 51, p. 386, U. S. Geol. Surv.; also, No. 52, pp. 399 and 520. By F. H. Newell.

capillary width. In the sand plains the former is the usual condition; in the massive exposures it may be either or both. When soil becomes perfectly dry, the pore space is entirely filled with air. This must be driven out before water can enter. In the fine soils the water of rainfall so thoroughly fills the surface pores that the air below is unable to escape and may even reciprocate by sustaining the water against further downward progress.* There are also other good and sufficient reasons why the water may not move downward except for a short distance. It enters at x —*Fig. 2*—working into the dry tube to some point, as N , while the storm is in progress. When it passes, the sun immediately sets up a rapid evaporation, at x . Rather than crowd its way further downward against dry walls, the meniscus at N sustains the weight of the decreasing, evaporating column. Evaporation, though greatest at M , operates throughout and with considerable rapidity at N , until the water is entirely removed.

It is doubtful whether upward capillarity is a notable feature in the above process, since such upward movement would probably result from surface evaporation only when the tube is immersed at N in the surface of a freely mobile and continuous water body.

If the surface materials are coarse gravels instead of fine sands, the meniscus N may be incapable of supporting the water column, but when water encounters, at greater depth, materials of more minute porosity, as it would in both the stratified sand plains and in the massive rocks, the condition of detention and evaporation would be established, and the process of removing the water would differ from that at the surface as illustrated in *Fig. 2* only in the rate of accomplishment.

One familiar result of evaporation near the surface is superficial induration or case-hardening. The horizon of extreme disintegration in massive rock exposures in Arizona is not the surface but a small depth below it. Outcrops apparently compactly indurated may change to sand and dust a few inches below the surface in places where it is not continuously stripped by erosion.

*F. H. King: Principles and Conditions of the Movement of Ground Water, Ann. 19, U. S. Geol. Surv., Part II, p. 105.

In the long intervals of desiccation, superficial materials are ideally prepared to contribute soluble materials to water at time of rainfall. The flowing water gathers such materials and, in case they enter the ground as described, precipitates them by evaporation. The result is a surface crust which, on the loose sands, will often sustain the weight of a horse, and sometimes becomes an indurated layer several feet thick.* For certain localities this has been called the "Caliche" by Professor Blake.

The phenomenon above illustrated is greatly modified by the existence of open joints and fissures at the surface. Water may readily enter such open crevices, and, if they are of sufficient size, in large quantity, and penetrate to comparatively great depth. Such descending water may, however, and probably usually does encounter, at some depth, barriers to further progress. It may then be gathered into a temporary, or at least rapidly varying, underground water body of limited extent. Such barriers, and their resulting transitory water accumulations, are exceedingly important to the explanation of the disposition of the richer commercial ores of the arid countries.

Underground evaporation in such regions, in all its aspects, whether affecting moving or stagnant water, is also a factor of essential importance to the comprehension of the mode of precipitation of localized ores.

Water will evaporate at all temperatures into an unsaturated gaseous medium, such as air. Water vapor forms in the underground atmosphere, as it does at the surface, to the point of saturation. The average capacity of the underground atmosphere is greater than that of the air at the surface, because of the greater temperature, as found in the deep levels of mines. The water in the rocks in dry countries is mostly in the form of underground streams, exceedingly variable and usually intermittent, but never water bodies of great extent. It is therefore specially susceptible

*Wm. P. Blake: The Caliche of Southern Arizona; Trans. A. I. M. E., Vol. XXXI, p. 220.

R. A. F. Penrose: The Superficial Alteration of Ore Deposits; Jour. Geol., Vol. XI, p. 292.

to evaporation. Water moving downward in a fissure may penetrate to only moderate depth, since evaporation, keeping pace with its movement, may finally become the controlling factor, entirely exhausting the supply of water.

To embody in a synoptical statement the relations of circulating underground water in the round of activities of the earth's "aqueous envelope," Zones I and II combine as the underground segment of the cycle of terrestrial water circulation. In the absence of the zone of flowing discharge in arid regions, the same relation is maintained, since water returns to the earth by evaporation, and Zone I embraces the entire underground segment of circulation.

Zone II is the upper part of Professor Van Hise's belt of saturation. In conditions of thermal adjustment, such as normally characterize the earth's crust, it is believed to embrace all of the circulating part of the underground sea, but not the entire zone of saturation, except in special cases of impenetrability above the normal altitude of the lower limit of the zone, or in localities where water supply is inadequate to saturate difficultly pervious rocks to great depth against the stronger tendency to horizontal flow to point of discharge through the more open passages nearer the surface.

Zone III, the Transitory or Static Zone.—Below Zone II, the zone of discharge, the state of underground water is only vaguely understood. Observation is usually impossible, and there is much uncertainty in the application of known physical principles of water movement. At great depths in the earth there is doubt concerning both the molecular state of the water itself, affecting its normal co-efficient of viscosity, and the condition of the rock masses in which the water may exist as regards their permeability. Nevertheless, basing assumption upon physical principles already considered in the discussion of Zone II, the conclusion seems inevitable that the movement of water which may be found below the level of the lowest point of discharge, for normal conditions, is infinitesimal.

Disturbing factors may enter into consideration in special cases, which may impart to such waters, probably static in their absence, important and far-reaching circulation. If a region of vulcanism exists in Zone III, convection is set up by the local introduction of heat. Since notable movement can take place only along open passages, such as fissures presumably existing at such depths, the effects of any form of disturbance to the static conditions are not general and pervasive, but restricted to such passages.*

Other sources of heat exist in the depths of the earth. These have been treated exhaustively by Van Hise. The main sources, outside the volcanic, which is itself probably only an intensified form of these, are dynamic and chemical. The former develops heat as the result of mechanical displacements attending crustal adjustments and, in the cases of orogenic movements affecting restricted areas, may be potent in effects upon circulation in Zone III. Chemical reactions liberating heat may become effective at certain points, but they are, to a great extent, dependent upon the activity of circulation engendered by other sources of heat mentioned, and operate chiefly as a means, so far as they serve as a factor in circulation, of promoting or accelerating the process already instituted.

From the numerous observations, reported from widely distributed deep openings in the earth's crust, internal heat is not adjusted to regular, concentric isotherms, but, for the first few thousand feet, at least, it is somewhat variable, and in certain mining regions, extremely irregular. Such a regional variation in temperature may set up a circulation in Zone III, if sufficiently extensive avenues of movement exist. Probably this regional variation is nothing more than the local expression of an intensified form of the dynamic and chemical processes mentioned in the last two paragraphs. At any rate, the mere process of circulation thus instituted, by redistribution of heat, works toward ultimate adjust-

*Clarence King: *The Comstock Lode*, etc.; U. S. Geol. Exploration, 40th Parallel; 1870. Vol. III, p. 87, *et seq.* Washington.

ment of such unbalanced conditions, and supplies in itself the means to its own final cessation. Hence, the normal condition, for the greatest areas of the earth's crust, is a state of balance, or adjustment, in the distribution of internal heat. Localized heat which would affect the circulation of water is only temporary, and institutes the process of its own dissipation. When this is accomplished, Zone III is static, and such a state is its norm.

Ordinarily Zone III depends entirely upon Zone II for its supply of water. It is the bottom part of a belt of saturation of which Zone II is merely the upper and flowing part. In special cases, either when Zone II is locally lacking, or there is a local barrier to downward egress from it, Zone III may have been supplied by lateral movement from the corresponding zone in the vicinity, but even then Zone II is the indirect, though not the immediate contributor.

Professor J. F. Kemp* and others have postulated the presence of water and its ore-building solutions as an indigenous part of volcanic magmas, and give water of such origin a leading role in the deposition of ores. That water, as a highly expansive vapor, largely supplies the explosive force of volcanic eruption, is subject to little doubt. Whether such water encounters or accompanies the magma is, however, somewhat immaterial to the question of the first origin of ores in solution. The effect would be the same in both cases.

The top limit of Zone III, as herein defined, corresponds normally to the lower limit of notable mobility in the saturating water body, or the upper limit of static water. It may be also an extensive barrier, for any reason efficient to prevent access of water from Zone II in any special locality and determining the bottom limit of discharge to the surface.

The bottom limit of Zone III is entirely a matter of speculation. If there is a downward limit to water of saturation, the zone is defined by this. That there is such a limit is an observed fact in most of the deepest mines, and it is reasonable supposition

*Genesis of Ore Deposits. A. I. M. E., 1901, pp. 687-689.

for any place in the earth's crust. The majority of such deep mines, at a certain depth passed through a zone of saturation of considerable vertical extent. Such a zone of saturation is divisible into the two zones here considered, the line of division depending upon local conditions of discharge to the surface, but scarcely observable in mine workings, except by certain effects ascribed to it, on account of the artificial conditions induced by pumping.

It is believed that Zone III is rarely extensive, except where there are deep open fissures, and that the rocks are commonly dry below 1,000 or 1,500 feet from the surface. Yet at sometime in the history of every important fissure vein there has been an active circulation below the zone of normally flowing water, *i. e.*, below Zone II. This, though temporary, has been all-important to the first segregation of ores, and will be discussed more fully at a later point. But, for much the greater part of the history of any vein, the necessary conception seems to be that the fissures do not remain open to great depth, and that water, in passing through dense rocks, not only does not sink to great depths, but usually finds the horizontal route to the surface easier to pursue than a downward movement in minute passages. Water will move slowly downward in dry capillary openings under sufficient pressure, but if it can find an open route it will choose this, even in a direction approaching closely to the horizontal and against its impulse to obey the direction of gravitation.

After a certain depth the spaces in the rocks do not form continuous passages of capillary size. In such sub-capillary openings it is highly probable that water is sustained against further downward movement by friction with the walls, surface tension at the base of the invading water column and molecular cohesion (viscosity) within the water itself.

Aside from all possible conditions, as those suggested above, by which Zone III might be greatly restricted, there are regions in which it is unquestionably absent.* In the desert, as already stated in the description of Zone II, evaporation underground is

*J. F. Kemp: *Op. cit.*, p. 696, *et seq.*

so rapid that water seeking the depths, even through fissures after heavy rainfall, becomes at a certain depth so depleted in volume that it is finally volatilized more rapidly than it can advance against friction and surface tension. This phenomenon of evaporation operates not only on water which might accumulate from the surface, but also on any which might, by seepage, attempt to move into the deep rocks of the arid regions from the saturated zones in surrounding country.

Summarizing the vaguely known phenomena of Zone III, water of saturation which might be assumed to exist in static condition below horizons of escape, in some localities is known to be wanting; moreover, there is ample reason to doubt, even where such water does exist, that it extends downward into the earth beyond a moderate depth,* and whatever may be its depth, it is static. The ordinary increment of temperature increase downward into the earth has not been demonstrated as effective in producing convection in minute passages. In theory it appears incompetent to overcome the resistance to movement.

Zone III contains, then, water isolated from the actively circulating aqueous envelope of the earth. It is not likely to be restored to the cycle of circulation, except by special and fortuitous means; yet existing undisturbed for great periods, especially when extending in fissures to great depth, any special access of energy impelling it to a higher zone would doubtless be a means to the so-called primary deposition of ores. This will be discussed at a later point.

Closer Articulation of Zones II and III with Prevailing Theories on Underground Circulation.—Zones I and II are essentially all of the normal underground circulation, as described by Van Hise. Zone III produces results of ore deposition very much as described by Kemp. Yet it appears to comprise the greater part of the vertical section of the belt of saturation postulated by Van Hise. This seeming anomaly results from the great depth of underground water assumed by the latter, which is believed to

*Prosepy: *The Genesis of Ore Deposits*, p. 243.

be excessive. Zone III corresponds exactly to that part of his belt of saturation supposed to be affected by convection, but it is not admitted that convection is a continuous characteristic of Zone III, but temporary, and, as stated above, though of vital importance in ore deposition, yet to be accounted for only by special and relatively intense accessions of heat of a somewhat catastrophic order of occurrence. In the latter features, the view herein of the deep circulation and its results, as to both its temporary nature and its impelling energy, corresponds very closely to the theory defended for so many years by Professor Kemp and still held by him.

It has appeared to the writer in the study of conditions in the deep mines, that the apparently opposing theories of these two writers are each broadly applicable to one of the two most important phases of ore deposition, viz.: the primary and secondary concentrations of ores in fissure veins. In a general way, then, the division of underground water bodies into the two lower zones in this paper, is an endeavor to combine existing theories. Herein lies the main significance of the division and the desirability of making it.

However, Van Hise has already established the necessity for some division of the belt of saturation by so clearly defining the functions of the "ascending" and "descending" circulations. Zone II marks off the realm of descending circulation, while Zone III is characterized entirely by the ascending circulation and its products. The ascending and descending currents do not ordinarily occupy together the entire belt of underground water, although Zone III, when actively circulating, must be supplied by a descending flow, yet, so far as deposition is concerned, it is the zone of ascending water. The hypothesis is herein advanced that the ascending and descending circulations are confined to two well defined zones and do not overlap in their deposition of ores, except as the descending overlaps the completed and abandoned work of the ascending as the ground surface descends by erosion.

The effects of oxidation and secondary deposition are so well defined ordinarily, and sometimes cease so abruptly, not at water

level but at a depth far below it, that it has long appeared that there must be in the circulation of underground water something that would account definitely for this demarkation. A constantly operating ascending and descending circulation throughout the entire cross-section is not satisfactory. There is ordinarily no ascending circulation below the bottom of Zone II; therefore, in that case, none at all in the entire cross-section.

Zones II and III are a proper division of Van Hise's belt of underground water, and do not oppose the dictum that water uses the entire cross-section, but only that the use of the entire cross-section in circulation is not continuous throughout the whole history of the vein; that Zone II is the only circulation which is unfailing. Given the special and temporary means to circulation in Zone III, the two lower zones then correspond exactly to Van Hise's entire cross-section, but even then Zone II still maintains its characteristic downward flow to discharge, and still accomplishes its characteristic function of secondary precipitation — is always a well-defined zone.

"In regions where vulcanism or dynamic action has recently occurred, the difference in density resulting from difference in temperature in the descending and ascending columns may be an even more important influence than in regions where the high temperature is due to the normal heat of the rocks."*

"It is believed that underground circulation may be promoted to an important degree by a difference of temperature of the descending and ascending columns of water, resulting from heat absorbed from the rocks, due wholly to their normal increment of temperature with depth."†

The former quotation expresses the importance of special heat. Regarding it as more important,—in fact, as a controlling factor,—there is no essential difference between this hypothesis and Van Hise's "Principles." It is with the convection idea in the latter quotation that exception is taken. Ordinarily, rocks do not admit water to great depth. It requires profound fissuring,

* *Genesis of Ore Deposits*, p. 304.

† *Ibid.*, p. 303.

not sealed by deposition or otherwise, to conduct water beyond a very moderate depth. The deep wells drilled in various parts of the world have become classic examples, but even more to the point is the evidence in the mines. There is no water in the deep levels at Butte, Mont. In the Tintic District, Utah, some mines have water systems conducting water from the surface for use by the miners for drilling and drinking. Not to multiply instances, the lack of water in the deep workings is the rule, not the exception, and that at a depth of 1,000 feet, or even less in the majority of cases. This has been reported by many observers, and the writer has seen for himself so many cases in Colorado, Arizona, Montana, Idaho, and Mexico, as to be thoroughly satisfied on the subject.

As already indicated, there are two means of changing the static condition of whatever water may exist in Zone III to active circulation: (*a*) Special and local access of heat to the zone and its waters; (*b*) deep open fissuring. These two causes are inter-related and inseparable at the time of their inception; either may be the result of the other, but neither can originate without the other, yet with lapse of time either may be discontinued. Fissures may be filled and closed by deposition from waters passing through them, or by mechanical adjustment of walls closing the sheet passages in time because of pressure; the sources of heat may wholly or in part continue. On the other hand, the influx of heat may expend itself while the fissure is still open. But both are to be regarded as temporary phenomena, which is consistent with the generally accepted view of the universal tendency toward adjustment of forces in the earth's crust.

In the latter case of deep fissures with absence of any abnormal heat, the condition of ore deposition from approximately static solutions becomes comprehensible, *i. e.*, such character of deposits as are so clearly described in Ransome's Silverton report. This is a common type of deposit. The former case suggests the cause of pinching of many fissures at depths, which contain important ore bodies above.

Diffusion has been appealed to by writers on ore deposition as a means of transference of mineral materials in solution. It may act in a static solution to bring to adjustment the dissolved contents. Otherwise its work would appear to be ineffective. It is of independent importance only in static solutions.

Convection, though already referred to in other connections, demands further comment at this point. It cannot operate except in a fluid possessing some degree of freedom of movement. Water in restricted passages of capillary or sub-capillary size will not transmit moderate heat by convection, but will remain static and conduct the heat as an immobile body. This is a familiar physical principle. Water bound by its own laws of molecular cohesion and by friction or adhesion with the walls of a minute conduit may then act as a solid and not be caused to circulate by the slight normal differences of temperature at different vertical points in the crust of the earth. Only by the absorption of a relatively great amount of heat at some deep horizon in such minute passages can the forces tending to maintain the static condition be broken up and circulation caused.

Convection, then, below the base of Zone II, acts only for an epoch in vein history, since filling or readjustment is bound sooner or later to close the fissure to such an extent that the mobility of the water is destroyed. When this is done, unless the fissure be reopened, the incident of circulation in Zone III is closed forever.

Zone III, as a static zone, is dependent upon an adjusted temperature increment or adjusted isotherms. Conversely, the catastrophic is necessary to account for the deep circulation which is, or has been, in any vein responsible for the primary deposition.

Closer Definition of the Lower Limit of Zone II.—

"Gravity is effective in the movement of underground water in proportion to the head. Head is due to the fact that water entering the ground at a certain level, after a short or long underground journey, issues at a lower level."*

To this must be added the other important condition: a continuous passage of sufficient size.

*Genesis of Ore Deposits, p. 302.

Slichter's *deductions were made on very restricted premises. They really should be applied only to the movement of water in certain sedimentary beds. The pore space in the crystalline and eruptive rocks, instead of about 30 per cent., as in King's experiments, is likely to be less than one per cent. In many places, as in Butte, the country rock may be practically uniform for the entire longitudinal section of the vein as mined. The dry cross-cuts attest its impermeability. In the structure, then, lies the means to underground flowage; in joints near the surface and in fissures at depth, and only in open, continuous and connecting fissures, *i. e.*, "water courses."

No fissure is long enough, nor any system of connecting fissures, to conduct the deep water from Pikes Peak to the fountain or Arkansas valleys, except with repeated interruption. Near the surface they are probably connected sufficiently to form continuous conduits. Slichter's conclusions apply only in so far as flow in the smaller, connected sheet openings, such as joints near the surface and fissures at deeper points, follows the same laws as the flow in sand capillaries. To large, open fissures they do not apply at all.

There can be no doubt that there is an increasingly imperfect connection between fissures as depth increases. In *Fig. 3* the light hatching extending below the dark shading represents separate fissures or parts of fissures in which there is water devoid of movement because isolated by lack of horizontal connection with any other passage. $x-x'$, $y-y'$, $z-z'$, $r-r'$, mark the lines of intersection of fissures. The downward narrowing and termination of the light hatching represents the limits and downward terminations of the fissures. They are largest near the surface, and past a certain depth grow shorter, until they disappear at depths where dislocation is accounted for by other means than rupture, chiefly by the readjustment of rock materials under strain.

*Principles and Conditions of the Movement of Ground Water, Ann. 19, U. S. Geol. Surv., Part II; by F. H. King.

Theoretical Investigation of the Motion of Ground Waters, *Ibid.*; by C. S. Slichter.

The inter-fissure spaces (g, d, t) then serve for all practical purposes as barriers to flow of water standing at G, D, T . Barring all siphon and artesian action and assuming an open vertical sheet passage of such width as to allow free flow of water, for any given case such as at the interference t , there will be a certain amount of upward flow from fissure T into fissure D over the crest of the obstacle, as there is in rivers from a deep pool over succeeding rapids. Friction and interference in the fissure T eliminated, the water body has head $x-z''$ at z as compared with head $z-z'$ at r . If discharge has taken place from r' to z' , the water column is diminished at z to the extent $x'-z''$. Hydrostatic head can be conceived to be effective only to the extent suggested in an open sheet passage. Any considerable upward flowage by this means would necessitate either passages in the form of isolated pipes or artesian conditions. In a single fissure or in a system of connected fissures, hydrostatic laws are scarcely adequate to account for the deep circulation which, at some time in the history of every vein that bears ore, accomplishes the primary deposition.

Referring again to *Fig. 3*, the bottom of Zone II is marked by an undulating line, $m-x-y-z-r-w-n$. The horizontal line $m-n$ is a geometrical limit to the bottom of Zone II, which the normal circulation may approach but never reach. This limit applies in case of fissuring to extreme depth and perfect connections of channels throughout the mountain mass above the line. It is fixed by the points m and n , the lowest points of discharge, and also by v , a point which is determined by the gradient of water flow as established by viscosity, friction, etc., assuming connected fissures to and below the horizontal line. The undulating line is determined by barriers due to imperfect connections between "trunk channels," and the altitude of such obstacles fixes its position at or above the line $m-v-n$, as the case may be. In some mining districts $m-w-n$ may approach the position of the line $m-v-n$ or even approximately correspond with it, but it is difficult to see how it can at any point exist below the latter.

Zone II is not established by merely emphasizing the circulation in trunk channels as more effective than any other circulation. The ground is taken that there are no other channels for the deep water circulation in mining regions than the trunk channels, as such are distinguished from the pores in the rocks and the sub-capillary sheet openings.

Incidentally, the question naturally suggests itself, What is the effect of a partial filling of water standing in the pores of the rocks? When such a condition exists water certainly does not circulate, since by the laws of surface tension it must be in the form of a film on the grains of the rock. If water in such form evaporates, as it must, and is replaced from time to time, cementation might be effected. This is probably an important process in the induration of rocks of too minute porosity to admit of circulation.

THE DEVELOPMENT OF ORE SHOOTS BY SECONDARY ENRICHMENT.

Since it is the aim of this paper to establish a connection between the zones of underground water and the productive ore deposits as they are found in the mines, those ores which are most familiarly known will be considered first. By following this order the historical sequence of the processes of ore deposition is not the guide, but the progressive mutations of underground water from the surface downward, this being regarded as the important genetic relation, particularly from the viewpoint of the mining engineer.

The ores of secondary enrichment in a vein may be defined as localized metallic deposits which owe their disposition and mode of occurrence to the waste and redeposition of pre-existing forms of the same materials. The term as usually employed implies some degree of concentration into smaller space; therefore, for at least some part of the segment of the vein affected, enhanced value.

Bonanza secondary ores are always localized in that they are invariably found near the surface of the earth or only to a moderate depth, and also from the fact that they often exist within well-defined longitudinal limits in the vein as "ore shoots," in the

miner's language, and clearly differentiated from the leaner parts of the vein. In other words, for various reasons certain places in the vein usually have been affected more than others by new accessions superimposed upon the minerals previously occurring at such points by virtue of their deposition and former existence in Zone III, the zone of first precipitation. Secondary ores are developed under the attack upon an ore body already existing, of physical and chemical agents at and near its outcrop in all stages of its history. By these agents the materials of secondary ore have first been supplied as aqueous solutions, and by these in turn transported and, by precipitation, distributed in the vein as they are found in mining.

The term secondary has been used in geological literature with a broad significance which to the mining engineer may bear a double meaning. It was incorporated into the language of economic geology from the petrographic vocabulary. The meaning of the word is the same when applied to the non-metallic minerals added to the body of the country rock in any region as when referring to the metallic and non-metallic materials entering an ore deposit in a mining region as the result of the processes of alteration. Discrimination in the use of the term is therefore necessary. The volcanic rocks of Cripple Creek, originally fragmental, have been, almost everywhere, indurated into massive form by a filling of silica which is properly called secondary in the rock, yet this has no relation usually to the secondary quartz introduced into the superficial parts of the veins. The latter is a product of comparatively recent times and an important mark of a certain class of rich ore bodies, while the former is relatively ancient and little concerned with ore deposition.

Secondary enrichment is a continuous process. It is merely a detail of the constant change which the earth's crust is undergoing. The physicist demonstrates the indestructibility of matter; the geologist, like the chemist, deals with the ceaseless transformations of matter. The effort toward adjustment and equilibrium of earth materials and the constant state of change involved is the

essence of geology. The long processes of epeirogenic movements of continents, the orogenic upheaval of special localities, and the incessant attempt of erosive agents to level all down again, are forever in operation. Such changes have exhibited themselves in their superlative form in most of the great mining regions, and have been clearly related to the origin and alteration of ores. Ore bodies suffer depletion by the disintegration and wasting away of their outcrops, and a world's wealth is scattered along river valleys and moved eventually into lakes and ocean. Yet there are natural laws working in the superficial parts of ore deposits themselves, by which entire loss of the materials of the outcrop is avoided, and the valuable ore materials, as they approach this danger line, are in part gathered up and transported to greater depths and there preserved as the bonanzas. Such is secondary enrichment.

The water zones have been developed in this paper with surface alteration and secondary deposition in mind. Zone II has special bearing upon the latter process, and has been suggested by the occurrence of the secondary sulphides, the vertical distribution of which is believed to be determined by the limits of this zone. It is further conceived that Zones I and II, in their interrelations and mutual reactions, effect the localization of the greatest known productive ore bodies.

Time is the essence of all geological processes. Secondary enrichment, though in the more favorable localities probably one of the speediest of geological phenomena, is nevertheless, according to the human standard, exceedingly deliberate. The period covered by the existence of a vein and the accumulation of its ores is one of the first features for an economic geologist to attempt to determine in a new district. Sometimes great effects are wrought in short geological epochs, but, all other things being equal, the greatest results are effected in the greatest time. The sufficiency of primary deposition, its special distribution or arrangement, may be a function of time, which thereby has its ultimate influence upon the secondary ores by enhancing or curtailing the supply of materials for their making. However, abundant ore deposition is

likely to depend to a greater degree upon the eventful or non-eventful character of the geological history of the region than upon mere lapse of time. Energetic conditions may promote deposition by the maintenance, revival or repetition of the factors solely responsible for the first accumulation of ore materials. On the contrary, mere age with extreme quiescence may bring an ore body to a condition of depletion. The physiographer's stages of youth, maturity and old age may be applied appropriately to veins. Primary deposition may have ceased in remote geological time and erosion stripped the deposit, leaving, as Kemp expresses it, only "the stump of a vein." As in the Appalachian regions, the resources of the first deep concentration may have been exhausted and the work of the secondary agents now be confined to the effort to preserve the meagre wealth inherited from the higher, richer horizons long ago in greater part wasted away. Such is old age in a vein. Maturity may be described as the stage of richest development, when rate of erosion is such that the least possible amount of metallic material is being wasted by denudation, and secondary solution and deposition in its downward progress with degradation have reached a point where they are engaged in the reworking and concentration of the resources of the most abundant horizon of primary accumulation. In such cases the latter would be either still in progress or just completed. The youthful stage is the period of inception of the activities of first mineralization, before the secondary agents have materials for attack, and the primary ores, even at depth, are lean and meagre. The conditions are geologically potential of future deposits.

The primary and secondary may operate simultaneously, the secondary forever following in the wake of the primary; or the primary processes may have spent themselves either by exhaustion at the source or by the isolation of the solutions from their regions of supply. If such isolation was sufficiently remote in time, the first deposition may have been thoroughly depleted by secondary agents and erosive waste. The latter operate continuously, until their working materials are exhausted.

Subdivisions of the Belt of Secondary Enrichment.—The upper part of a vein is divisible into two zones on a basis both of minerals contained and the processes operative. The two are distinct to this extent, yet in nature they almost invariably overlap, the failing substance of one following downward the increasing marks of the other, sometimes for hundreds of feet. The upper is the zone of oxidation and disintegration, and the lower the zone of precipitation.

The upper zone includes the various minerals familiarly known as the products of oxidation; the oxides, sulphates, chlorides, bromides, carbonates, silicates, etc., and native metals derived by the elimination of their enclosing or combined materials. Some of these are relatively insoluble precipitates or residua, therefore stable and permanent so far as chance of any succeeding alteration is concerned, but for the same reason transitory to the vein because of exemption from attack by agents which might transport them to greater depth beyond the reach of erosive destruction. The soluble compounds are transitional forms, unstable in their state and place, but possibly a stable part of the vein because of their chances of preservation by being taken into solution and transported to the zone of precipitation. These may, nevertheless, if discharge from water Zone II be too rapid, or precipitants be lacking, still be conducted to the surface and thus lost.

The metallic minerals of the zone of oxidation are accompanied by the looser, lighter, hydrated and decomposed gangue materials.

The lower zone of precipitation may also be called the zone of reduction. It includes secondary deposits, mainly of the sulphides, but also of the arsenides, antimonides, etc., and possibly of the tellurides, tungstates, molybdates, and other less familiar minerals. These may exist at the same horizons with identical minerals of primary deposition, yet usually can be distinguished by criteria discussed at a later point. They are all derived by the precipitation of minerals accumulated in solution in the zone of oxidation.

The secondary sulphides are accompanied by the denser and more compact, but usually simple, gangue minerals. They may

not differ greatly from the primary gangue of the vein except in physical relations and in their simplicity of composition.

Both zones of secondary enrichment are usually accompanied by the upward diminishing remnant of the first or primary deposit.

The Zone of Oxidation.—It includes water Zone I and an indefinite part of Zone II.

There are many factors affecting the rate of oxidation. A treatment of these should include a discussion of the entire list of geological agents active at or near the surface, for they are all involved in the superficial alteration of ores. Such an exhaustive discussion will not be attempted, however, and only the more conspicuous factors which are essential to the comprehension of the subject will be considered. Nevertheless, it should be emphasized that no factor is so insignificant that it may not be of great local importance. The conditions at the surface of the ground, in so far as they affect the processes of oxidation, also indirectly affect the amount of material furnished for precipitation in the succeeding zone; therefore the consideration of the following special factors seems to have its appropriate place at this point.

Differences in climate have a vital relation to secondary alterations, particularly in the matter of water supply and temperature. Yet these may exhibit a state of balance of efficiency between different regions. An exceedingly dry climate may be intensely hot, and a little water at long intervals, working upon the products of rapid chemical reaction due to the unusual heat, may accomplish as much in the way of solution as a great volume of perennial water in a cooler climate.

The phenomena of concentrated precipitation in arid climates have been considered in connection with the discussion of water Zone II. In such places oxidation is very rapid. Hence materials are thoroughly prepared for immediate assumption and transportation downward in solution in the transitory water. Rainfall may be so uniformly distributed and so abundant as to greatly abbreviate the zone of oxidation by establishing a condition of satura-

tion at very shallow depth. Any marked variation, annual or seasonal, may effect concomitant variations in the depth and rate of alteration.

Climatic changes of a revolutionary order may bring about a profound modification of the rate of secondary enrichment. In the desert regions of the Southwest, veins which possibly existed at one time in a humid climate are now affected by conditions of extreme aridity. The main effect in this case was an enormous increase in the depth attainable by oxidation.

The topographic relations of outcrop may have a controlling effect upon the extent of secondary enrichment. These may have been essentially the same for all stages in the history of the vein, or they may have radically changed at different times. The main influence of topography is in the control of the rate of erosion. The apex of the vein may be in mountain, valley or plain. Degradation may be so exceedingly active as to destroy the effects of oxidation as soon as produced,* or it may be so slow that oxidation may reach to great depth. On the other hand, rate of degradation and rainfall may be so adjusted that both extensive erosion and deep oxidation are operative. In a general way great relief and abundant rainfall will permit only a moderate depth of oxidation, but be particularly favorable to the development of the deeper zone of secondary sulphides; while great relief and meagre rainfall may produce profound oxidation and restrict the vertical extent of the latter, though its ores may be of extreme richness. The former conditions should produce widely distributed ores, but of lower grade, in the zone of precipitation. Low relief with great humidity will not only render the zone of oxidation shallow, but may prevent extensive development of secondary sulphides. Arid conditions, even with extremely low relief, may promote excessive oxidation, and at the irregular limits of downward percolating water extremely important bodies of secondary sulphides may be precipitated.

*Ransome: Bull. No. 182, U. S. Geol. Surv., p. 101.

The hydrographic relations of the outcrop may be an important condition. Outcrop may be either a line of water accumulation or a line of discharge. It may so strike along a slope as to form a catchment. The Copper Queen apex accumulates much of the drainage of one slope of a range of hills. The United Verde, at the position of the richest ore shoot in the vein, forms a basin into which surface water may converge from three directions. The effect of such marked accumulation into the oxidized outcrop is obvious. The outcrop may, on the contrary, so strike with the dip of a slope as to descend it to points within the horizon of discharge from Zone II. At the latter altitudes, if the discharge is continuous, oxidation into the vein may be prevented. If it is intermittent, oxidation may take place, but results in no important enrichment of the vein, because materials are transported away from the outcrop, and not downward or inward to the zone of precipitation.

Heat promotes chemical reactions. Rapid changes of temperature at the surface of the ground are particularly effective in rock disintegration. The heat affecting the alteration of veins is derived from two sources, external and internal. The former is much the more important to secondary enrichment, the latter to primary enrichment. External heat is that due to climate, and may so vary, by annual, seasonal and diurnal changes, as to have irregular or intermittent effects. The supply of heat from within the earth varies between localities and between different geological epochs in the same place. It is at its maximum during igneous activity and at its minimum at times most remote from vulcanism. Chemical reaction of the heat-liberating order may be a source of heat promoting other reactions. It is at first an effect of mineralizing processes otherwise established, then later a contributing factor.

Deformations and dislocations of an orogenic order are generally prevalent in mining regions. They are primarily essential to the accumulation of lode ores by their formation of the deep-reaching fissures of circulation and receivers for deposition. In the development of ores of the payable order, the repeated revival

of circulation by the reopening of fissures, due to this cause, is of the utmost importance. By reopening of the vein fissure, or, as Emmons terms it, "post-mineral strike fissuring," fresh access may be given to solutions along the entire ore-bearing part of the vein, thus affording a means of maximum attack on primary ores and the possibility of rich reconcentration in secondary form. Cross-fissures, on the contrary, may supply either avenues of dispersion from the vein or of concentration into it; they may form new receivers for deposits of a secondary nature, or they may serve merely as an escapement for water laden with such minerals in solution

Post-mineral dislocations may have a notable effect in the local readjustment of hydrostatic conditions. The lode, as a whole, or in part, may be so depressed or elevated, with reference to water-level, as to establish reversed conditions of a revival and superimposition of primary deposits upon previously formed secondary; or an intensification and increase in depth of the latter, on the other hand.

Volcanic renaissance, though of extreme importance in the concentration of primary ores, generally has only an indirect effect upon the secondary agents, except that it might, under some conditions, cause an invasion of the field of the latter by the former. Its greatest importance is in the contribution of fresh materials for later alteration and reconcentration.

The special domain of oxidation is Zone I, because of the open structure of the rock and the unimpeded circulation of the air through it. But air occluded in the flowing water of Zone II also has its effect, and oxidation is often well marked for hundreds of feet below water-level. The vertical oscillation of the top of Zone II, with variations of rainfall, may develop a narrow belt approaching Zone I in character, though at times included in the zone of saturation. The oxygen in water gradually becomes depleted, hence the decreasing prominence of oxidation below water-level. Zone II is the zone of neutralization of solutions, and the waters of Zone III are, therefore, ineffective in oxidation.

Oxidation affects the products of both the primary and the previous secondary deposition. It may concentrate values in a vein, aided by water as transporting agent. Native metals may be left as residua by a process of elimination of gross materials, such as the original gangue or the baser parts of the sulphides formerly containing the precious metals. The removal of a part of the valueless material renders the ore proportionately richer.

A vein may be robbed of value near the surface. The function of oxidation is to prepare materials for solution; the function of water is to gather these up and transport them to some point of precipitation in Zone II. The United Verde was a gold mine and supposed to be nothing else for a considerable depth. Yet in its deeper levels it is now one of the world's greatest copper producers. The more soluble copper compounds were leached and redeposited as chalcocite and bornite in Zone II, leaving the less soluble gold near the surface. Many other instances of a similar selective leaching have been described by geological writers.

The depth of oxidation ranges from a few inches to many hundred feet. In general it varies inversely as the rate of erosion and directly as the depth of discharge of underground water. It depends upon all factors modifying or controlling the limits of Zones I and II.

The Zone of Precipitation.—Water Zone II has been referred to as the zone of secondary precipitation. Zone I is then the zone of disintegration, Zone II of induration. The materials to be deposited are accumulated, to a minor extent, within the latter, yet in far greater part from Zone I, either from the superficial parts of the veins or the disintegrating wall-rock. The gangue materials deposited are mostly gathered from the country rocks, silica from the weathering of the silicates, lime from the calcareous sediments and from the decay of many minerals of the crystalline formations, kaolin from the weathering of the feldspars, etc. The materials of metallic enrichment are obtained in

the veins, or sometimes in the country rock, where oxygen and oxygenated waters may prepare them and eventually take them into solution.

The existence of a zone of secondary precipitation of ores has been recognized among geologists for many years, at first as a belt near the surface in which the products of alteration were accumulated. Later it was noted by Weed, Emmons and others that certain ores of the sulphide category at intermediate mining depths, which had formerly been assumed to be in all cases original constituents of the veins, by their physical relations in many mines exhibited all the features of later enrichment, the origin of which was evidently not deep-seated but the result of the reduction and precipitation of the materials acquired near the surface by descending meteoric waters. In writing of the ore deposits of the Neihart District, Montana, Weed* draws the conclusion:

"Surface waters altered in character and robbed of their oxygen in their descent by the changes they induce in the metallic sulphides of the upper parts of the veins are believed to be the agents producing the rich sulphide ores forming secondary enrichments. Where new veins are opened all show silver sulphides deposited by secondary enrichment as crusts or crystals lining cavities, or as films or thin coatings along fractures of the primary ore, or in the oxidized zone as the so-called 'sooty sulphide' ores that occur with manganese oxides."

Ransome† recognized "a sooty amorphous sulphide of copper" in the same relation in his report on the Silverton quadrangle. Emmons says. "At Butte, such secondary sulphides, which extend to 1,500 or 2,000 feet, may have been deposited by descending currents." In discussing the origin of rich segregations of blende below water-level in the Boston-Get There Mine, in the Ozark lead and zinc region, Bain concludes:‡

It also seems clear that the waters active in this process (sulphide enrichment) were downward-flowing surface waters, and that the chemical

*Ore Deposits of the Neihart District, etc., Montana; Ann. XX, U. S. Geol. Surv., Part III, p. 421, *et seq.*

†Op. cit., p. 102.

‡Preliminary Report on the Lead and Zinc Deposits of the Ozark Region, by H. F. Bain, C. R. Van Hise and G. I. Adams; Ann. XXII, U. S. Geol. Surv., Part II, p. 161.

reactions were essentially of oxidation of sulphides to sulphates in the early portion of the waters' course and their redeposition, mainly as sulphide, in a later part of their journey."

Enrichment in Zone II depends for materials upon oxidation and solution. These, though primarily operative in Zone I, are by no means confined to it, but, as already suggested, accomplish a limited but important work in Zone II itself, where precipitation is the characteristic reaction.

Certain sulphides and tellurides, antimonides and arsenides, either original or secondary in origin, are more amenable to solution than others, but all ores of this class may be ultimately taken up and redeposited. Also certain products of oxidation are relatively easy of solution, while others are very difficult and form the stable and permanent ores of Zone I until they are removed by erosion. The copper carbonates and silver chlorides are examples of the latter, while the majority of the same compounds of the other metals are exceedingly unstable.

The function of surface water is, then, to aid in oxidation and to remove in solution, or by mechanical means, the sulphur, tellurium, arsenic and antimony of the various gold, silver, copper, lead, zinc, iron and other ores, and afterward, by aid of the solvents, already sufficiently discussed, to take into solution the oxidized metallic products along with silica, lime and other gangue materials. The function of Zone II is to supply the reagents and physical conditions suitable to the precipitation of materials thus transported to it.*

Precipitation may be accomplished directly from solution by accumulation of materials to the point of saturation and in the order of solubility of the minerals contained, or it may result for any compound of low solubility by the introduction of another of greater solubility. These reactions rarely take place in nature, since the processes of preparing materials are so slow and the water

*S. F. Emmons: The Enrichment of Mineral Veins by Later Metallic Sulphides; Bull. G. S. A., XI, 1900, pp. 179-206. Also, The Secondary Enrichment of Ore Deposits; Trans. A. I. M. E., XXX, 1900, p. 177, *et seq.*

in contact with them so transient and so quickly displaced by other water following it, that the requisite saturation is not attained.

Precipitation by the formation of insoluble compounds by chemical combination is doubtless the most prevalent and effective means to enrichment. Oxidized materials may be thus precipitated by any of the reducing agents found in or contributed to the vein in Zone II; the metallic sulphides, organic matter, such as that of the bituminous formations,* and carbon dioxide, which is universally present in the veins themselves at certain depth, or transported into vein solutions by water from the wall rocks. Mingling solutions may be exceedingly efficient in accomplishing the necessary chemical combinations. Though the process of mingling may sometimes retard, its usual effect is probably precipitation.

It is well to bear constantly in mind, however, in any discussion of ore deposits, that rich ore accumulation is the exception and not the rule, and that where kilogrammes of valuable material are transported to the surface by the discharge of Zone II, only grammes may be saved by precipitation. In the great majority of cases the reactions are so feeble that no accession to ore deposits is accomplished. The formation of rich ore shoots is a gift of nature deviating from normal processes. The law of transformation of matter is not concentration but dissemination. The ultimate end is a world homogeneous and uniform of composition. Concentration is instability, and this applies to veins as well as to the evolution of continents.

Synthetical experiments have been made by H. V. Winchell,† demonstrating the efficiency of relatively soluble sulphides in the precipitation of sulphides of the metals in solution. Pyrite digested in a solution of copper sulphate containing sulphurous anhydride, precipitated chalcocite, the SO_2 acting as the agent of reduction. The reaction of precipitation in sulphide form may take place between the salt or oxide of a metal and either its own sulphide or

*Walter P. Jenny: *The Chemistry of Ore Deposition*, New Haven Mtg., A. I. M. E.
 †The Synthesis of Chalcocite, etc., Bull. G. S. A., 4th Ann. Mtg., 1902.

the sulphide of another metal. Pyrite may thus be replaced by the sulphides of copper, silver and lead, and probably also by the tellurides, arsenides and antimonides of the other metals.

The precipitation of minerals by chemical combination may effect results of selective distribution similar to the zonal arrangement which might be accomplished from precipitation by saturation in order of solubility. Solution and precipitation follow the laws of ionization, and depend for their order of occurrence upon the valence of the metal in the compound dissociated or combined. We may, therefore, find, for example, in a lead-silver-copper vein a superficial deposit of argentiferous galena, at a moderate depth an argentiferous sulphide of lead and copper, as stromeyerite; still deeper, argentiferous bornite and chalcocite or even chalcopyrite; the zonal distribution being the result of selective secondary precipitation.*

The veins of the Smuggler Union Mine and other veins of the San Juan are richer proportionally in silver near the surface and in gold in the lower horizon of secondary enrichment, because of the much greater solubility of the minerals with which the gold is originally associated than of the galena which is the chief silver mineral. Fine free gold, or gold-silver alloy, forms a residuum from the decomposition of auriferous pyrite and other sulphides in the shallow parts of the vein, and is transported mechanically and concentrated in native form mostly in Zone II, or included in precipitating sulphides. Zone II is thereby enriched in gold much more rapidly than in silver, and Zone I is left proportionally rich in the latter.

Gold and the platinum group are not so susceptible to the processes of reprecipitation as the other metals familiar in mining, yet they may be introduced into Zone II mechanically in a state of extreme comminution. This result is greatly promoted by their high specific gravity. Many of the secondary sulphides, therefore, when precipitated include the gold in native form. For this

*F. L. Ransome: *Op. cit.*, p. 111.

reason good percentages of the gold can often be saved by amalgamation from ores which have an extremely refractory appearance. Specimens from the Blue Bird Mine of the Stratton C. C. M. & D. Co., Cripple Creek, understood to have been taken from a depth of about 1,100 feet in November, 1902, showed tetrahedrite including abundant visible gold. This association demonstrates both the secondary nature of the gray copper deposit and the characteristic mode of accumulation of gold in Zone II from the weathering of tellurides at high levels. In the Dorothy vein of the Gold Coin Mine at Victor, Colo., at a depth of 900 to 1,200 feet, the latest deposit is highly auriferous pyrite with some sylvanite, and rarely lead and zinc sulphides, in the walls of cavities and crevices, with a gangue of quartz and fluorite, in the form of encrustations upon an older and much leaner pyrite ore. It is reasonable to regard the former as secondary pyrite in which the fine native gold produced by the oxidation of tellurides at high points was included mechanically at time of precipitation. If chlorinated water was present, it is possible that a certain amount of gold may have been taken into solution and deposited as sulphide along with the pyrite, but this cannot be determined.

The secondary ore deposits of Zone II, though characterized by the sulphide group of metallic minerals, may contain any of the products of oxidation, precipitated from solutions derived at higher horizons or formed in situ by oxygenated waters. In the Tom Boy and Camp Bird mines Ransome finds that "black oxide of manganese occurs in the deepest workings. * * * In these cases the oxide seems to be associated with post-mineral fracturing and crushing and to have been deposited later than the bulk of the ore."

The products of oxidation are likely to be particularly prominent near the top of Zone II, since the free oxygen in the water is rapidly exhausted on entering Zone II in the oxidation of the various unaltered materials with which it comes into contact. Exceptional freedom of downward flowage and great relief may, however, allow the carriage of oxygen to unusual depths, as in the

case cited of the Camp Bird and Tom Boy. A certain amount of oxidation is also accomplished below water-level by the abstraction of oxygen from combination with mineral materials in solution. The same reaction may be a means of precipitating metals in native form or as sulphides and other compounds.

Hydration may take place in vein materials anywhere in Zone II and possibly in some cases in Zone I, though the transiency of water in the latter renders the reaction improbable. Hydrated materials in Zone I usually have had their origin in Zone II. The habitat of hydration is the whole of Zone II, but does not extend greatly into Zone III, since expansion in volume is involved, and at the latter depth the requisite space does not usually exist.

Certain minerals may become hydrated without previous oxidation. Kaolinization is effected by CO_2 and water, "which react on the feldspars and form alkaline carbonates, kaolin and free or hydrous silica."* For the majority of compounds, however, oxidation not only promotes hydration but is necessary to the reaction in nature.

Hydration of vein minerals has two minor effects which may be of local importance in the concentration of ores. (1) If sufficiently rapid it may develop heat adequate to promote solution and other chemical reactions. (2) By the formation of considerable bodies of expanded materials of impervious texture it may establish barriers to downward-transporting waters, and thus localize ore shoots. The phenomenally rich bodies of oxidized ores in the Wild Horse vein in the Cripple Creek District are probably thus formed. The vein, which near the surface has a westerly dip of about 70 degrees from the horizon, at a depth of a few hundred feet begins to turn gradually toward the vertical. It is immediately below this curve that a tight dam of kaolin has been formed. On the strike the kaolin mass descends northward at a low inclination. It has been developed for a length of about 1,000 feet, with the invariable accompaniment of rich ore lying within and above

*R. A. F. Penrose: *The Superficial Alteration of Ore Deposits*, Jour. Geol., Vol. II, p. 297.

it. Below the kaolin the vein contains small caverns, and everywhere to the depth attained in the mine (1,100 feet) exhibits exceedingly open structure. In the two lowest levels remnants of auriferous sulphide deposits are found. But at these levels the vein shows the effect of exceptional leaching below the kaolin. The original water-level of the district was at a depth of nearly 1,200 feet at this point and has not been reached.

The disposition of materials in Zone II is controlled by a great variety of factors, any one of which may be of special local importance. The sulphide enrichment has its maximum habitat throughout the vertical extent of the zone, but probably seldom occupies its entire range. It may be specially segregated at the top or at any horizon according to conditions imposed by Zone I, by structure within itself, or by local contribution of precipitants.

The sulphide enrichment is repeatedly gathered up and redeposited lower in the vein *pari passu* with degradation. While the original deposit exists, enrichment is always in a condition of overlap with it. If the age of the vein is such that the entire primary deposit has been invaded and exhausted, there is a lack not only of fresh working materials but of the effective precipitants. All the activities of descending and discharging water may then work to depletion of the vein.

In Cripple Creek, it is believed that the majority of the important ore bodies are due to secondary sulphide-telluride enrichment. The Portland, Gold Coin, Mary McKinney and others have opened important bodies of auriferous pyrite in their lower levels, the last-named at a depth of only about 600 feet. The higher grade pyrite occupies fractures of a later date than the first vein-fissuring, and are superimposed upon pyrite of low grade enclosed in the older gangue materials. Local and isolated occurrences of other sulphides, such as tetrahedrite, chalcopyrite, sphalerite and galena, are found associated with such deposits, and have also been observed, apparently as remnants of an older sulphide enrichment, at all horizons of the belt of weathering, even to the base of the soil. Some of the veins on Beacon Hill are

reported to have produced specimens of tetrahedrite in surface workings, and the Deadwood vein on Bull Hill contained an extensive pocket of the same mineral near its apex.

The distribution of the rich telluride ore shoots in Cripple Creek deserves special comment in this connection. The first few hundred feet of Zone II have contained the remarkable segregations of calaverite which have made the district famous. Their position is such and their bottom limits in some cases so well-marked, that their origin by secondary precipitation is strongly suggested. These ores are gradually succeeded in depth by auriferous pyrite and sulphides of other metals, sometimes with associated sylvanite or other tellurides of gold, silver and lead, the mineralogy of which needs more thorough study. It may be that the latter more complex forms were the original minerals, and, all being comparatively easily oxidized to tellurates, telluric oxides and hydroxides, have been taken into solution and by selective precipitation given a zonal arrangement as calaverite, sylvanite and the sulphides in order of solubility. Precipitants may have been other tellurides and the sulphides.

Rickard, in the *Engineering and Mining Journal* of December 27, 1902, by drawings of longitudinal sections in Stratton's Independence, illustrates both the localization of tellurides in the first few hundred feet below water-level and special accumulation along an intersecting vein. Original water-level in the mine was at about the second level, and the bodies of the calaverite ore extend to about the sixth level, with the remarkable ore shoot for which the mine is noted lying midway. The Portland, Gold Coin, Strong, Doctor-Jack Pot, Mary McKinney, El Paso and several others have mined bonanza calaverite bodies at the same general horizons described in Stratton's Independence by Rickard.

In the veins of the Raven Hill and Beacon Hill mines, there is locally a considerable amount of auriferous stibnite associated with the tellurides. The workings of the Doctor-Jack Pot passed with a depth of about 600 feet from a deposit of calaverite in quartz-fluorite encrustations into a rich complex of calaverite,

sylvanite and tetrahedrite with some native gold and auriferous pyrite. The stibnite which has been found locally in the same region may have been derived from the decomposition of tetrahedrite, from which the copper content has been leached away or deposited as chalcopyrite at greater depths.

Viewed in their comprehensive relations, the reactions effecting secondary enrichment form a chemical cycle, through the oxidation and decomposition of the sulphide group of minerals and a final reduction to approximately their original form or to a simpler compound belonging to the same category.

The Localization of Secondary Ores Into Ore Shoots.—Ore shoots are local segregations of ores of commercial value in a vein. Ore shoots of secondary concentration may owe their location and definition to a zonal arrangement corresponding vertically to water Zones I and II; to a form imposed by the outline of primary deposit; to vertical differentiation in the composition of the latter; or they may be diverted from the position of the original ores by post-mineral vulcanism; by extensive faults; by post-mineral strike fissuring or cross-fissuring, and the resulting establishment of new water routes in vein and country rock, thus affording means of mingling solutions and local spaces for deposition; by topographic change, modifying the catchment and discharge of water; by a combination of any or all the factors named.

If the hanging-wall country becomes penetrable by water, the tendency is concentration of downward circulation into the vein; if the foot-wall, dispersion of circulation from the vein may be effected. Discontinuity of permeability at any horizon, as by impervious beds, may form planes of concentration of circulation and mingling solutions at the intersection with the vein. Barriers may be formed in the vein itself by the expansion of volume with alteration or by the precipitation of new materials, and this condition once established may cause the localization and growth of an ore shoot.

Wall rocks may be locally adapted to serve as receivers for the ores of impregnation by a texture of a certain degree of

porosity; or, if sufficiently soluble or containing minerals soluble in the vein waters, may aid in precipitation, and by dissolution afford space for deposition. The wall rocks, through their local avenues of circulation, may contribute, according to the composition of their soluble materials, solvents or precipitants at special points in the vein. They may be more easily disintegrated and removed than the lode outcrop, or vice versa; in the former case promoting dissipation of the contents of the outcrop by erosion, while a depressed outcrop supplies the most favorable conditions for the solution of ore materials and their final redeposition as secondary minerals.

From the commercial viewpoint, Zone II is the most important zone of ore deposition. Bonanza ore is often found in Zone I, either in the form of concentrated residua of oxidation and leaching, as in the case of the Wild Horse vein cited, or as remnants of older secondary precipitation. Such bodies are, however, often characterized by irregularity and discontinuity. The ores of secondary precipitation, on the contrary, may be exceedingly high in grade and, under proper conditions, extensive and regular in disposition. Though occasionally found to depths of 1,500 or even 2,000 feet, they do not ordinarily attain such deep development, since relief and the structure of the rocks in most mining regions do not supply the conditions to a freely discharging underground circulation to such depth.

Secondary Enrichment in the Absence of a Belt of Saturation.—The absence of any continuous or extensive underground saturation in the arid regions has received so little definite comment in geological writings that it merits special attention at this point. Though the relations of the secondary ore deposits are in a general way similar to those in the humid regions, they have a special mode of formation, which has been suggested already in the consideration of underground water in the desert.

Processes of oxidation, though differing in degree, are otherwise similar to those in other climates. It is accomplished by atmospheric oxygen, aided only at intervals by transitory oxygen-

ated waters. Permanent dessication would admit of no oxidation effective in enrichment. The occasional water serves both as a means of promoting oxidation and as the segregating agent of its products.

In the desert countries gases play an important role. They maintain zonal relations much as their solutions do in other regions, and for somewhat the same reasons. Oxygen and the surface gases predominate at shallow depth; carbon dioxide and the heavier gases gradually displace them as depth is attained. The arrangement is largely gravitative and determined by relative densities. CO_2 is produced at the surface by organic decomposition, and below the surface from the alteration of certain rock materials. Unless uniting with other materials in chemical combination, it finally seeks its proper horizon in the rocks, below the penetrating atmospheric envelope of the earth. Nearly all mines encounter it at some depth, and it is frequently a serious obstacle to operation because often difficult to eliminate by any method of forced ventilation.

In the region of transition from the oxygen-saturated to the carbon dioxide-bearing rocks, a physical and chemical boundary is established, corresponding somewhat in effect to water-level or the top of Zone II. Waters transporting materials derived in the belt of atmospheric oxidation precipitate their chemical burden in the carbon dioxide zone, which is the zone of chemical reduction, providing they descend to such depth. They may deposit at any depth by evaporation. Such waters, also bearing oxygen, may invade the carbon dioxide zone to great depths and accomplish some degree of oxidation. They are in fact restricted as to depth, either in the secondary deposition of ores or in their oxidizing effects, only by the limit to their downward movement. There appears to exist, therefore, in the arid regions a zone of reduction and precipitation corresponding in its main details with the zone of secondary precipitation in regions of underground water saturation.

Criteria for the Recognition of Secondary Minerals.—The products of oxidation are usually easily recognizable. They include the oxides, carbonates, sulphates, bromides, chlorides, iodides, silicates, etc. It is the sulphide group which demands closer study. Mineralogical relations often afford proof of secondary character. Minerals which are clearly derivatives of others known in the vein, at the same or different horizons, are evidently secondary. Pseudomorphs are always secondary, and usually supply a clue to the ancestor of the mineral. In the compounds of any metal those of low specific gravity are likely to be secondary.

The most obvious means of recognizing secondary minerals is by physical relations in the vein. Minerals superimposed on others are the younger, whether in the primary or the secondary ores. Sulphides deposited upon other sulphides may not be distinguishable as secondary. But when a deposit of the sulphide order is found imposed upon and indubitably later than materials derived by alteration, or in any way exhibiting evidence of contemporaneity with such materials, its secondary nature is established. The Sunshine vein near Cameron, recently brought to public attention by protracted apex litigation, contains deposits of pyrite in kaolin, and even in loose mud mechanically accumulated in the vein fissure. Ransome, in describing the ore deposits of the Red Mountain region, says of the kaolin of the veins: "A characteristic form is that in which the kaolin is traversed by numerous anastomizing veinlets of pyrite, giving it a spotted and sometimes a schistose appearance."* Sulphides which include products of alteration, as the native metals, are also secondary.

The gangue materials accompanying the metals are subject to the same criteria. Moreover, they often show the time relations between the metallic minerals. The secondary gangues in the upper horizons are porous and disintegrated; below water-level they are compact, and, except for simplicity of form and composition, may closely resemble the original ore matrix, but always

**Op. cit.*, p. 73.

interpolated, enveloping or imposed upon it. The secondary gangue is usually quite closely adapted to its physical environment, the primary may not be; the stable minerals of the superficial parts of the vein being usually secondary, the unstable primary. There may be mechanical inclusions of older minerals in the secondary gangue, but these generally can be recognized by associated fragments of older gangue, or by physical features, such as rounded outlines due to wear or solution, and pitting and etching by corrosion.

THE ZONE OF UNMODIFIED PRIMARY DEPOSITS.

The primary minerals exist in their normal state in water Zone III. They may be found throughout Zones I and II as remnants of bodies formerly occupying Zone III, but by surface degradation subjected to the invasion of the downward-advancing upper zones. Their ordinary condition in the two upper zones is a gradual diminution from an unaltered state at the base of Zone II, to nearly or quite complete alteration at the surface, though they may have entirely disappeared from Zone I and to a marked extent from Zone II.

The ultimate source of the ore minerals is non-essential to the intent of this paper and, at the present stage of scientific progress, unknown. It is sufficient to say that ores were first precipitated, in all probability, from solutions in Zone III. How these materials were acquired in solution is a matter of extreme speculative interest, but it may be beyond the reach of demonstration. They may have come from profound depths in the earth, or have been minutely disseminated in the wall rocks, or both. They may have been deposited as an accompaniment of volcanic action, or by normal and continuous processes of segregation by circulating water, by both, or by one as modified by the other. Water is undoubtedly capable of accumulating and depositing metallic minerals in any case, wherever it may exist, but circulating under high pressures and temperatures attending igneous disturbance, or

in the period of returning quiescence following, it would be so enhanced as a solvent and transporting agent that the most reasonable hypothesis would appear to refer at least the productive ore bodies to this combination of original causes.

The first requisite to primary deposition is some source of abundant supply of the proper materials for solution. The sources of supply can scarcely be sufficiently well known to afford any practical working basis for judgment as to promise shown in any undeveloped district. However, there has been in the exploited mining regions of the world such a uniform coincidence, as many writers have noted, between the occurrence of commercial ores and bodies of igneous rock, usually belonging to the later geological periods, that the presence of such rocks, and of the conditions concomitant to their formation, may well be the first feature to be considered in exploratory work.

In the beginning of vein mineralization there must be a means of free circulation to considerable depth, whether by a single open fissure or a combination of many fissures. Ascending waters will, in time, fill and seal their own conduits. The abundance of the valuable minerals deposited may then depend also upon the frequency of revival in mineralizing circulation by the reopening of water routes. Veins which show an absence of water in deep mine workings have passed the primary depositing stage, and whatever water may exist in Zone III has resumed its normal static condition. Primary mineralization is then dormant.

Such structure within the fissures must obtain as will serve as a receiver for deposition. Expanded or brecciated parts of faults and fissures or open contacts may supply this requirement. A promising mining region must, then, be well fissured, but above all, a special access of energy, in the form of heat or otherwise, has been necessary to the mobilization of the normally stagnant solutions, in order that the ore materials may be brought to their place of deposition.

There must also exist conditions inducing precipitation. Any substance dissolved in any other substance precipitates when solution is saturated. Saturation is not a fixed or constant state, but varies with any change of temperature or pressure, and, in flowing solutions, with change in the velocity of movement. An upward-moving current in a water body undergoes a constantly decreasing pressure. There is also a decrease of earth temperature from its interior toward the surface. A solution, with solvent capacity only partly satisfied at great depth, may thus approach, and eventually reach, a condition of saturation in its upward journey. Chemical reactions absorbing heat may, to a minor degree, assist in precipitation by lowering temperature.*

There is a further means to decrease in the temperature of deep solutions which may be more important in the segregation of ore than any or all the factors above named, the secular decrease in temperature attending expiring regional vulcanism. Highly-charged solutions, though relatively stagnant, may, by this means, precipitate *pari passu* with decreasing temperature. This conception emphasizes the role of igneous activity, both as a means of first promoting solution and as an efficient cause of final precipitation. The unbanded structure of such a large percentage of the great ore bodies would favor the hypothesis of such a mode of deposition. The majority of the primary deposits of Cripple Creek bear evidences of such conditions, and it is further emphasized by the intimate association of the ores with the volcanic area. Ransome† calls attention to this form of lode structure in the following language:

"The quartz, galena, sphalerite, chalcopyrite, pyrite and other minerals are all crystallized irregularly in the fissures without external crystal form and without definite arrangement. As a rule, the constituent minerals appear to have crystallized practically simultaneously."

There are few mining camps where such ores are not found. The process may have been repeated and thus developed the banded structures in some cases.

*Van Hise: Genesis of Ore Deposits. A. I. M. E., 1901, p. 340.

†Bull. U. S. Geol. Surv. No. 182, p. 87.

The mingling of solutions is probably a notable cause of deposition in special instances, and has a particular bearing upon the localization of ore in shoots. Several solutions, each of which may be remote from state of saturation, may, when combined, produce precipitation, either by chemical reaction forming less soluble compounds, or by the saturation of the solution with reference to some one or more of its dissolved minerals by the mere effect of mixture.

All the conditions above described may have been repeated any number of times. Vulcanism usually operates intermittently, and in some cases is known to have recurred after the first formation of veins. Orogenic movement and similar dynamic disturbances are in operation in the mountain regions at almost all times. They are usually repeated movements of small magnitude, aggregating in the course of time great effects of dislocation. Primary deposition may be regarded in different places as having taken place continuously for comparatively short periods, or intermittently for long periods. All other things being equal, evidences of many epochs of disturbance is a favorable feature in a mining region.

The Localization of Primary Ores.—Although the richest ore bodies are those which have resulted from special concentrations of the metals in water Zones I and II, nevertheless there have been found, below the latter, ore shoots of strictly primary character which, though of lower grade, have been so extensive as to be amenable to mining, and these have in some cases produced great fortunes. The mining engineer can not ordinarily predict their existence, and it would be hazardous to make the attempt. The increased expense of mining from great depths, and of milling the refractory ores, has, in most places, necessitated a higher grade of ore than is found at such depths. Yet the notable exceptions to this statement, as in the Lake Superior copper regions, the Rand, and the Comstock lode, render it important, in any case, that the possibility of the existence of payable primary ore shoots be considered.

Probably the most important horizon of original precipitation when it is in progress, is, at all times in the history of the vein, at and near the base of Zone II, because of the deposition induced by the mingling of the deep ascending waters and the superficial discharging water. If it has ceased, and has been dormant for some time, primary ores previously deposited here, may have risen by erosion into the two upper zones, and the vein below the base of Zone II may become abruptly, and for any depth, permanently lean. Each ore-bearing vein may represent any stage between the two extremes described.

Although the intersection of fissures does not by any means always mark the locus of ore shoots, since the crossing fissures need not have been contemporaneous with active deposition, yet there are but few cases where great ore bodies have not had some physical determinant somewhat of this nature. Any cross-channel of pre-mineral age, or even the intersection of a porous or otherwise permeable region in the country rock, may serve to localize deposition. The latter may be so loose and extensive, however, as to produce extreme dissipation of materials.

It is possible that locally expanded conduits, either in the form of exceptionally large open space in the fissure or its equivalent, a broad brecciation, may be a minor cause of precipitation by retardation of flow. There is such a correspondence between the rich ore bodies and the specially expanded portions of the veins that is natural to attach to it such genetic significance.

Intersection of the vein with limestone beds and other exceptionally soluble rocks is likely to be the locus of great ore shoots, both because of the supply of precipitants and the creation of space for deposition by the solution of the rock. Any rocks supplying precipitants locally, as the bituminous formations, or soluble materials diverse to the character of the solution in the fissure, may induce precipitation even in contracted spaces.

The horizons of primary deposition when this is active are constantly moving downward in a vein. The finished product of it is likewise at all times passing out of the realm of the solutions

which produced it. Thus the zone of actively depositing solutions is forever being curtailed at the top. That the vertical extent of the zone is diminished correspondingly under ordinary conditions is a matter of little doubt. In other words, the fate of first deposition is destruction, unless its agents are revived and given access to new materials. There may be a localization of productive ore bodies by vertically differential deposition. This is of two kinds: a zonal arrangement of any given group of minerals in horizons of special richness, or a differentiation of the deep deposits into zones of diverse minerals. The former may result from particularly active mineralization at some epoch in the history of the vein, and may occur at any horizon, but most likely near the base of Zone II. A long pause in the descent of the zone of secondary precipitation, for any combination of causes, may have produced the same result. Where diverse primary minerals appear at different depths there may have been a variation in the character of materials available at their source at different epochs. By recurring disturbances the solutions may have had access to new materials, or a progressive exhaustion may have taken place in the order of solubility, the solutions therefore precipitating only certain minerals at any time, and because of secular change of locus depositing in overlapping zones. Also, a differential precipitation in downward order of solubility could conceivably take place from an approximately static solution containing many minerals at the same time, though it is not so probable.

The foregoing is a partial list of the means in nature of depositing productive primary ore bodies. Their effects cannot be foreseen in the early stages of mine development, but sometimes at a later stage such deductions may be made as will serve as a safeguard against extensive and fruitless expenditure below the zones of secondary enrichment. In crude form, the following rules for guidance may be postulated:

(1) If secondary deposits merge gradually into primary ores of good grade, primary deposition has been operative until a very recent date, and the special primary concentration near the base of

Zone II has been invaded only moderately by the superficial zones. A mine may in such case produce sulphide ores for several hundred feet, or even to the limits of practicable mining. The Comstock lode is probably the best instance.

(2) If, however, the transition from secondary ores is abrupt, both in physical demarkation and in change of grade, the assumption is that primary processes are extinct and their products have long since been resolved and concentrated in secondary form above, and the prospect for deep ore bodies of good grade is extremely discouraging.

Criteria for the Recognition of Primary Minerals.—

(1) Relations to other minerals in the vein sometimes show conclusively the primary character of a mineral, though positive determination is frequently impossible. By relations of superimposition and inclusion, relative age of two minerals may be determined. Yet one may be primary or both may be either primary or secondary.

(2) Absence of evidence of alteration, such as oxidation and hydration; lack of mineral forms of low specific gravity derivable from other forms of the same materials of greater density, and of similar physical changes which may be either observed or deduced, are all obvious criteria for the determination of the original constituents in the upper parts of veins. Pseudomorphs, though themselves products of alteration, may supply evidence of the character of the primary mineral. Pitted, roughened or rounded crystals have been subject to some degree of decomposition, and are likely to be of deeper nativity than their freshly crystalline neighbors. In a general way it may be assumed, excepting certain well-known difficultly soluble sulphides of the metals occupying high positions in the scale of specific gravities, that any mineral is of secondary character in Zones I and II until proof is positive that it can be derived by alteration and redeposition from nothing which still exists or by any evidence ever did exist within the same segment of the vein.

CONCLUSION.

It has been the first aim of this paper to present, in orderly form, some of the genetic relations of ore deposits to the conditions believed to control the effective circulation of underground water, as it has been observed in the western mining regions of the United States. Much of the subject has been covered many times by others. Zone II, though possibly an obvious conception, is believed to be somewhat new, and of importance, in the above application of it to ore deposits. At first, it appealed to the writer as a local condition specially affecting the Cripple Creek region, and was studied with such limitation in mind. It has since, in the course of observations in other places, appeared to have a broader significance, and, with the qualifications given it, is believed to be of general importance, and sometimes a controlling factor, in the deposition of profitable ores. Although it may appear to be a local and restricted division, since it cannot be conceived to exist in the great areas of the plains, nevertheless it cannot be denied existence in any region of notable relief and underground water, and, with the modifications given it for arid climates, it admits of the explanation of secondary precipitation and oxidation below water-level without strained conceptions of circulation.

Clearly suggested by the analysis of the characteristics of Zone II, and almost corollary to it, is the conclusion that, outside and below, those regions in the rocks within which water is given a means of movement under gravity by free outlet, the normal state of it, both by deduction from physical laws and from observation in deep mines, is stagnancy and isolation from the circulation of the earth's crust. If, therefore, aqueous solutions are responsible for the deposition of the deep primary ores, a means of inducing circulation is a necessary condition, and can be found only in the somewhat catastrophic phenomena of nature. There has been a tendency among geologists to refer all phenomena of the earth's crust to the working of forces, operating slowly and quietly before our eyes in the normal conditions of approximate quiescence. This practice has been prolific of important results in

clearing the scientific atmosphere of violent geological conceptions. Yet the catastrophic does exist and, in its local way, accomplishes its own extraordinary work. The explanation of the result which is exceptional calls for causes of the same order. The rich ore deposit is, as compared to the whole expanse of the earth's surface, one of the rare phenomena of nature. Why, then, should the effort be made to avoid the extraordinary in the study of its genesis? It is true that the normal activities of underground water are sufficient in the explanation of the special, and really most important, bodies of ore, namely, the secondary deposits. There must be, however, materials for the making of these, an extensive, and, in the aggregate, rich primary deposit. This, in the writer's belief, could not have been formed by meteoric waters, aided only in their underground movements at great depths by gravity, operating under such physical conditions as obtain in regions of dynamic adjustment and quiescence.

SYNOPSIS.

	PAGE
Statement of the subject.....	193
Agents of ore deposition	194
Physical	194
Meteoric water.....	194
Gravitation	194
Chemical.....	194
Solvents.....	194
Precipitants	197
The flowage of underground water	198
Directions of flowage	199
Passages through the rocks	199
Barriers to flowage	200
The zonal disposition of underground water.....	201
Zone I, the Gathering Zone	201
Limits and variations	201
Effects of arid climates	202
Zone II, the Discharging Zone	202
Directions of flowage	202
Water routes	202
Limits of the zone.....	202
Analysis of flowage	203
Conditions to the absence of the zone	205
Zones I and II the underground segment of the cycle of circulation	209
Zone III, the Temporary and Static Zone.....	209
Movement normally infinitesimal.....	209
Effects of local heat and its sources.....	210
Limits of the Zone	211
Conditions to its absence.....	212
Contains water isolated from the cycle of circulation.....	213
Articulation of Zones II and III with prevailing theories	213
Closer definition of the lower limit of Zone II.....	217
The development of ore-shoots by secondary enrichment	220
Definitions	220
Relations with the water zones.....	222
Stages of vein history.....	222

SYNOPSIS.

	PAGE
Subdivisions of the belt of secondary enrichment	224
The zone of oxidation and disintegration	225
The zone of reduction and precipitation	229
Limits and characteristics of the zone of oxidation	228
The zone of precipitation as related to water Zone II	229
Agents and reactions	231
Conditions to the development of ore-shoots	238
Importance of the zone commercially	239
Secondary enrichment in the absence of a belt of saturation	239
Criteria for the recognition of secondary minerals	241
The zone of unmodified primary deposits	242
Native to Zone III	242
Conditions to deposition	243
Disturbances to static conditions	243
Causes of precipitation	244
The localization of primary ores	245
Conditions to productiveness	248
Criteria for the recognition of primary minerals	248
Conclusion and resumé	249

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
Vol. 7, pp. 253-266.

THE NEW GEOLOGY AND VEIN FORMATION.

BY FRANKLIN R. CARPENTER.

DENVER,
PUBLISHED BY THE SOCIETY
MARCH, 1904.

THE NEW GEOLOGY* AND VEIN FORMATION.

BY FRANKLIN R. CARPENTER.

Read at the Meeting of the Society March 4, 1904.

Some of the most original and far reaching contributions to our recent knowledge of vein formation were first made by members of this society. In looking over our earlier papers we are forced to the conclusion that there were indeed "giants in those days." Their observations and conclusions were of the utmost importance, and must ever remain matters of permanent interest. Recently, however, there has come to the notice of the scientific world a new hypothesis of the earth's origin, destined to modify our views of its history in many directions, and, incidentally, of ore deposits.

At the recent meeting of the Geological Society at St. Louis, Professor H. Le Roy Fairchild presented a paper upon this new hypothesis for the purpose of provoking a discussion from working geologists; and it is rather for the purpose of calling attention to the possible relation of the "New Geology" to vein-formation and the genesis of metalliferous deposits than that I can add anything to the subject, that I present this paper.

The old geology, based upon the now widely discredited nebular hypothesis, dealt with a cooling globe, condensed from an incandescent gas or "fire mist," first to a molten or liquid stage, then to a cooling crust floating, or at least resting, upon a molten interior. The constituents of the ocean and atmosphere were a gaseous envelope surrounding it. As the earth's surface cooled, the sus-

*No special originality, of course, is claimed for the views maintained in this paper; as they are all in some manner suggested by Professor Fairchild's communication to the Geological Society. He, however, is in no way responsible for my application of them to ore-deposits.

pended waters condensed, and the resulting hot solvent* ocean dissolved from the fire-formed crust many substances, a part of which later, according to T. Sterry Hunt, were precipitated upon the crust from which they were at first dissolved, thereby forming the first rocks that were not igneous, or fire-formed, but a further part is still held in solution.

Professor Fairchild points out that in the beginning geologists took their ideas of the earth's origin from dreamers and philosophers, Swedenborg and Kant being the sponsors of the nebular hypothesis, which was given a mathematical form by La Place, and later the brilliant imaginations of Hunt and others, aided by physicists, but carried these views to their legitimate conclusions. Altogether, they bound geological science in swaddling clothes, which has long prevented a healthy growth.

In place of a white-hot globe derived from an incandescent gas, we now have the falling together of discrete and cold particles of matter, as proposed by Chamberlain, provisionally called by him "planetesimals." By this theory, the earth's surface was always cold and the oceans and atmosphere were a part of its original composition, squeezed out or vaporized from the interior. There never was any igneous crust nor hot primal oceans, and the first water forced out from the interior was doubtless frozen and reburied† under the incoming "planetesimals," for it could be only after the atmosphere was developed that the surface could be warmed by the sun's rays above the freezing point. By the old view, the moon was a dead world, having absorbed its water and atmosphere, and we were taught that the earth would undergo the same process. By the new view, the moon is but a case of arrested

*This "primal ocean" was very acid at the beginning, containing sulphuric, hydrochloric and carbonic acids in great abundance. Like the ocean, they had been suspended in the atmosphere, but now, dissolved in the hot waters, they came in contact with the complex silicates of the fire-formed crust, and decomposed them. The alkaline bases were taken up by the acids, and many reactions occurred. Some of the resulting compounds were soluble, and remain in solution today; others that were slightly so, were precipitated to the bottom, and thus formed the first limestones, dolomites, argillites, etc. This age of the earth's supposed history has been sketched for us by Winchell in the most beautiful word-painting, and, personally, I dislike to think that the "primeval storm" may have never occurred.

†Fairchild.

development, never having had either atmosphere or oceans, being unable to hold the vapors that came from its interior, for, owing to its small size,* they would have been dissipated into space. The earth, however, holds many of its forced out vapors and gases; and the oceans and atmosphere, so far from being absorbed, are even yet increasing in size. The new view, it is believed, gives a far longer time for geological processes.

When Lord Kelvin proved that a cooling globe, formed under the old view, would have reached its present stage in about twenty millions of years, notwithstanding that known geological facts call for many times this allowance, many geologists, having nothing better to offer, set about bringing their requirements within this limit, with almost the same reverence for authority that formerly forced ecclesiastics to try to fit observed facts to the supposed requirements of Genesis—and the work of making geological science was continued in the closet rather than in the field.

The old view of necessity rejected water as a part of the earth's interior, and all water, therefore, circulating in the lithosphere, save a small amount of combined and entangled sea-water (and even this remotely), was meteoric water. As very many of the observed facts of vein-formation required water for their explanation, we were under the necessity of forcing surface water down into the earth against the very same forces that brought it back. How deep it could go, what work it could do, became largely a question of physics, but, notwithstanding the accepted origin of the earth, a few, indeed, dared to assume that water was a part of the earth's interior, though the great majority held to the view that the work was done in the main by descending and ascending meteoric water in the face of the almost insurmountable difficulties in the way of forcing it down against both heat and pressure. In

*And also their high molecular activity. The earth can not, even now, hold free hydrogen, and, while hydrogen is found in the atmosphere, it must come from the interior and is being lost into space, or unites with oxygen to form water. The earth would also be unable to hold helium.

the light of the new view, the Rev. O. Fisher, Dr. A. C. Lane and others are seen to have been brave pioneers.

When Sandberger revived and elaborated the theory of lateral secretion, we seemed to have a clear view of the formation of some ore-deposits, and this view, it has been said, reached its high-water mark with the publication of Emmons' work upon Leadville,* the most of which the distinguished author, as his views developed, presented to this society. Descending meteoric water did everything, collecting the thinly disseminated metalliferous substances from over-lying rocks and redepositing them at favorable horizons where proper conditions occurred. With the appearance of Posepny's paper,† ascending waters deposited the principal vein substances, and while it is not expressly so stated, the inference is that it is ascending meteoric water, which must in some way be forced into the earth before it can come back. With the new view, which regards water as an original part of the earth's mass, we are not limited to a permeable zone of fracture within the so-called lithosphere, wherein only meteoric water may collect the metallic substances of veins, but we have the ascending vaporized or squeezed out volcanic deep earth-waters that may have come originally from any depth whatever, even from the so-called "centrosphere" itself; and this process is still going on, perhaps not from the deepest parts, which, doubtless, were long since dehydrated, but still from depths which the old view could not permit. These deep or volcanic waters and other vapors, it is here suggested, were the original metal-bringing agencies, and the real ascending vein-forming waters, and will be referred to later.

It is fully admitted that the work of oxidation in general, but not altogether,‡ of rearrangement and of secondary enrich-

*T. A. Rickard.

†Published first by the American Institute of Mining Engineers.

‡As all the oxygen of the atmosphere was derived in the beginning from the earth's interior, and as carbon, hydrocarbons, and even hydrogen may be so derived, the work of either oxidation or reduction may take place at any depth without the action of surface waters; or reactions may take place between the volcanic water carrying the metalliferous substances and the surface waters, or even solids carrying proper reducing agents, and from this cause I imagine many surface deposits have been formed. It is easy to imagine conditions.

For other conditions, see "Ore Deposition and Vein Enrichment by Ascending Hot Waters." Also, for other similar views of "primitive or igneous" water, see "Ore Deposits Near Igneous Contacts,"—both by Walter Harvey Weed, Vol. XXXIII, Trans. A. I. M. E.

ment as generally understood, are the work of surface waters, and certain deposits, like the Lake Superior iron deposits, in their present condition, at least, are wholly so. This view, however, was ultimately extended to unwarranted proportions. So many difficulties were encountered that it finally broke of its own weight. Water had to be circulated, forced deep into the earth, brought back, and a universal sea of groundwater that can hardly exist—certainly does not in arid regions—was predicated, all because we dared not consider water as a constituent of the earth's interior.

The most complete, luminous and elaborate work upon ore-deposits, groundwater and its underground circulation ever published, was brought together by Van Hise,* who probably gives the most widely accepted views of ore-deposition. Briefly, he holds:

"The waters which perform the first work in the genesis of ores are descending waters."

These waters are carried laterally into the fissures.

"Lateral secretion is, therefore, an essential step in the first concentration of ores."

After passing into what he calls trunk fissures, where, from various causes, he says, "they tend to rise," they meet with waters from other directions containing different solutions, and the character of the wall rock varies from place to place:

"Therefore, many ores in their first concentration are precipitated by ascending waters," and later descending water does the work of secondary enrichment. All this work of ascending and descending, of collecting and circulating, is confined to the zone of fracture within the lithosphere, and above the zone of rock-flowage; "For if any one asserts," he says, "that the metalliferous materials of mineral veins are derived by water circulation from the centrosphere, or are derived from the lithosphere below the zone of rock fracture, I hold this to be a pure unverified assumption," all of which under the old view was of necessity true.

*Trans. A. I. M. E.

Professor Van Hise's paper has been discussed by Raymond, Kemp and many others, and its fine points and limitations noted. The elaborate system of water circulation called for by it is not, it is claimed, satisfactorily explained by the author, who ascribes it to gravitative stress. No reference is made to igneous rocks or ascending vapors, which are omitted purposely. His paper confines itself to circulating meteoric water and sedimentary rocks, hence is not of universal application. Vogt, Kemp, Spurr and Lindgren lay greater stress upon igneous intrusions as the sources of metalliferous substances:

"Igneous districts, or districts of combined igneous and sedimentary rocks are almost always the regions in which veins occur."—*Kemp*.

This is true beyond all question, and it is fully admitted that some veins may be wholly so formed, as will be mentioned later; but such igneous intrusions often, at least so far as an ordinary assay shows, are barren of value, even when they show no decomposition whatever; or these rocks may be so limited in quantity that they do not seem to be sufficient to furnish gold or other metals equal to the known production of certain districts; but they do show that the regions where they occur have been the localities of vulcanism. Such dikes in the Black Hills and many other places give no evidence that they were in any proper sense molten lavas. If they had been, the walls of the enclosing rocks would give some evidence of metamorphism from heat, whereas, in the Black Hills at least, they do not, for I have often looked for it. The rocks are absolutely unchanged up to the dikes. They are generally acid rocks, highly infusible to dry heat, but which may yield readily to hydrothermal fusion.* The new hypothesis provides the necessary water for this process without the necessity of supposing the rocks thus fused to be marine sediments. They are,

*It does not add to the difficulty of Richthoven's order of eruptives in which the acid rocks, trachytes, etc., are followed by basalts. We do not have to suppose the water to be uniformly distributed within the earth's mass, or its mass of uniform composition. The acid rocks would first yield to hydrothermal fusion and, later, the basic rocks to true igneous fusion.

therefore, probably the products of a hydrothermal, or aqueo-igneous fusion, and at the time of their intrusion were accompanied by volcanic water, just as volcanic eruptions now are accompanied by water and other gases and vapors. Single eruptions of Aetna have been followed by the exhalation of thousands of millions of gallons of water. By the old view, this was interstitial water, or water which was derived from the sea or atmosphere, but how it got into the volcano through heated strata of great repulsive force and of little or no absorbing power cannot be explained. The idea of supplying it through fissures or subterraneous conduits is a point that Professor Fairchild thinks not worth considering.

The new view simplifies the problem by making water volcanic, and the accompanying vapors indigenous to the earth's mass, and the real reason that volcanic waters resemble sea-water is not that they were derived from the sea, but that the sea itself had the same origin, hence is itself the product of vulcanism. Here again, according to the new hypothesis, we have reversed matters, putting cause for effect.

Professor Fairchild points out that the gases found in volcanic emanations could not all be derived from meteoric water, while some of them are not found in sea-water. The abundant sulphur compounds are not accounted for at all. The volcanic waters and other emanations, are, therefore, original constituents of the earth's interior, and seem to have all of the requisites for forming metalliferous veins without the necessity of forcing meteoric water down against heat and pressure to acquire them, and I believe that these are our true mineral carrying waters and vapors, filling fissures and permeating rocks, and from which minerals are deposited by precipitation and crystallization; and the reason that metalliferous veins are most often found in the regions of igneous rocks is not so much because they are derived from such magmas, but because such extrusions have opened up the way for, and are accompanied by volcanic waters and gases that do form the ore-deposits. As almost all ore-deposits pass into sulphides with depth, this view is believed to give a better explanation of their origin.

If we apply this view to the Cripple Creek "volcano," do we not get a new light upon the origin of the gold there? Was it not the volcanic waters accompanying or following the Cripple Creek eruptives that filled with mineral solutions the actual fissures and joint planes that were formed by cooling or otherwise; and not the far wandering and over-worked meteoric waters which for ages would have been repelled from the section by the heat of the volcano? This very heat, under the view here presented, may have aided in the deposition of the gold by slow evaporation of the waters as they were replaced by ascending volcanic waters from greater and inexhaustible depths.

Does not this view incidentally give an added value to the Cripple Creek gold mines, by the suggestion that they were not formed by the shallow surface waters, although their surface enrichment was doubtless so accomplished? If the deepest workings are below surface effects, is there any reason to fear an immediate exhaustion; or exhaustion to any depths within the reach of ordinary working; or until fissures may become impossible by rock-flowage? Are not the increasing quantities of sulphides now showing with depth at Cripple Creek in favor of this view rather than of secondary enrichment?

Volcanic waters may also throw light upon obscure mineral deposits, other than those called metalliferous. Mr. T. A. Rickard* presented a paper upon the Bendigo gold reefs, in which he traced the origin of the gold to the entangled or imprisoned sea-water, which was so entangled at the time that the enclosing sedimentary rocks were deposited. The probability of this view was attacked by Mr. Philip Argall, a member of this society, in a quantitative calculation tending to show that even the quantity of gold already mined could not have been so derived, to say nothing of the yet unmined gold, while Mr. Richard Pearce, another member, without attacking Mr. Rickard's theory, pointed out that if the gold was so derived from the sea-water, the great salt deposits

*Trans. A. I. M. E.

at Strassfurt, presumably formed by the evaporation of sea-water, should also carry gold, whereas they were not known to show any. Mr. Rickard admitted the force of Mr. Pearce's suggestion, but fortified himself against Mr. Argall's figures by quoting from T. Sterry Hunt's views, now believed to be untenable, and the assertion that all of the gold need not have come from the entangled sea-water of the immediate vicinity. In the light of the new view of the earth's genesis, the opinions of both Pearce and Argall, as well as the original paper, have an added value. Volcanic water, having the same origin as the sea-water itself, probably accompanied the much discussed dikes of that section, while by the old view we cannot by any satisfactory supposition, account for the great localization of salt at Strassfurt, in one place nearly a mile in thickness, or the very pure Louisiana deposits found far below sea level. They were probably not formed by the evaporation of sea-water, but again like the sea itself, they were the products of vulcanism. The great local deposits of oil at Baku are not satisfactorily explained by the old view, but if salt and hydrocarbons were originally constituents of the earth's interior, they might well become so localized. By the same view limestones are probably not all organic, nor are all bituminous substances necessarily so. It is hard to believe that the great localizations of pyrite beneath Leadville, or those at Rio Tinto, or the deposit of metallic sulphur in Louisiana were all formed by the action of rain-water, or entangled sea-water.

It will be seen that the new geology bids us to about face and march in the opposite direction at more points than one. It may not be established in its entirety, but that it must modify our views very greatly no one doubts. Its influence upon ore-deposits must be felt. We do not have to imagine a universal sea of groundwater. We do not have to get up elaborate schemes for its circulation. We do not have to force it down empty to great depths against the opposing forces of heat and pressure that it may come back loaded, nor explain how the lighter surface waters displace the heavier and deeper mineral waters. If there is any

such sea of groundwater, it must contain many islands, while in other places it appears to be a "Dead Sea"—but above all, there is no call for such a system, although it apparently satisfied the mind; but in opposing the views of these new Neptunists it is possible that our new Plutonians have gone too far in the opposite direction, notably Spurr, whose paper has but recently appeared. He has extended the views of certain Swedish geologists who have long held to the view of the eruptive character of some ore-deposits, much as Van Hise had extended and enlarged the opposite view. In the light of the new geology, his premises must be rejected, because based upon a molten fire-formed crust in which the concentration of metals had already begun. The first sediments he derives from the disintegration of these igneous rocks, and their elements are further concentrated through mechanical and chemical means. Calcium becomes concentrated into limestones, silica into sandstones and quartzites, and, among the commercially valuable minerals so derived are salt, gypsum, borax, phosphate of lime, etc., and even the metals may be so concentrated, especially iron. No such satisfactory conclusion, he says, is reached for silver, copper, lead, etc., for these metals go largely into solution, and such waters go into the sea; but it is impossible to think that the sea holds in solution all of the metals so derived since the world began and since the igneous crust has been going to pieces, so that we must have chemical precipitates along with mechanical concentrations deposited in certain places which are relatively richer in these metals than the igneous rocks from which they are derived, which can be still further concentrated by groundwaters. But the real object of the paper is not to trace these substances into ore-bodies, but to show the further concentration by segregation within molten masses, and his conclusions lead to the hypothesis: "That by magmatic segregation the metals of commercial value, as well as other rock-forming elements are irregularly and to a certain extent independently concentrated in certain portions of the earth's crust. Such portions, characterized by the relative abundance of certain metals, may be called metalliferous prov-

inces, * * * and; moreover, within these provinces magmatic segregations produce sub-provinces and finally, within these rocks, the commoner metals may be segregated, chiefly into certain portions, even producing workable deposits without further concentration, and in the case of the less common metals, either directly workable deposits, or rocks relatively so rich that they require only the concentrating action of other agents, chiefly circulating waters, to create ore-bodies, * * * and the reason why some districts are metal producing and others non-producing is due primarily to magmatic segregation." (Vol. XXXIII, Trans. A. I. M. E.)

Thus starting from a homogeneous fire-formed crust, by means of magmatic segregation alone, he arrives at workable deposits, as well as those that were derived by denudation from the crust, and that were concentrated by mechanical and chemical means.

By the new view, there is no "magmatic crust" to be separated into mineral "provinces"—nor is it necessary, for we may suppose that the incoming cosmic matter was of dissimilar composition—hence the new view favors heterogeneity, and thus gives a plausible origin to both the petrographical and metalliferous provinces. The subsequent view of magmatic segregation and its attendant phenomena is as favorable to the new hypothesis as to the old, perhaps more so, as vulcanism in all its forms is advanced to the first place in vein-formation.

It will be seen that we have been presented with a multiplicity of views—but perhaps it is the old story of the shield, the observers saw different sides of it, and all were in a manner right.

Van Hise collected and extended all of the views relating to the work of groundwaters, and gave us a "descending, lateral-secreting, ascending, descending, lateral-secreting," theory. (Page 173, Vol. XXX, Trans. A. I. M. E.), in which meteoric water did everything. Vogt, Kemp, Lindgren and others showed the influence of igneous rocks, while Spurr and others have traced the complete formation of some ore-bodies to igneous agencies only.

In some sense all of their views may be correct, but of course not in all cases in the manner asserted. It may be the province of

the new geology to give a new meaning to the undoubted facts, and to reject the theories that will not stand its tests.

All these views are put forth tentatively. It is my object to inquire how the new geology, if established, will affect our views of vein formation. If it is accepted, may we not conclude:

First.—The work done by meteoric water in the formation of metalliferous veins is local and comparatively shallow, and is confined to alteration, redeposition and to local enrichment.

Second.—Metalliferous ore-bodies in their original form are the results of a general process called vulcanism, which in some cases has formed intrusive or igneous veins, but in general they are the result of ascending volcanic waters and gases which were a part of the earth's original composition, and were not derived either from the sea or atmosphere, both of which are themselves the products of vulcanism, and the reason that metalliferous ore-bodies are most common in the regions of igneous rocks is not that they were derived directly from these rocks, so much as from the volcanic waters and gases which accompanied them.

Third.—In view of the second conclusion, fissure veins, after passing through the effects of surface alteration and concentration, are not likely to change materially within workable depths, and a progressive impoverishment which followed under the old view does not necessarily follow under the new. It therefore tends to reestablish the old view of the greater permanency of fissure veins.

Fourth.—The so-called petrographical and metalliferous provinces that undoubtedly exist are not to be accounted for by magmatic segregation of an original fire-formed homogeneous crust, but rather by dissimilar incoming planetesimals, which view favors heterogeneity in the materials forming the earth's mass.

Fifth.—The heat-producing volcanic action is not from the residual heat of an incandescent globe, but is the result of gravitational and, perhaps, chemical action within the globe, which view is as favorable to the formation of dikes, laccoliths, lava sheets, etc., as the old view was, for it allows genuine igneous fusion as

well as furnishes a more rational origin of the hydrothermal fusion of rocks, which need not be sedimentary rocks carrying imprisoned surface or sea-water.

Sixth.—Nothing remotely resembling the precipitated rocks of T. Sterry Hunt's primal ocean has ever been identified, and in the view of the new hypothesis, they do not exist, nor are there any such concentrations and precipitates derived from the degradation of an igneous crust as is put forth by Spurr, but the magmatic segregation of ore veins formed by igneous action and all of the so-called pneumatological phenomena are even more allowable under this view than under the old.

NOTE.—The views maintained in this paper, save the origin of the ascending water, are believed to be in harmony with those of the older geologists, who were, I think, in the main, correct. They considered a fissure as an opening that established a connection between the earth's surface and its interior, through which mineral solutions rose from unknown depths, depositing ores and other vein stuffs by relief of pressure and by cooling. The influence of wall-rocks and the reducing action of organic matters were early recognized, but almost all veins were believed to be the result of solfataric action. Sandberger put forth the idea that vein stuffs were derived by lateral secretion from enclosing rocks, and the expression, "unknown depths," was discredited; but as we were still in the dark as to the origin of the metals in the enclosing rocks, we were not much better off, and were still obliged to bring them from "unknown depths" by igneous intrusions. Here again, I fear, we have reversed matters, and that it is possible that the enclosing rocks were saturated by the same waters which formed the ore deposits themselves, and in the case of igneous rocks this saturation may have taken place in the unknown depths whence they were extruded. The difficulty of supplying sea-water, or water from other sources, is avoided by making water a constituent of the earth's mass—the original source of "The Fountains of the Great Deep" itself! This water was forced upward by heat and pressure, and supplied the hot alkaline solutions, the alkaline carbonates and sulphides that are the natural solvents of quartz—the commonest of all vein matters. If these waters contained an excess of carbonic acid, they were capable of dissolving carbonates of lime, baryta and iron, all of which are common to vein fillings.

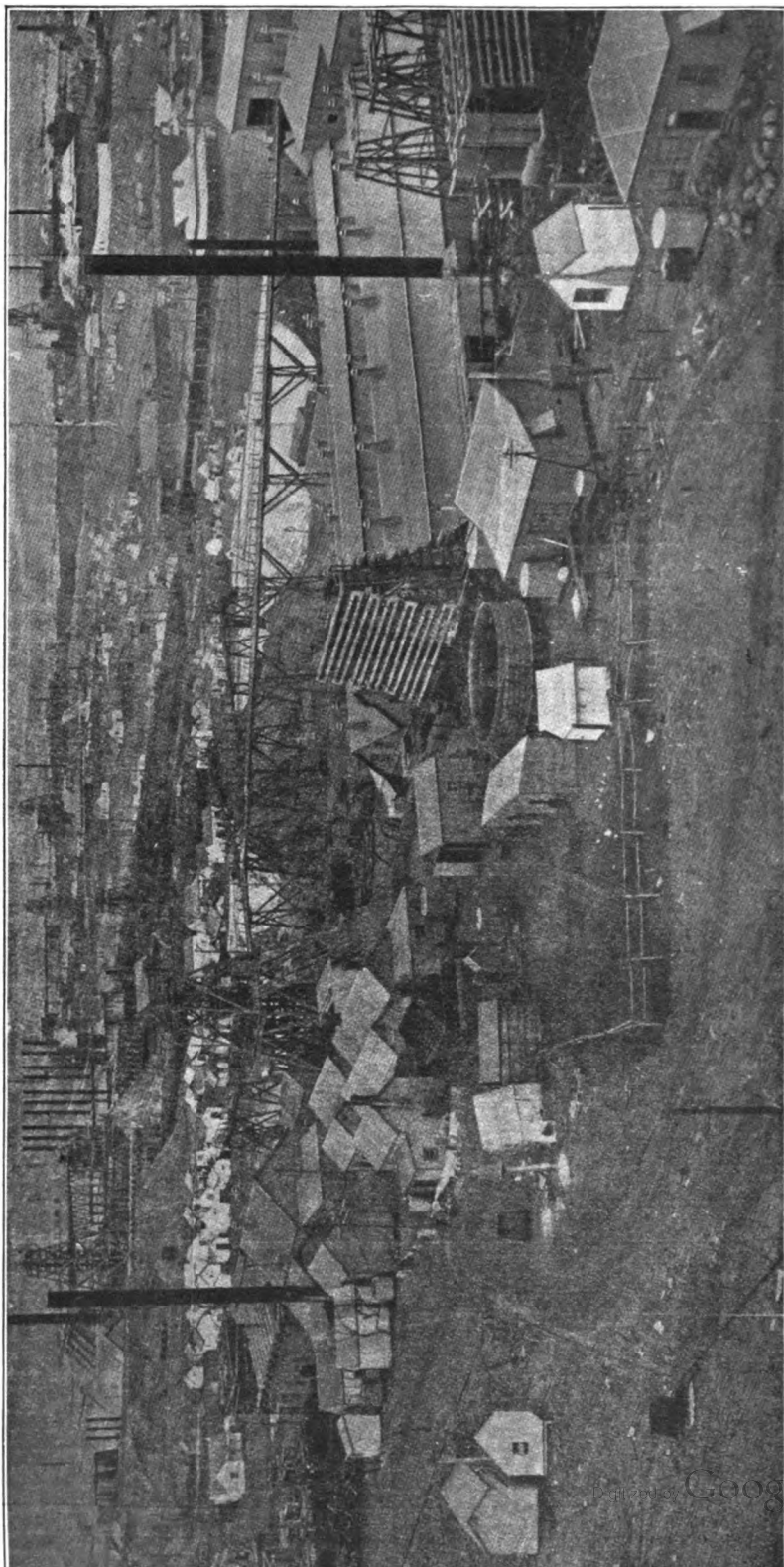
I do not wish it inferred that because these waters came from the earth's interior, veins will get richer as they go down. It must be remembered always that local alteration and enrichment of veins are mainly surface actions, and for this reason the most valuable part of any vein is likely to be its outcrop—the first five hundred feet probably being the best portion; but to this rule there are many exceptions. I only wish to maintain that a vein is not likely to change very much after the original unaltered sulphide portions are reached.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
Vol. VII, pp. 267-288.

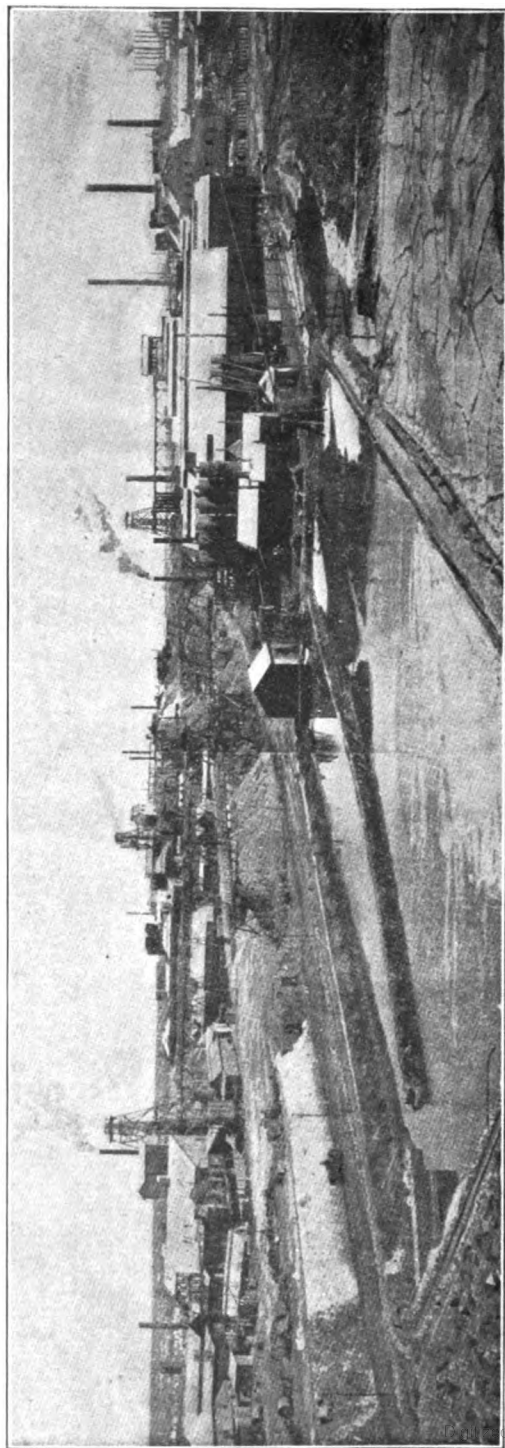
THE PROGRESS OF GOLD MINING IN KALGOORLIE,
WESTERN AUSTRALIA, IN 1903.

By E. BARTON-HACK, M. Aust., M.E.

DENVER,
PUBLISHED BY THE SOCIETY
MAY, 1904.



View of the Golden Mile, Looking South from the Kalgurli Shaft.

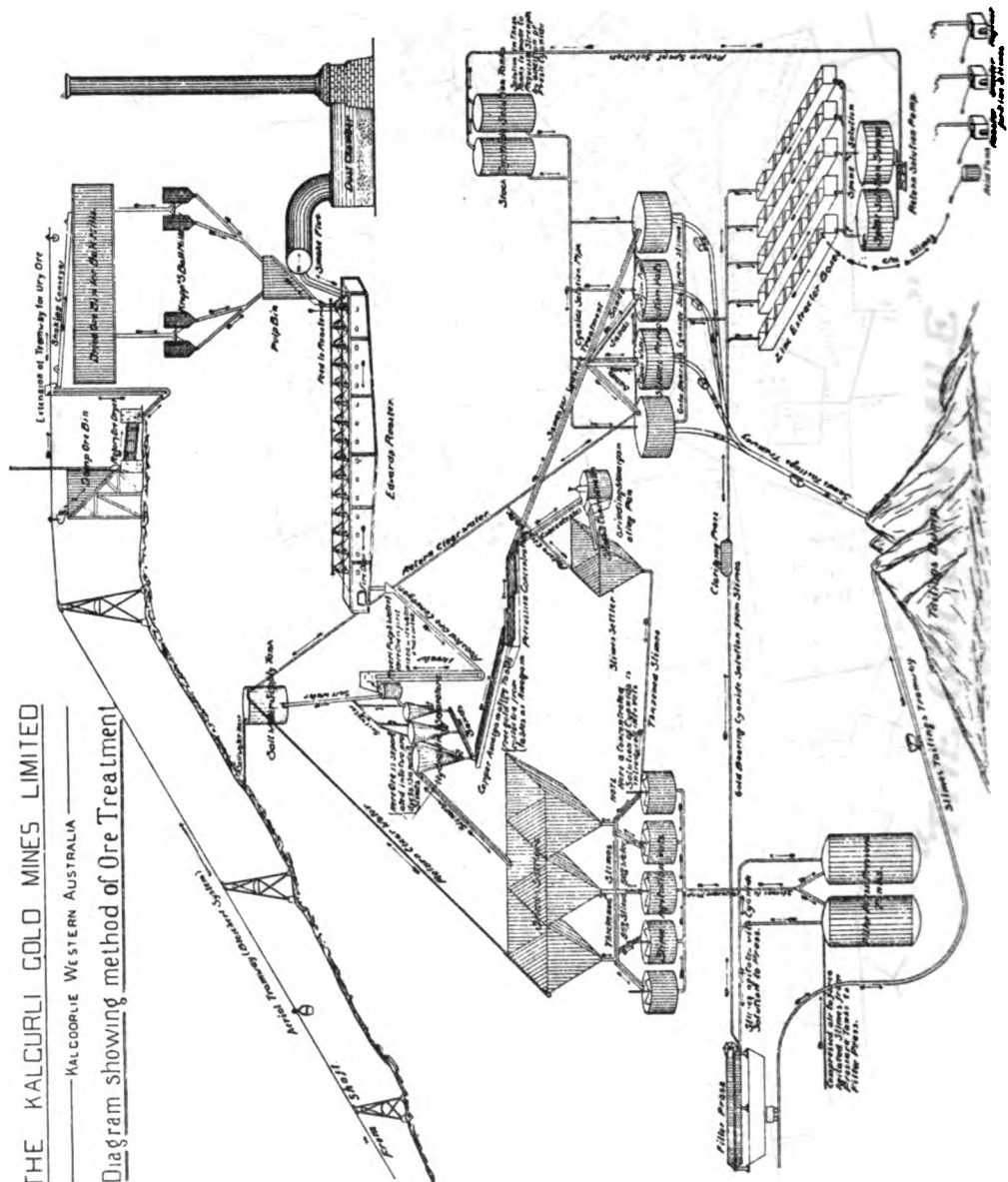


Southern End of the Golden Mile Showing the Ivanhoe and the Great Boulder Mines.

THE KALCURLI GOLD MINES LIMITED

KALCOORIE WESTERN AUSTRALIA

Diagram showing method of Ore Treatment



THE PROGRESS OF GOLD MINING IN KALGOORLIE, WESTERN AUSTRALIA, IN 1903.

BY E. BARTON-HACK, M. Aust., M.E.

Read at the Meeting of the Society, April 2, 1904.

The East Coolgardie Gold Fields of Western Australia occupy the van amongst the various gold fields scattered throughout the State. In fact, not only stand out ahead of every other field, but as a gold producer it is well in advance of the whole of the eighteen other gold fields combined. This will be more readily perceived, when it is stated that to the total of 1,781,928 ounces of gold produced during the first nine months of last year, East Coolgardie (the "Golden Mile" at Kalgoorlie and Boulder) contributed no less than 988,115 ounces, while the eighteen other fields supplied 793,813 ounces. Thus, Kalgoorlie's contribution to the total gold production was 54.8 per cent. of the whole. Compared with the production of 1902, this percentage shows an increase of 2 per cent., the East Coolgardie percentage for 1902 being 52.8.

There has been a general increase in gold production in nearly all the other gold fields of the State; the total output for the year being about 2,400,000 ounces, an increase of about 282,859 ounces in excess of the yield for 1902, or more than equal to the total gold yield of the State previous to the beginning of 1898.

A further evidence of the progress that the gold mining industry in this State is making, may be gleaned from the particulars of the dividends that have been paid by Western Australian gold mining companies during the past three years. In 1901, nineteen companies paid dividends amounting in all to \$5,358,660.50. In 1902, the number of the dividend paying companies

increased to twenty, and the total amount of dividends rose to \$6,978,932.80. During the year 1903, the approximate amount in dividends paid out by twenty-four companies was, for the first nine months, \$7,133,434; for the last three months, approximately, \$1,803,798; total, \$8,937,222; and this amount of dividends is paid on a total nominal capital of a little over \$31,070,900.

Up to the end of 1903, companies owning mining properties in this State returned to their shareholders a total of no less than \$45,080,000.

Of the output from the various fields of Western Australia, the yield from East Coolgardie was a long way in advance of the total yield from all the other fields combined. The following table will show how the fields stand with regard to each other as gold producers today, and also how they have fared since the first time that they were established:

	Output for Nine Mos., Ended Sept. 30, 1903.	Total Output to Sept. 30, 1903.
	Ounces.	Ounces.
1. East Coolgardie	988,115	6,325,671
2. Murchison	182,403	1,149,172
3. Mt. Margaret	161,164	984,165
4. N. Coolgardie	148,153	976,759
5. E. Murchison	79,977	481,328
6. Coolgardie	46,629	733,211
7. N. E. Coolgardie	44,100	615,617
8. Dundas	30,982	271,587
9. Peak Hill	23,590	197,569
10. Broad Arrow	21,887	244,314
11. Yilgarn	17,125	247,777
12. Pilbarra	7,908	121,409
13. Philips River	6,230	20,389
14. West Pilbarra	3,519	13,900
15. Yalgoo	2,436	55,894
16. Kimberley	734	16,955
17. Ashburton	596	7,302
18. Donnybrook	58	1,190
19. Gascoyne		524
Gold fields generally	902	2,454
To a gross weight	1,781,928	12,482,725
Total fine gold	1,510,204	9,455,108
Total value	\$31,240,788	\$226,833,321

The other minerals, such as copper, tin and coal, have been produced and are still being mined successfully, but the operations with regard to them have not so far been responsible for any noteworthy addition to the prosperity of the country.

The figures for the production of all minerals in the various states of the commonwealth of Australia and New Zealand, up to a recent date of last year, are not yet available, but those for 1902 are at hand, and as they show at a glance the position of mining throughout Australia, they should be interesting. The following table shows the relative positions of the states with respect to the production of the leading minerals:

	<i>Western Australia</i>	<i>New South Wales</i>	<i>Queens- land</i>	<i>Victoria</i>
Gold	\$39,618,310	\$3,355,363	\$13,331,132	\$15,003,938
Copper	39,614	1,513,723	927,080	.....
Lead .....	.....	223,525	13,230	.....
Silver	46,335	7,096,878	343,611	.....
Tin	194,915	263,060	568,238	.....
Coal	422,222	10,814,331	843, 02	762,685
Iron .....	.....	403,038	.....	.....
Precious Stones .....	.....	740,498	58 410	.....
Totals	\$40,321,330	\$24,410 416	\$16,084 933	\$15 776,603

	<i>Tasmania</i>	<i>South Australia</i>	<i>New Zealand</i>	<i>Totals</i>
Gold	\$ 1,477,708	\$ 466,133	\$ 8 562,022	\$81,814,606
Copper	3,332,016	2 075,273	.....	7,947,708
Lead .....	.....	169,165	.....	345,920
Silver	1,071,434	96,700	352,593	9,007,551
Tin	1,189,651	29,773	.....	2,245,637
Coal	2 3,412	.....	3 633,620	16,679,452
Iron .....	.....	.....	565	403,603
Precious Stones .....	.....	.....	.....	798,938
Totals	\$ 7,334,221	\$ 27 77,044	\$12,548,800	\$119,243,413

The Government has inaugurated a state battery system which has proved a very great assistance to the prospector and miner in the far back districts. Wherever there are centers of mining operations not easily accessible to a public custom plant, the Government has erected batteries, complete with amalgamating and concentrating accessories, so that the prospector on discovering

his outcrop may collect a camel caravan load or a few tons of ore and have a bulk sample tested at the Government plant at a minimum cost. These state batteries have already done good work, but there are said to be numerous openings still for a profitable extension of the system. The total returns from each of the state batteries, up to the end of August last, will show to some extent the value of the system. The figures are as follows:

<i>Name of Battery.</i>	<i>Total Ten- nage Tons.</i>	<i>Total Yield.</i>
Norseman	13,090	12,490
Mulline	29,013	42,777
Lennonville	13,826	22,305
Mulwarrie	9,232	12,874
Laverton	4,040	4,560
Meekaanarra	10,679	9,093
Darlot	4,476	11,339
Mount Ida	12,451	14,046
Niagra	9,079	10,727
Leonora	10,960	10,153
Widgiemotha	2,971	1,188
Boogardie	1,606	870
Tuckanarra	4,019	7,145
Ravelstone	5,329	5,680
Paddington	191	46
Batteries, closed	7,919	5,796
Total	138,886	171,108

The following table shows the monthly mint returns since the beginning of 1899.

	<i>Mint Receipts.</i>			<i>Exports.</i>		
	<i>1901</i>	<i>1902</i>	<i>1903</i>	<i>1901</i>	<i>1902</i>	<i>1903</i>
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>
January	65,972	84,233	108,856	72,724	79,925	101,594
February	49,584	82,338	112,147	85,912	70,353	80,249
March	52,309	92,542	115,816	75,535	84,963	78,907
April	62,589	11,591	121,639	87,420	71,940	86,987
May	57,306	102,759	114,721	86,786	61,467	92,779
June	67,810	124,287	135,781	94,157	65,333	72,278
July	91,604	124,788	122,501	68,689	69,439	90,176
August	58,531	124,402	124,352	103,238	63,568	82,265
September	87,402	132,355	129,832	93,260	55,812	71,581
October	83,508	118,675	.....	85,761	75,708	.....
November	89,175	123,119	.....	84,324	74,077	.....
December	94,500	129,518	.....	82,581	60,236	.....

The subjoined table shows the monthly returns since the beginning of 1899. The fractions of ounces are included in the grand totals.

	1899	1900	1901	1902	1903
	Ounces.	Ounces.	Ounces.	Ounces.	Ounces.
January	110,090	143,819	158,696	168,159	210,451
February	100,565	117,849	135,487	152,692	192,397
March	106,098	126,049	127,845	177,505	194,724
April	116,466	113,506	150,028	183,531	208,627
May	114,624	120,312	144,087	164,266	207,501
June	161,912	136,787	161,967	189,620	208,059
July	137,931	113,601	160,294	184,277	212,501
August	145,397	131,458	161,770	187,971	206,617
September	167,075	148,305	178,295	188,167	201,404
October	205,186	133,285	169,270	194,387	.....
November	139,867	146,635	174,481	197,197	.....
December	138,660	148,331	177,165	189,754	.....
Totals	1,643,877	1,580,950	1,879,390	2,177,442	1,842,281

The following table shows the yearly gold yield since 1886:

Year.	Ounces.
1886.....	302
1887.....	4,873
1888.....	3,493
1889.....	15,493
1890.....	22,806
1891.....	30,311
1892.....	59,458
1893.....	110,891
1894.....	207,131
1895.....	231,513
1896.....	281,265
1897.....	674,994
1898.....	1,050,184
1899.....	1,643,877
1900.....	1,580,950
1901	1,879,390
1902.....	2,177,442
1903 (nine months)	1,842,281
Totals	11,816,744
Total value.....	\$217,021,383

The past year has been eventful in the history of Kalgoorlie. Besides being a year of remarkable industry, it has been especially marked by the growth and expansion of this important inland

mining center, by the completion of that gigantic engineering achievement, the great goldfields water scheme, by a substantial increase in the gold output from its mines, and by the extension of the area of the valuable gold deposits which nature has so lavishly endowed it with.

Barely a decade has gone by since this rich goldfield was first discovered, yet a truly wonderful transformation has been wrought. The mighty efforts of practical enterprise have caused the silent wilderness of brush and scrub to disappear, to give place to one of the busiest, most prosperous and up-to-date cities in the commonwealth. Kalgoorlie has long since lost its character as an outback mining camp. Structures of architectural beauty line its paved main thoroughfares. Electric trams flit along its macadamized streets and connect it with its suburbs, its mines, and its twin center, Boulder City. Rows of pepper trees and fragrant eucalyptus fringe its sidewalks. Fresh water is reticulated hither and thither within its borders, and electricity illuminates it by night.

The event of the year has been the successful completion of the water supply scheme. Magnificent in its inception, spirited and energetic in its execution, this scheme has, after meeting with many unexpected difficulties, and in the face of persistent predictions of failure, at last triumphed over the forces of nature, and, besides proving worthy of the courage and the enterprise of the man who conceived it, (Mr. C. Y. O'Connor, Engineer in Chief for the State), become a priceless addition to the luxuries now enjoyed by the residents of this golden desert.

It is probably the largest pumping scheme in the world. There is no other place where five million gallons of water per day can be taken from its low level stream, forced from reservoir to reservoir through pipes, over 350 miles of arid country, until it finally is delivered into a storage basin such as surmounts Mount Charlotte, (a hill to the east of Kalgoorlie), 1600 feet above the level of the stream whence the water comes. Thence the water is reticulated by gravitation to the door of individual

consumers and to the mines of the Golden Mile. Already the supply of fresh water to the mines has enabled a substantial reduction in the cost of gold production to be affected, and has stimulated mining throughout the field.

The following list gives particulars of the consumption of fresh water during the month of October, as reported by the local Chamber of Mines.

	Total Consumption	Daily Average
	Gallons	Gallons
Associated	1,280,000	40,645
Associated Northern	104,000	3,354
Chaffers	5,000	161
Devon Consols	438,000	14,129
Golden Horseshoe	2,852,000	92,000
G. B. Main Reef	328,000	10,516
Perseverance	1,754,000	56,580
Gt. Boulder	2,140,000	69,032
Hainault	489,000	15,773
Hannan's Star	407,000	13,129
Ivanhoe	2,343,000	75,580
Kalgurli Gold Recovery Co.	57,000	1,838
Kalgurli	1,036,000	33,419
Lake View Consols	1,854,000	59,806
Lake View South	106,000	3,419
North Boulder	36,000	1,161
Oroya B. Hill	1,295,000	41,774
South Kalgurli	112,000	3,612
Brown Hill Extended	99,000	920
Totals	16,623,000	536,218

Never in the history of the Kalgoorlie field has there been such a soundness and solidity about its great gold industry as now exists. All the leading mines within the Golden Mile are showing improved prospects, now that greater economy in working is being exercised, and there seems no limit to their possibilities as contributors to the State's gold production.

During the past year the Kalgoorlie mining companies have devoted some attention to the question of costs, and their efforts in this direction have been marked by fair success. In reckoning expenditures it must be born in mind that the Australian ton is

2,240 pounds or long ton, and is, therefore, 12·29 per cent greater than the American ton of 2,000 pounds. The width of the lodes in most of the Golden Mile mines being large, the cost of development per ton of ore, is fairly low. The more or less irregular occurrence of the ore, however, makes it impossible to set out from month to month what the actual development cost may be, and as pointed out by Mr. H. C. Hoover in an article recently published in the *Engineering and Mining Journal* it can only be arrived at by taking reserves from year to year and then determining what adequate redemption should amount to. The balance sheets for 1902, of five leading mines, show that the average redemption should be about 96 cents per ton. According to Mr. Hoover, the growing tendency to place levels at a greater distance apart, and other changes in the mines, should bring down costs of development in the largest mines to under 60 cents per ton. The average cost of ore extraction to delivery in the plant bins has been from \$2.06 to \$2.50 per ton.

In a recent controversy in the *Engineering and Mining Journal* between Mr. Philip Argall and Mr. Hoover, anent the costs of the "Diehl Process" of sulpho-telluride ore treatment as contrasted with the dry crushing and roasting treatment, Mr. Hoover, in reply to a thoughtful letter from Mr. Argall, states that to thoroughly exemplify the whole matter, he would be prepared to contribute costs from all the wet crushing mills at Kalgoorlie treating the richer as well as the low grade ores of the field, and will contribute them upon any basis of allocation which Mr. Argall will suggest, providing that Mr. Argall will give detailed costs of two or three Cripple Creek mills. Mr. Argall's contention is that "Dry Crushing-Roasting Processes" will ultimately prevail at Kalgoorlie, and bases his argument upon a paper by Mr. Knutsen (a metallurgist connected with the London and Hamburg Gold Recovery Company, the company exploiting the "Diehl Process" at Kalgoorlie) and upon published costs of treatment from Lake View Consols, Great Boulder Perseverance and Hannan's Brown Hill Plants.

Until a uniform basis of allocation is agreed upon in comparing the relative costs of the two processes, showing the horse-power used on a per ton basis, and the cost of horse-power upon a horse-power basis, together with total hours of labor employed on per ton basis, and the cost of labor per hour, as Mr. Hoover says, the matter cannot be settled. But it is impossible to compare the cost in Kalgoorlie with any treatment mills at Cripple Creek, as the "economics of ore treatment at the latter place is probably the worst in the known world," quoting again from another article by Mr. Argall.

There are two distinct methods of ore treatment in force at Kalgoorlie, one a wet method of crushing, concentration, classification and leaching with solutions of cyanide and bromo-cyanide, with roasting of concentrates. This is now called the "Diehl Process." The other, dry crushing with fine grinding, roasting amalgamating and cyaniding. Both these processes have been greatly improved during the past year and are now, with two isolated exceptions, working at from \$4.95 to \$5.10 per ton. The total cost of handling ore on the best managed properties, including development, mining, milling, cyanidation and all other charges incurred, now figure out between \$5.52 and \$5.76 per ton for free milling ore (such as is obtained in the Maritana, Croesus and Hannan's Reward, on the north end of the Golden Mile, and at Burbanks, Bailey's Reward, etc. at Coolgardie 25 miles southeast) and from \$7.68 to \$7.90 for refractory ore, such as occur in the southern part of the Golden Mile, where the majority of the ores are of a sulpho-telluride character. These results, obtained in the face of natural economic difficulties compare more than favorably with those obtained in other regions. There is a fair amount of competition existing between the mine managers of the field as regards working expenditures, but the rivalry which has been engendered thereby has always been tempered with capacity and good feeling, and, therefore, proves a great incentive to economic gold production. Further reduction

in working costs may reasonably be looked for in the near future, and mining generally is gradually being reduced from absolute speculation to a solid industrial enterprise.

One of the rankest evils existant during the past years has been the constant theft of gold and rich telluride ore from the large mines, so much so, that many of the big mining companies are being continually robbed of their gold. In fact, gold stealing at Kalgoorlie has, it is affirmed, become as great and as rampant an evil as that which in South Africa, called for the passing of the "I. D. B." act. The spoil is portable and of high value, hence the need of the best precautionary measures being taken for its safety. In the past strenuous efforts have been put forward to prevent gold thefts, but in spite of the most careful watching, and searching of the underground men on leaving shift, the efforts of the mine managements are impudently checkmated by organized cliques of thieves. It is estimated that the Kalgoorlie mining companies are robbed of thousands of dollars worth of gold monthly, and in view of this the local Chamber of Mines is straining every nerve to have the law so amended as to render gold stealing difficult and easy of detection.

An effort has been made during the past year to introduce a uniform system of mine accountancy, which is a step in the right direction. This with a rigid and regular monthly publication of cost sheets with returns, would go far to rehabilitate this field in the favor of investors. Some of the companies publish costs, but for all practical purposes and for comparison, these are often useless. What is wanted is not the publication of *some* costs, but of *all* costs, and a return of outputs on a basis of fine gold values, instead of the present system in which the output is stated in ounces of gold with the alloys, which depreciate the value.

Reciprocity among mining companies is now almost general at Kalgoorlie. With a good understanding such as this, companies working on similiar ores, and under the same general conditions, can effect a saving of expenditure in many directions. For instance, the engineering, metallurgical and mining results of

the various concerns can be systematized under a common system, and economy exercised in the carrying out of the experiments, methods of working, and selection of supplies and machinery. Then again such an arrangement as this offers great facilities for the development of certain areas which, from the occurrence of faults in the deposits, or from their geographical position, may be difficult of access to the mine owning same. An example of this was the discovery of the Golden Link continuation of the Lake View Lode, when cross cutting from the Lake View South main shaft.

A pleasing feature of the year's work has been the steady increase in gold production, and that increased milling power is receiving the attention of the companies. It is only a matter of a few months more when the present gold yield of nearly three tons avoirdupois monthly will be substantially increased. In the Great Boulder Proprietary there is good ore and plenty of it down to the 1,750-foot level, which is the deepest point yet reached in this mine. The Horseshoe, Ivanhoe, Perseverance, Kalgurli and Associated have proved their lodes to be strong and of high average value down to a great depth, while the Oroya Brown Hill mine, whose main workings are on one of the richest bonanzas in the world, continues to open up marvelously well and is fast coming to the front as a gold producer. It is a matter of regret, however, that apart from the fourteen or fifteen mines, little or nothing has been done to exploit the large area of ground held under lease in the district. Many of those non-producing blocks have been only superficially prospected, and if thoroughly tested, would perhaps quickly prove valuable holdings.

Taking the mines individually, no more reliable information as to the value of the Kalgoorlie lodes can be obtained than that supplied by the main ore bodies in the Great Boulder Proprietary.

The production of gold from this mine to the end of last year has been 896,792 ounces, (equal to $27\frac{1}{2}$ tons avoirdupois) realizing \$15,593,752. The grand total of this company's dividends during the nine years of its existence amounts to \$7,376,138, or nearly

eight times its present nominal capital—a good record. The mine is opened up to 1,750 feet, down to which point its main ore chute has proved highly payable for a maximum length of over 800 feet and for a width ranging from 7 feet to 30 feet. The mine is indeed surpassing itself in depth, and a recent official announcement to the effect that at the lowest level the main lode is worth \$28 per ton, over a width of 30 feet, seems to suggest that the property, despite its already brilliant record, is but at the beginning of its career. The intersection of 30 feet of rich ore at the deep level proves, that the Boulder's main lode is holding down and preserving its grade in deeper ground, and also that in the last 150 feet in depth, it has almost doubled its width, and what is of importance, it constitutes the final answer to certain foreign (American and German) critics, who years ago described the Kalgoorlie field as "a superficial show." When the Boulder lode was first opened up it was about 20 feet east of the main shaft, and remained approximately in that position down to about 200 feet when it dipped westward, crossing the shaft until at the 800-foot level it was over 130 feet west of the shaft. At that point it looked as if its westerly underlay would carry it into the Golden Horseshoe lease. It, however, remained almost vertical between the eight and ninth levels, and then turning eastward, it came steadily toward the shaft again and should pass through this point before a vertical depth of 2,000 feet is reached. The development of the mine's other ore-bodies continues productive of excellent results, especially in regard to the large and rich sulpho-telluride formation (supposed by many to be a slice of the Horseshoe No. 4 lode intersected a few months ago with the main shaft at the 1,000-foot level). This body has so far been opened up for a little over 100 feet in length and has proved of good width and high average value for the full distance driven.

Other work done on the property is the diamond drill boring from the bottom of the Southern shaft (Lane's), to prove the extension of the Ivanhoe East lode. The tonnage now blocked out is estimated at many years ahead of present mill requirements.

There are nearly twelve miles of development footage underground, and about four superficial miles of diamond drill boring.

The ore being refractory, the process in use is one of the two processes already mentioned—dry crushing, roasting, amalgamating, cyaniding in agitation vats with subsequent filter-pressing of the slimes. The ore is trucked from the main shaft brace to Gates crushers, from whence the material is conveyed to Griffin mills, where it is finely ground and then passed into Edwards and Merton roasting furnaces. After roasting, the hot ore is mechanically mixed with three or four times its bulk of weak solution, and the pulp is run into amalgamating and grinding pans of Wheeler type, where the amalgamation of coarse gold amounts to from 35 to 40 per cent. The pulp is then run into series of Spitzkasten, the surplus liquid removed, and then agitated with cyanide solution for twenty hours, and filter-pressed. The average gold extraction is 92 per cent. of the assay value of the ore.

The Golden Horseshoe Estates, Limited, holds an enviable record. During the few short years of its existence it has produced 834,490 ounces smelted gold from 459,769 tons of ore treated, while up to the end of October last, has paid dividends amounting to \$6,856,500. The main ore-bodies have been followed to a vertical depth of 1,100 feet, and are of considerable length, good width and high average grade. A diamond drill bore hole from the 1,000-foot level has proved that the body of ore remains within the Horseshoe boundary. There was some doubt of it so doing, the dip east warranting the conclusion that the lode passed into the Great Boulder lease. However, after the 1,000-foot level, the lode underlays westerly again, and from the bore tests appears to be richer at further depths. The quantity of ore "in sight" on the 30th of July last year, was estimated at 671,126 tons, containing 827,839 ounces of gold, and this, even without the bodies of ore since uncovered, is sufficient to maintain the present monthly output of 18,000 ounces for at least four years. The ore estimated "in sight" but not "blocked out," more than doubles this quan.

tity. Instructions have been given the company's general manager (Mr. J. W. Sutherland) to continue sinking the main shaft to 2,000 feet, and to open out at each 100 feet below the 1,000-foot level, and the work is proceeding at about thirty-five feet per month.

The mill treats about 6,000 tons per month, and consists of wet crushing, amalgamation, classification, concentration, cyanidation and filter-pressing. A smelting plant is also installed for the treatment of the richest ore and concentrates.

The Ivanhoe Gold Corporation, Limited, has from its inception been in possession of a rich, solid, and comparatively free milling series of ore lenses, which, backed up by shrewd and economic management, has enabled this company to enjoy a prosperous career. Three main lodes traverse the full length of the Ivanhoe lease, and these bodies are known as the Middle, East and New lodes. Down to the deepest point mined the two first named range from 9 feet to 10 feet in width, and have been proved of average grade for a length of about 700 feet. The New lode is a narrow vein, having an average width of barely two feet, but of high assay value. The Boulder Loop lode, and a slice of the rich Horseshoe No. 4, or boundary lode, also strikes across the southeast corner of the property. Development work has been pushed during the past year; a new steam hoist has been put in capable of lifting from 3,000 feet, and over \$200,000 has been expended for the purchase of new machinery and surface equipment. On the 30th of June last the ore reserves totaled 499,135 tons, estimated to contain 481,656 ounces of gold, and since then further development has materially increased this reserve. The method of ore treatment is wet crushing with stamps, amalgamation, cyaniding and filter-pressing, the concentrates and rich telluride ore being roasted in Edwards furnaces. To September 30th, the Ivanhoe has yielded 580,688 ounces of fine gold from 515,458 tons tested, and paid in dividends \$3,944,500.

The Lake View Consols is now under the general management of Messrs. Bewick, Moreing & Co. who have envolved order from the chaos caused by the slipshod supervision of former managers. Since the above company has taken charge 35,000 tons of ore have been treated for a yield of 105,000 ounces of fine gold, the ore reserves have been trebled in bulk and the working costs of mining and ore treatment reduced from \$11.92 to \$6.64 per ton. So far the Consols has been proved to a vertical depth of 1,400 feet, at which point ore-bodies known as the Main and Perseverance lodes are now being opened up. This mine has been handicapped with an obsolete ore treatment plant, consequently crushing operations have not proceeded very satisfactorily. This plant has now been replaced with a new stamp mill, the process being the "Diehl." Up to September 30th last, the Lake View Consols had produced 736,544 ounces of gold, recovered from 450,585 tons of ore and has paid dividends amounting to \$6,431,250.

The Boulder Main Reef is another property under the management of Messrs. Bewick, Moreing & Co. The main shaft has reached a vertical depth of 1,371 feet. In the mine's bottom levels the ore is of variable width and quality but of average payable value. The ore reduction plant consists of Krupp ball mills, four Edwards roasters, Spitzkasten, cyanide agitation tanks and filter-presses. The output to date is 95,869 tons for a yield of 119,028 ounces, and has paid dividends of \$127,400.

Another mine under the above company's management is the Oroya Brown Hill, estimated reserve, 212,000 tons of ore, valued at about \$9,000,000, the majority of the ore being high-grade, assaying from two to four ounces per ton.

The Hannan's Star, at the south end of the Golden Mile, has three lodes of small width but of average values. The ore is dry crushed and then treated by Diehl bromo-cyanide process. The stone is delivered on to a 15-inch Blake-Marsden rock breaker, and thence to two No. 5 Krupp ball mills, where it is crushed to 30-mesh. An elevator and conveyor then conducts it to a revolv-

ing arm mixer, where water is added. The wet pulp passes to Spitzkasten, the sands going to two 12x6 feet copper amalgamating tables, and thence to a Krupp flint mill, where they are slimed. The slimes are again settled, and the pulp, containing about 50 per cent. moisture, is treated with bromo-cyanide and filter-pressed.

In the Associated Gold Mines, Limited, recent discoveries in the mine's deepest levels justify its being described as a very much improved property than it was twelve months ago. Adversity's mists, which once enveloped this concern have rolled away, and in future it should yield a golden harvest. Most of the ore now being developed and added to the already large tonnage of reserves, is being opened up on the western side of the main workings, where the lode channels are of great width and high average value, and the management confidently expect to intersect within its borders that great bonanza, the Brownhill chute. This body has now been followed southward across the Aroya North block, to within 100 feet of the Associated, and so wide, so strong and so rich is it at that point, that its continuance further southward into the latter property is almost certain, and as this is one of the richest telluride and free gold ore-bodies yet discovered in Kalgoorlie, its continuance will be an acquisition to the Associated.

The plant has been greatly modified and altered during the year. One outcome of this work will be a substantial increase in the tonnage and a considerable reduction in working costs. The ore reserves now blocked out are estimated to be equivalent to nearly three years' mill supplies, based on a monthly production of about 7,500 ounces. Up to September 30th last the Associated has treated 276,785 tons, for a total yield of 361,646 ounces fine gold, and has distributed \$1,755,617 in dividends.

To date, the Associated Northern Blocks, Limited, has treated 26,715 tons of ore for an aggregate yield of 154,521 ounces, and has paid in dividends \$1,283,800. Its main source of ore supplies is a rich telluride chute, which bears north and south at a flat angle, the cream of the ore being found in bunches, sometimes very large. The ore now in sight is estimated at 57,350 tons, of

an average value of \$32 per ton. Although this appears to be a small reserve tonnage, there is good reason to believe that a much larger quantity of payable ore will be exposed in the course of further development. A good ore reduction plant has just been erected, the process of treatment being similar to that in operation at the Great Boulder, and is as follows:

The ore is delivered direct from the trucks into No. 5 Gates rock breakers, and thence tipped into a 300-ton bin, from which the partly crushed material is elevated into a series of Krupp ball mills, and the finely pulverized pulp fed into Merton furnaces, thence the hot roasted ore is discharged via push conveyors into mixers, thence into amalgamating pans. In these the coarse gold is extracted from the sludge, which is put through Spitzkasten, the sands being run into vats and percolated with cyanide solution, and the slimes charged with solution and filter-pressed.

The Kalgurli Gold Mines, Ltd. The area of this property is 18 acres, and its main shaft is sunk in the middle of the big lode channel which ranges in width from 100 feet to 150 feet. So far 1,050 feet is the deepest level. At this point the ore was met 90 feet west of the shaft and has been driven on for a length of 130 feet. The ore averages \$21 per ton. The Kalgurli is remarkable for the great width of its short lenses of ore. At the 640-foot level the main stope has an average thickness of 45 feet over a length of 150 feet, and the 200-foot level stopes average 110 feet wide, while the lode across the face of the south drive at the 850-foot level has a total width of 125 feet. The Kalgurli ore is extremely refractory, only 3 per cent. of its assay value occurring in the form of free gold. For the year ending July 31st last 45,125 tons were treated, for a return of 44,261 ounces fine gold, while the gold output for the succeeding two months was 9,445 ounces recovered from 8,020 tons treated.

A shade under 10 per cent. of this quantity was recovered by amalgamation on the copper plates, and in the grinding pans after roasting. The average grade of the ore treated was \$18 per ton and the average cost of working now stands at \$6.72 for mining,

development, milling and administration and depreciation allowance. \$323,400 was paid in dividends during the year, out of \$843,957 gold won, making a total of \$3,644,385 paid shareholders since 1897 when the first dividend was distributed.

The ore treatment adopted is a combination plant consisting of dry crushing, roasting, classification, and cyanidation with filter pressing. In detail the ore is delivered from the trucks on to a grizzly, and thence into a Gates ore breaker, and the partially crushed ore carried by an aerial tramway up a hill to the mill into a large bin whence it is delivered into a series of No. 5 Krupp ball mills where the ore is pulverized to about 40-mesh. An alternative arrangement is installed whereby the ore may be taken through revolving ore dryers and thence elevated to the bin, but this machinery is rarely used as the ore from the mine comes up fairly dry, occasionally a chute of ore occurs that is wet and then the material is diverted through the ore dryers. The pulp is discharged from the ball mills into a long steel ore bin, whence it is delivered by a series of feeders (of a peculiar but a most efficient type) into nine Edwards roasters. The roasted pulp is then taken via a scraper conveyor to a mixer, and thence elevated to a series of Spitzluten where it is classified into sands and slimes.

The sands are passed over amalgamating plates and Halley percussion concentrating tables, the gangue going into cyanide leaching vats (double process). The slimes from Spitzluten are taken to slimes settlers (or Spitzkasten) the clear water returning to head-water tanks, and the thickened slimes passed to a series of five vertical Montejus which are arranged in a circle. The agitation is done with compressed air introduced into the Monteju through a perforated coiled pipe, which gives the pulp a swirling or vortex motion. After agitation for a period of from four to six hours, the Montejus are closed, compressed air applied, and the mass forced into filter presses. The solution being afterwards precipitated in the usual manner.

The Perseverance possesses two ore-bodies known as the Lake View and Perseverance lodes, which extend through the whole

length of the lease. Both lodes are of good grade and have been worked to a depth of 900 feet. The driving of the 1,100-foot level has recently been in progress and the manager reports that the bore has pierced the Perseverance lode opposite the main shaft. The body is almost 20 feet thick, averaging over \$20 per ton. The estimated reserves in the mine are three and one-half years supplies for the mill, which is treating an average quantity of 11,500 tons per month.

The process of ore treatment used is somewhat similar to that at The Great Boulder Proprietary. The ore passes through a No. 5 and thence through two No. 3 Gates ore breakers, and is delivered by belt conveyors from the main ore bin to Griffin mills. The pulp is thence conveyed to six Holthoff-Wethey roasters, the dust being taken through up-casts into a long brick settling chamber. After roasting the pulp is cooled on a long hearth, elevated to a Spitz mixer, and then distributed over a series of 8-foot amalgamating and grinding pans where the whole of the pulp is slimed, and thence passed on to a series of mechanical agitating vats, thence to filter presses. The discharge cakes are delivered on to a belt conveyor and elevated at an angle of about 30 degrees to the top of dump. The solutions are taken to the extractor boxes and the gold precipitated on zinc shavings.

There are several other properties with small plants, but the above are the great producers.

The fuel used at Kalgoorlie and all the eastern and northern gold fields, both for boiler and roasting purposes, is the product of the district, a heavy, hardwood, locally called "salmon gum." It is a eucalyptus (*Eucalypti Beatsoni*) that grows to about 36 inches girth and about 60 feet high. Another hardwood used is the She-Oak (*Casuarina-quadrivalvis*), but this does not give the same heat nor is as good as the former for fuel.

The best coal from New South Wales costs about \$11.50 per ton, delivered at Kalgoorlie. The local firewood costs \$4.08 per ton, and approximately two tons of wood are equal to one ton of N. S. W. coal in calorific value.

The coal from the Collie Coal Fields of Western Australia, a low-grade brown variety of lignite, costs about \$5.60 delivered at the mines, and in calorific value compared with firewood, is 1 to about 1 $\frac{1}{4}$. The average cost of horse-power per month is \$18.50, or \$222 per year.

Labor costs are as follows:

Underground miners	\$3.60 per day of 8 hours.
Underground machine men	3.84 per day of 8 hours.
Carpenters	3.84 per day of 8 hours.
Masons	3.84 per day of 8 hours.
Laborers	2.88 per day of 8 hours.
Engine drivers	4.20 per day of 8 hours.
Firemen	3.60 per day of 8 hours.
Millmen	3.60 per day of 8 hours.

The following is a recent analysis of ore from one of the large mines on the Golden Mile:

	<i>Per Cent.</i>
Insoluble	62.80
Fe	3.85
S	4.40
Ca	7.75
Mg	3.50

I have received the following comparative summary, showing grade of ore, costs, profits, etc., of the principal West Australian gold mines for the years 1901-1902, compiled by Mr. J. W. Sutherland of the Golden Horseshoe Estates:

	Grade of Ore.	
	1901	1902
	1502 Ozs.	1402 Ozs.
<i>Per Ton Treated.</i>		
Gross value	30.87	23.64
Costs	15.90	13.92
Profit	15.07	9.72
<i>Details of Cost Per Ton Treatment—Extraction</i>		
Mining	3.21	3.31
Development	2.81	2.19
	6.02	5.50
Reduction	7.47	5.82
Maintenance and Management .....	.94	.69
<i>Expenses</i>		
Depreciation	1.47	1.79
	15.90	13.80
<i>Per Ounce Produced</i>		
Gross value	17.43	18.94
Costs	10.59	9.84
Profit	6.84	7.10
<i>Development</i>		
Cost, per foot.	25.52	24.80
Diamond drill'g; cost per ft. not available		3.87

In conclusion, I would express my obligations for many particulars in this article to *The Western Argus* of Kalgoorlie, *The Western Mail* of Perth, and other papers; also much data sent me by various correspondents in Westralia.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. VII, pp. 228-236.

THE NEW GEOLOGY AND VEIN FORMATION.

BY FRANKLIN R. CARPENTER, PH.D.

DISCUSSION

BY W. F. EDWARDS.

DENVER,
PUBLISHED BY THE SOCIETY
MAY, 1904.

THE NEW GEOLOGY AND VEIN FORMATION.

BY FRANKLIN R. CARPENTER, PH.D.

Meeting of the Society April 2, 1904.

DISCUSSION.

W. F. Edwards.—There are three steps in the development of a theory: (1) An assumption; (2) an hypothesis; (3) a theory. The first may not be more than a mere guess, while the second requires some facts to support it, and the third requires that all known related facts be consistent with it. The nebular assumption, even if originating with philosophers who were long on speculation and short on facts, has had sufficient support to give it a first-class record in the second step as a working hypothesis.

In a strict sense the nebular hypothesis belongs to the far-reaching cosmogony and is more directly a subject for the astronomer, since it is our knowledge of other members of the solar system and of nebulae and stars rather than that of the earth that furnishes facts in support of the hypothesis. However, the geologist is interested, for even paleontological geology needs some kind of working hypothesis concerning the anterior condition of the earth, since it may be fairly assumed that subsequent mutations were in some measure conditioned by it.

I am inclined to believe that geology as a practical working science will not be materially changed in any respect by substituting accumulation of cold (or hot for that matter) discreet matter ("planetesimals"), for condensation of a gaseous form of matter at high temperatures. So far as practical geology is concerned, I am inclined to agree with the father of the Plutonic

Geology, that it is in no part of the province of geology to search for the origin of things. In geological research "no trace of a beginning and no prospect of an end" has been found.

About a hundred years ago there was a great and heated contest between the Plutonists and Neptunists. The one cried fire and the other cried water. Subsequently it became clear that there was right on both sides, and that the mistake made was in assuming that all things must be from fire or water alone. Today we have the advocates of the nebular and the meteoric hypotheses; the one crying gas and heat and the other crying stones and low temperature. Subsequent research may show that both have good support and that both hypotheses are in the pathway to the working theory. The nebular hypothesis, by reason of its age, cannot be said to have any advantage over the meteoric hypothesis, even though the latter is (in its latest form) scarcely two decades old, for in these times twenty years is time enough for a searching inquiry into the merits of an hypothesis. It is the astronomer and physicist, however, in this case, that must give the test, as I have before intimated.

A brief historical sketch will illustrate this and bring out some interesting facts. One hundred and fifty years ago nothing was known of the nature of *nebulæ*, and only a half dozen were known to exist and could only be described as patches of light. However, Kant boldly assumed that there was the closest relation between them and stars, and that stars were an evolutionary product from them. Some forty years later La Place independently made the same assumption, but assumed, in addition, that the *nebulæ* were bodies of gas at a high temperature. It is not intended to give a general outline of La Place's hypothesis. Sir William Herschel adopted this view which was enough to give a very authoritative value to the hypothesis, and it held the field for some years with no scientific opponent. When Lord Rosse made his great reflector and began to use it he imagined at least that he could see, on clear and still nights when he could employ high powers, that the *nebulæ* showed a possibility of resolvability, and

here doubt arose as to the soundness of the nebular hypothesis as given by La Place. Later on the spectroscope came into use by astronomers, and one of the first verdicts was that the nebulae were gaseous, and were simple permanent gases, and that, therefore, Rosse was mistaken. Moreover, there could be no relation of the sun and fixed stars as known, and these nebulae which were then considered as surely simple permanent gases. This verdict was given in the early part of the seventh decade of the nineteenth century, but the nebular hypothesis continued to have its advocates and has them to this day.

In the year 1868, spectroscopic observations made in India during an eclipse of the sun, were destined to re-establish the relations of the nebulae and stars, even though only half a decade had elapsed since the spectroscope had decided against any such relation. The spectrum of the sun taken at this time showed a line that could not be reproduced by any terrestrial substance then known under any known condition. Lockyer assumed a new substance, and called it helium. Within a year several other new lines had been found in the spectrum of the sun, none of which corresponded to any line produced by any terrestrial substance.

The next important step in getting the relationship of the stars and nebulae re-established was made in 1888, when Dr. Hillebrand, at Washington, in experimenting with the mineral uraninite, found that it gave off a gas which he finally concluded was nitrogen, although he was aware that the spectrum of the gas seemed at times to give lines not to be accounted for by any known element.

In 1894, Lord Raleigh and Professor Ramsay announced the discovery of argon associated with nitrogen. This led to an investigation of Hillebrand's nitrogen from uraninite by Professor Ramsay who, to his surprise, found it to give the unknown orange line found in the spectrum of the sun obtained in India in 1868. This was followed by other work by Lockyer, who found that the gas from uraninite gave all the unknown lines of the solar atmosphere.

Meanwhile, beginning with 1886, these same unknown lines had been found in the spectrum of the nebulae in Orion, and in many stars, including stars like Arcturus, whose spectrum is like that of our sun, and the stars of a few line spectrum, such as the chief stars in Orion.

The relationship of the stars and nebulae to the solar system and to one another was now on a very sound basis as compared with anything before, and this relationship was independent of thermodynamics, and even went so far as to declare that some so-called stars were really nebulae with strong condensation centers. Moreover, the relationship has been extended till all stars are classified under six types, which represent the order of the processes in their evolution from nebulae, and are as follows. (1) nebulae and bright-line stars; (2) mixed fluting stars; (3) dark-line stars (ascending temperature); (4) broad hydrogen-line stars; (5) solar stars (descending temperature); and (6) carbon-absorption stars.

Meanwhile other considerations of new and variable stars, comets and meteors, taken together with these spectroscopic revelations, have led some astronomers to adopt Professor Tait's suggestion of explaining the various phenomena by postulating meteorites instead of hot gases. This does not militate against the nebular hypothesis of La Place, as it had already been shown that the most natural consequence of this hypothesis was to create a multitude of very small bodies instead of a few large ones.

Now, let us go back to the year 1848. In this year Dr. Mayer, the author of the expression "mechanical equivalent of heat," as a result of investigations on this equivalency, found that the sun's heat could not be accounted for by combustion or mere cooling, and introduced the meteoric hypothesis of supply. He showed that meteoric bodies falling into the sun would furnish from five to ten thousand times as much heat as the combustion of an equal weight of carbon. This hypothesis did not long survive, for it became evident that the enormous amount of matter to

keep up the sun's heat in this way would materially affect the sun's mass, and consequently its gravity effect in the solar system, and at the same time slow its rotation on its axis.

However, the hypothesis held long enough to be applied to the earth as the source of its materials, but here again it was abandoned on the ground of gross inadequacy.

In 1854 Helmholtz gave what stands to this day as the soundest reason for the principal supply of the sun's heat, namely, contraction of its size and condensation of its mass. It was shown that a contraction of one mile of diameter in twenty-five years would account for the heat given off by the sun. At this time he pointed out that in La Place's hypothesis it was not necessary to endow the primitive gases with a high temperature.

As Newcomb has said, we cannot call this proved till we can, by measurements, prove the contraction of the sun, but it affords such a satisfactory explanation that it is not doubted by anybody, and is one of the strongest proofs of the probability that the sun has at some time extended even beyond the bounds of the planetary system as known to us. Helmholtz's hypothesis is, then, a complement to the nebular hypothesis, and has led to the modification that dispenses with an initial high temperature.

In 1871, Sir William Thompson (Lord Kelvin), in a report to the British Association for the Advancement of Science, said of the nebular hypothesis that "This hypothesis was invented before the discovery of thermodynamics, or the nebulae would not have been supposed to be fiery." Thermodynamics showed conclusively that a gaseous body, in condensing into one like the sun or the planets, would grow hotter and hotter until a certain stage was reached, after which it would grow cooler. This, however, did not tend to overthrow the nebular hypothesis but simply to modify it.

In this same report attention is called to Professor Tait's suggestion that the luminosity and spectroscopic appearance of the nebulae and comets might be explained by assuming gaseous exhalations due to collisions of meteoric stones. However, the

view that nebulae were permanent incandescent gases practically held sway for fifteen years after this, it being held by many that they were residual gases of primitive matter after the condensation into suns and planets had taken from them most of the elements.

The nebular hypothesis of La Place was again in serious trouble when the astronomers discovered that the satellites of Uranus and Neptune revolved about their primaries in a direction opposed to all other known revolutions in the solar system, and that the inner moon of Mars revolved about it at a higher angular rate than that of the planet on its axis. This most serious stumbling block was, however, destined to throw light on some of the mathematical obscurities of the hypothesis as applied to rates on the solar system in general.

Mr. Darwin's researches on the effects of tidal friction on the relations of the earth and moon led to a most remarkable result, namely, that its effect is to destroy the rotation of the body on which the tides were raised with respect to the body raising the tides. This is exactly the case of the earth and the moon, the moon presenting the same "face" to the earth continuously.

Many other interesting things were suggested by this research, but they are not yet susceptible of the same analytical proof that obtains in the case of the earth and the moon. Among these suggested things is that a satellite may change from direct to retrograde revolution under the proper conditions, and that also a satellite may slow up and increase its distance from the primary, or speed up and decrease its distance from the primary.

This brief historical outline shows: (1) that the swaddling-clothes which Dr. Carpenter mentions in his paper as having prevented a healthy growth of geological science have been torn and patched for a century, and that the patches have not kept the garment whole long enough to prevent a healthy growth of geological science; (2) that the adoption of the meteoric hypothesis does not necessarily imply the rejection of the nebular hypothesis as modified by the theory of thermodynamics and the theory of

the conservation of energy, nor the necessity of dealing with the earth as a body that has always had a cold surface; (3) that the "now widely discredited nebular hypothesis" has survived all the attacks made against it and is today the strongest it has ever been, not being shown to be inconsistent with a single fact.

The "New Geology" seems to me to be clearly entitled to credit for two new features in the meteoric hypothesis: the substitution of the word *planetesimal* for the word *meteor* or *meteorite*, and the cold surface feature. The first needs no discussion, and the second I cannot discuss on account of lack of access to the original papers. However, I may suggest that the evidence is most probably that belonging to the real province of geology, and if well supported the cold surface idea will again disturb the nebular hypothesis, but perhaps it will be destined, like the other disturbing elements of the past, to throw more light on the hypothesis and strengthen it.

SOME NOTES ON VANADIUM.

By W. F. EDWARDS.

DENVER,
PUBLISHED BY THE SOCIETY
MAY, 1904.

SOME NOTES ON VANADIUM.

BY W. F. EDWARDS.

Read at the Meeting of the Society, May 7, 1903.

In the first year of the nineteenth century Del Rio pointed out the existence of a new metal found in a lead ore of Mexico. He named the metal erythronium, a name derived from the Greek word meaning red, suggested by the color of the salts made from hot acid solutions. A few years later Del Rio concurred in an opinion that the supposed new metal was really only an impure oxide of chromium, which opinion held good for more than a quarter of a century.

In the year 1830, Stefstroem discovered a metal in a Swedish iron ore near Taberg, which yielded bar iron noted for its malleability. He named this new metal vanadium, from Vanadis, a name of the Scandinavian Goddess, more commonly known as Freia.

Notwithstanding that Woehler, in this same year showed that the discovery of Del Rio in 1801 was that of a new metal, as he had at first supposed, and that the metal was the same as that found in the Swedish iron, and that the mineral of Mexico was a vanadate of lead, yet the name vanadium was retained and the name erythronium was lost.

Berzelius carried on extensive investigations with the materials obtained by Stefstroem, and published the results in *Poggendorff's Annalen* in 1831. He described a large number of vanadium compounds and drew the conclusion that the element resembled chromium, a view universally adopted up to the time of

Roscoe's work, in 1867. Roscoe's work showed that the element was related to nitrogen, phosphorus and arsenic much more closely than it was to chromium.

Up to the time of Roscoe's work there had been considerable confusion concerning the atomic weight of vanadium, the number having been given as 137, or 68.4, instead of 51.4, the number now in use, based on the number 16 for oxygen. This discrepancy was due to the error of supposing the oxide VO (now called vanadyl), or the nitride VN to have been the element itself.

The metal now has a well-established atomic weight, and its chemistry clearly places it in the phosphorus group. It forms five oxides, which correspond very closely with those of nitrogen. It forms chlorides and oxychlorides corresponding very closely with those of phosphorus. Its acids and their salts are like those of phosphorus, there being meta, pyro and ortho salts under much the same conditions that obtain for the similar salts of the phosphoric acids. It is like arsenic, in that it acts as a metallic base in the formation of salts of the ordinary acids, and forms sulpho compounds with ammonium sulphide, and is reduced from the vanadates to a lower oxide by hydrogen sulphide in acid solutions, but hydrogen sulphide does not precipitate a sulphide of vanadium in these acid solutions.

Thalen has shown, by using the chlorides, over fifty visible lines in the spectrum of vanadium, lying between wave-lengths 6240.5 and 4085. Four of these lines are shown in the spectrum of the reversing layer of the sun. I am not aware of any lines in the ultra violet or the ultra red belonging to vanadium. The spectrum of vanadium is of little value, so far, in the study of its chemistry, and the absorption spectra of its colored solutions are not characteristic.

The thermo and electro chemical constants of vanadium compounds are, for the most part, uninvestigated.

Until quite recently vanadium has been considered a very rare element, as occurring as an essential constituent in only a few very

rare minerals, even though it was known that it was quite widely distributed as a trace in terrestrial matter, and existed in the sun.

It exists in no less than ten different minerals, with variations, but is usually a vanadate. Silver, lead, copper, zinc, bismuth, calcium, barium and potassium are the more commonly occurring metal bases of these vanadates, as many as three of them sometimes belonging to the same mineral.

In the only four divisions of the United States having a common corner-stone—Colorado, Utah, Arizona and New Mexico—vanadium can scarcely be considered as a rare element, as it not only is widely distributed through this district but is also of sufficiently high per cent. content in many localities to make its commercial extraction worthy of consideration.

In Colorado and Utah it is distributed through many sandstones, in the cementing material, in amounts varying up to 7 per cent. of the pentoxide. In these sandstones it is mineralogically more or less closely related to roscoelite, volborthite and mottramite. Occasionally the trioxide of vanadium is predominant.

Among other varieties of minerals in these two states is the new mineral, carnotite, which is essentially an uranium vanadate. This mineral has been the source of a great deal of disappointment to the many uranium-radium hunters, due to the supposition that any sandstone carrying a yellowish cement material must contain uranium and radioactivity due to contained radium. I have examined several of these sandstones, and find many of them carrying vanadium without any uranium at all, and others carrying varying percents of vanadium and a very small per cent. of uranium—usually less than one-half per cent.

I have examined sandstones from Utah carrying copper and vanadium in the cementing material, but in varying proportions in different layers of the sandstone from the same ledge. In a particular case three different samples were taken from a hundred pounds taken from the same ledge; one contained 4.93 per cent. of vanadium pentoxide and 4.9 of copper, a second piece contained 6.67 per cent. of vanadium pentoxide and 2.48 per cent. of cop-

per, while a third contained practically no vanadium at all, but about the same per cent. of copper as the first. In the first and third, containing the higher per cent. of copper, the sandstone was of a greenish blue cast of color and contained considerable carbonates while the second was of a yellowish cast of color and practically free from carbonates. All three were practically free from uranium, but were considered in the locality from which they came as fair uranium ores.

In New Mexico and Arizona vanadanite and vanadiferous mimetite are the prevailing vanadium minerals. These are quite abundant and in many cases very rich in the vanadium content. In many cases the lead chloride has been changed into carbonate, the chlorine being in some cases almost entirely wanting.

Vanadium compounds have been chiefly of interest to the scientific chemist but have been shown to have commercial possibilities in at least four different industries, namely, ink-making, coloring fabrics black, by aniline, coloring leather that has been tanned with gall nuts, and in the steel industry.

The ink is made by mixing a neutral solution of ammonium vanadate with gum water and a solution of gallic acid. This ink is not destroyed by acids or alkalies and is not bleached out with chlorine, but for some reason not well understood is not permanent. Berzelius was the first to suggest this ink, and his friend Woehler, to whom he wrote letters with it, was the first to discover its lack of permanency.

For dyeing the chlorides are used in connection with a chlorate as an oxygen-carrier for forming aniline black on the fabric by using aniline hydrochloride. The amount of vanadium chloride required is a very small fraction of that of the aniline hydrochloride used. This process gives a splendid and permanent black, but unfortunately there are difficulties in the drying to be overcome. Different tints seem to be caused by different rates and temperatures in the process of drying.

For this industry the vanadium chloride can be easily obtained from vanadinite by mixing the finely ground vanadinite

with from two to four times its weight of lampblack, to which a little oil has been added, and heating to a high temperature, after which it is cooled to about three hundred degrees centigrade and treated with dry chlorine gas, when the chloride distills over and is collected in suitable receivers.

Its use with leather tanned with nut galls is very simple. About a 1 per cent. solution of neutral ammonium vanadate in water is applied to the leather, which is afterwards washed and dried.

In the steel industry the metal or ferro-vanadium is required. The first step in its preparation is the extraction of the metal in some form from its ores. The second step is the production of the ferro-vanadium in the electric furnace or by the aluminothermic process.

The metal has been produced in France in the electric furnace, by heating the oxide intimately mixed with carbon, seventy volts and one thousand amperes being used. When only two or three hundred amperes were used almost no vanadium was obtained, and when one thousand amperes were used there was always more than 17 per cent. of carbon mixed with the metal.

Ferro-vanadium has been made by incorporating the oxide of vanadium into carbon electrodes which form the anode in a furnace having molten steel for the cathode. Over this molten steel floats melted calcium carbide containing iron fluoride in which the anode is suspended. Vanadium fluoride is formed at the anode and displaces the iron fluoride, which must be renewed from time to time in the electrolyte. The vanadium alloys with the molten steel cathode.

Proctor Smith, in England, has made ferro-vanadium by the aluminothermic process. He first made an impure vanadic oxide containing 18 per cent. of the oxide and 77 per cent. of ferric oxide, containing some silica and other impurities. This was powdered and mixed with powdered charcoal in the proportions of eight to two and introduced in small portions into a crucible after

an electric arc had been established in it. When the mixture is fused one part of aluminum is added in very small portions.

Heat enough is produced to melt the alloy, which is heavy and falls to the bottom of the crucible.

The alloy formed was very brittle and contained 16 per cent. of vanadium, 70 per cent. of iron, 2 per cent. of silicon and 12 per cent. of carbon and aluminum.

Instead of using charcoal and an electric arc in the crucible, the oxide may be mixed with powdered aluminum and portions introduced into the crucible from time to time. The first part is ignited by placing on the top of it a cone-shaped portion of a mixture of sodium peroxide and aluminum dust in the proportion of about five to one, and firing it with a hot iron.

This process gave an alloy containing about 26 per cent. of aluminum.

A steel was made having 0.56 per cent. of vanadium, and compared with another practically like it, except that it contained no vanadium and only about a third as much silicon, with the result that the elastic limit and tensile strength were found to be very much higher in the vanadium steel.

Another experiment showed that vanadium steel is very hard when tempered and very soft when annealed.

There is room for further investigations concerning the effects of vanadium in steels made and treated under differing conditions, but enough has already been done to warrant careful attention to the production of ferro-vanadium. So far as our present knowledge is concerned, it resolves itself into the problem of producing ferro-vanadium at a low enough price to successfully compete with chromium and nickel alloys of iron.

The analytical chemistry of vanadium will be an important factor in the further investigations of this subject, and inasmuch as the subject-matter of this chemistry is scattered here and there, and has not been brought to any very definite state, I shall devote the remainder of this paper to it, making no attempt to exhaust the subject or to add anything new to it.

The detection of vanadium is not difficult, and yet it is not like copper, for example, subject to a definite serial treatment with a certain final test at the end, no matter what inorganic salts may be in the complex. This is attested by the fact that the element is placed in the copper-tin group in one of the two leading college text books on qualitative analysis, and in the iron-zinc group in the other.

In many ways this element supports the copper-tin group position, but analytically it does not, for the simple reason that it is not precipitated by hydrogen sulphide in a hydrochloric acid solution. Like iron salts (ferric) and chromates and arsenates, it is reduced by hydrogen sulphide charging the solution with sulphur, but it is not precipitated by it even when the solution is acidified with acetic acid.

Vanadic salts form soluble sulpho salts with ammonium sulphide, as arsenic, antimony and tin do, and a sulphide may be precipitated from this solution by the cautious acidification of the solution.

In the iron-zinc group its behavior depends somewhat on its condition of taking a part as a base or as an acid radicle. If it is a vanadate or has been oxidized by peroxide of hydrogen after reduction by hydrogen sulphide (or any other reducing agent) it acts like a phosphate in that it will be precipitated with iron and aluminum and barium salts by ammonium hydrate. The basic acetate method does not serve well for its separation from iron, and it is all around not amenable to schematic treatment in the iron-zinc group by the ordinary processes.

In the method whereby separation of the iron-zinc group bases takes place after the precipitation with ammonium sulphide, the vanadium will be in part in the precipitate and in part in the solution that is carried on for the next group (the alkaline earth group.) If strong ammonium hydrate solution has been used in large excess and the solution is not too high in precipitated bases the greater part of the vanadium will be in the filtrate from this group. The filtrate will be colored an intense cherry-red if there is any considerable amount of vanadium salts in the solution. As

before suggested, it can be precipitated from this filtrate by cautious acidification with acetic acid.

When ammonium carbonate is added to this ammonium sulphide filtrate containing the sulpho salt of vanadium the sulpho salt is not affected by it unless salts of barium are present, when it seems to be decomposed, as is indicated by the loss of the red color. I am unable to state what the change is, but I expect to give it further attention.

Since the vanadium salts play such a very unsatisfactory part in any scheme for systematic analysis, it is usually detected by some special test. Among the special tests, the cherry-red sulpho salt test just described, the hydrogen peroxide test, the ferrocyanide test, the strychnine sulphate test and the reduction tests—all color tests—are the most commonly used.

Hydrogen peroxide added to an acid solution of vanadium salt gives a red color in solutions having, say one part of vanadium salt in thirty thousand parts of solution. Mixtures of ferric and ferrous salts sometimes give this color, and chromates seriously interfere with it. Chromic salts do not mask the color very much but the chromates mask it so that it is of very little value.

The chromates may be reduced with alcohol and hydrochloric or sulphuric acid, and the excess of alcohol and the aldehyde formed boiled off, after which the test may be applied. Ferric and vanadic salts are not reduced by the alcohol and acid (vanadic salts are reduced by strong hydrochloric acid alone).

The ferrocyanide test is delicate but cannot be applied in the presence of copper, iron, zinc or uranium. It can be applied in the presence of chromic salts, but is very much masked by chromates. The ferrocyanide test is always made in acid solution, preferably hydrochloric acid. A greenish-yellow or very green precipitate or color indicating vanadium.

Vanadium can be separated from the copper and other second-group bases by treatment with hydrogen sulphide in acidified solution.

The zinc can be separated for this test by the ferrocyanide itself by careful additions, if the solution is not too strong in zinc salts.

Iron and uranium can be sufficiently well separated by boiling the solution made alkaline with sodium carbonate to which a little sodic hydrate has been added, some vanadium is carried down in the iron and uranium precipitate, but there will always remain enough in the solution to give a test.

In the test with strychnine sulphate a few drops of the solution containing the vanadium salt is added to a few drops of strong sulphuric acid containing a crystal of the strychnine sulphate. A violet color is at first produced which, after a few minutes, changes to rose color. Here again chromates are liable to mask the test, but dilute chromic salts do not interfere.

Among the reduction tests, that due to tartaric acid is as useful as any. When tartaric acid is added to a solution containing a vanadate or a vanadic salt, the solution is at the first changed to a yellowish color which rapidly changes to a blue color.

Oxalic acid, citric acid, boiling hydrochloric acid, hydrogen sulphide, sulphurous acid, and many other reducing agents, reduce vanadates and vanadic salts to the blue hypovanadium compounds in acid solutions. This blue color test is not very delicate but is sufficiently characteristic.

The microscope may be used to advantage in the detection of vanadium by determining the characteristic crystals of ammonium metavanadate, silver pyrovanadate and thallos chlorovanadate.

When ammonium metavanadate is precipitated from an alkaline solution of vanadic acid by ammonium chloride, the crystals formed are small and of lenticular form, giving a marked polarization extinction in the direction of their length.

When silver nitrate is added to a hot solution of a metavanadate strongly acidified with acetic acid, orange-colored rods are formed. These rods can scarcely be mistaken for the crystals of silver chromate or arsenate, which are formed under like conditions, by any one who has the requisite experience for using these tests at all.

When thallous nitrate is added to a solution of metavanadate containing free ammonium hydrate and ammonium chloride, light yellow hexagonal rosettes are precipitated after some time.

Vanadium may be estimated colorometrically, volumetrically and gravimetrically. The volumetric method is the more often used, on account of its simplicity and fair degree of accuracy.

The colorometric estimation depends on equalizing the color made by a known quantity of hydrogen peroxide when added to a definite quantity of a solution containing the vanadium salt, to be determined by adding an equal amount of hydrogen peroxide and the required quantity of standard vanadate to an equal quantity of a solution of water and acid, and any colored salt that may be in the solution that would interfere with the tint of color produced.

Salts of nickel, copper and chromium are the colored salts that may interfere, and which must be allowed for by adding the same percents to the water solution. This method can not be used in presence of titanium, since it colors the solution in a way not to be disposed of by matching it in the known solution.

A suitable solution of hydrogen peroxide may be made by dissolving about seven grams of sodium peroxide in a fourth-liter of nitric acid (one to two), or sulphuric acid (one to three), and then making the solution up to a liter with water.

A tenth normal solution of ammonium metavanadate may be approximated by dissolving the vanadate in hot water and acidifying with sulphuric acid and evaporating to decompose the ammonium chloride that is a common impurity in the vanadate of the market. The value of the solution is found by titrating with permanganate solution as described below. This solution may be of any strength that is not too strong, and may make the bulk of the water solution with which the unknown is compared, the unknown being made of the same approximate strength by trial before making a final test.

In steel analyses the standard solution is that of a similar but vanadium free steel to which the peroxide and standard vanadium solution is added to match the color of the vanadium steel solution.

The common volumetric estimation of vanadium depends on the absorption of oxygen from potassium permanganate in an acid solution (usually sulphuric acid) in the conversion of the tetroxide to the pentoxide.

The tetroxide is usually formed from vanadates and vanadic salts by adding alkali sulphites or sulphurous anhydride to the acid solution and then boiling off the excess of sulphurous anhydride.

The standard solution of permanganate may be the same that is used for the estimation of iron. One cubic centimeter of a tenth normal solution of permanganate represents five and fourteen-hundredths milligrams of vanadium, or nine and fourteen-hundredths milligrams of the pentoxide.

When the reduction to the tetroxide is made by hydrochloric acid the vanadate or vanadic salt is heated with a large excess of the acid until it is reduced to a small bulk and the operation repeated. Then strong sulphuric acid is added and the heating continued until fumes of sulphuric anhydride are given off to indicate the complete expulsion of the hydrochloric acid. After cooling it is diluted with water and titrated with standard permanganate solution.

This hydrochloric acid method has been applied to the estimation of vanadium in vanadium steels. Briefly stated the steel is dissolved in nitric acid and evaporated to dryness to form oxides. These oxides are dissolved in hydrochloric acid and boiled for a few minutes. The solution is cooled and mixed with ether in a separatory funnel in order to extract the iron salt with the ether. The aqueous solution left after the separation is treated with hydrochloric acid and sulphuric acid and titrated with permanganate as above.

A more common way of estimating vanadium in its alloys with iron is to dissolve the alloy in nitric acid, or hydrochloric acid and nitric acid, evaporate to dryness, fuse the residue with sodium carbonate and extract the vanadate with water. Repeated boiling with water is necessary to extract the whole of the vana-

dium. The solution is acidified with sulphuric acid evaporated to a small bulk, diluted with water, reduced with sulphurous anhydride and titrated with permanganate in the usual way.

The volumetric estimation of vanadium in the presence of iron, without removing the iron, has been attempted by taking advantage of the fact that there is a momentary pink coloration of the solution at the time when the iron is all oxidized and the oxidation of the tetroxide of vanadium is about to begin; or by taking advantage of the fact that solutions of potassium bichromate do not oxidize the tetroxide of vanadium, the iron being titrated by the bichromate and the iron and vanadium together by permanganate.

Either of these methods is of service only in the hands of an experienced analyst who has had experience with these methods in particular. With proper care and experience either method can be made to yield fairly accurate results.

The gravimetric estimation of vanadium depends on the formation and separation of the pentoxide which is then fused and weighed.

The pentoxide may be obtained in three different ways. (1) by precipitating ammonium metavanadate by saturating a solution of alkali vanadate with ammonium chloride and then decomposing the metavanadate by heat; (2) by precipitating mercurous vanadate and then decomposing the washed salt by heat; and (3) by precipitating lead or barium vanadate, decomposing the salt with dilute sulphuric acid, separating the sulphate by filtering and washing, evaporating the filtrates and then igniting the residue.

The first of these ways, while furnishing a very characteristic salt, is not sufficiently accurate for fine work. Ammonium chloride does not completely precipitate the ammonium metavanadate except under the most favorable conditions. This precipitate must be washed with a saturated solution of ammonium chloride so that the dried material always contains ammonium chloride.

In the decomposition by ignition the sublimed ammonium chloride and the ammonia fumes from the metavanadate always carry away some finely divided vanadium pentoxide.

Aluminic and chromic salts and alkali silicates must be absent from the solution of vanadate that is to be precipitated by the ammonium chloride. If any considerable quantity of either is present in the solution it will be discovered when the ignition takes place by the difficulty of fusing the pentoxide formed and by the form of and color of the crystalline compound. When it is pure it fuses easily and gives long striations on cooling, but if impure it fuses with greater difficulty and gives a dark colored mass instead of the reddish crystals.

The solution can be freed from these interfering salts by evaporating it to dryness and extracting the residue with dilute ammonia water. This ammonia water solution may be concentrated, after which precipitation with the ammonium chloride may be carried on in the ordinary way.

The production of vanadium pentoxide by the use of mercurous nitrate is carried out as follows: An acid solution of vanadic acid is nearly neutralized with solution of sodium carbonate, after which a solution of mercurous nitrate and some freshly precipitated mercuric oxide is added to the solution. The oxide is added to insure a completely neutral solution.

One may start with an alkaline solution of the vanadic acid and nearly neutralize it with nitric acid, in which case the mercuric oxide is necessary.

If chromates, arsenates, phosphates, molybdates and tungstates are present they will all be precipitated by the mercurous salt with the vanadium.

In case the interfering elements are such as will not interfere with the volumetric estimation with permanganate, it may be more satisfactory to ignite the mercury salts and decompose the vanadate and then extract the residue with hot water and titrate with permanganate after reduction of the pentoxide with sulphurous anhydride.

The precipitation of vanadates by lead acetate or barium nitrate in solutions slightly acidified with acetic acid is very complete.

Here again chromates, arsenates, phosphates, molybdates and tungstates interfere.

The precipitate of lead or barium vanadate is decomposed by the least amount of sulphuric acid that will suffice. The lead or barium sulphate is then carefully washed and the combined washings and filtrate are evaporated to dryness and the residue is ignited and weighed as vanadium pentoxide.

This method is very accurate when applicable and carried out with care.

Which one of all the methods given is the best to use will depend on the salts in the solution, with the vanadium salts, and somewhat on their relative proportions. The chemist must determine the method for each case.

The estimation of vanadium is not at all difficult in simple solutions containing no salts of other elements. A brief statement concerning the special treatment of some mixtures may be of service in making the necessary separations, and will furnish a suitable conclusion of this subject.

It is already clear that the separation of vanadium from silver and mercurous salts may be brought about by the use of hydrochloric acid; from lead barium and strontium salts, by the use of sulphuric acid; and, from the copper-tin group by the use of hydrogen sulphide in solutions acidified with hydrochloric acid. Since these separations are in general satisfactory, no more will be said about them except to state that the vanadium can be separated from alkaline solutions of vanadates, tungstates and molybdates of the alkalis by the precipitation of ammonium metavanadate by means of ammonium chloride, in the way already described. We have then only to consider further calcium and magnesium salts and those of the iron-zinc group.

Vanadium may be separated from magnesium by precipitating the magnesium with disodic hydric phosphate in the usual way, magnesium not being precipitated as a vanadate in solutions alkaline with ammonium hydrate.

Calcium may be precipitated from neutral solutions of alkali vanadates by means of oxalic acid.

From solutions containing vanadic, ferric and uranic salts, the vanadium can be separated by the use of sodic carbonate and hydrate, as already pointed out, but it is not the most satisfactory for the separation from uranium.

In solutions containing only vanadic and uranic salts, the separation may be made by evaporating the nitric acid solution to dryness and then extracting the uranium with a saturated solution of ammonium nitrate.

If a hot solution of vanadic and uranic salts be slowly stirred into a hot solution of microcosmic salt containing some ammonium acetate, the uranium will be precipitated and the vanadium will remain in the solution.

Vanadium may be separated from uranium by the electrode position of the uranium from an acetate solution.

Vanadium may be separated from chromium by precipitating barium chromate and vanadate, and then decomposing the salts with dilute sulphuric acid and precipitating the vanadium as ammonium metavanadate, as already described.

Vanadium may be separated from neutral solutions of aluminic, cobaltous, manganous, nickelous and zinc salts by precipitating lead vanadate by means of lead acetate from the solutions made acid with acetic acid. This method can be applied to mixtures with various other salts.

These separations are sufficient to suggest methods of procedure for any ordinary case that may arise. Various interesting methods have not been mentioned, as it is considered unessential for the purpose of this paper.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. VII, pp. 313-340.

HOISTING IN DEEP SHAFTS.

BY CHARLES W. COMSTOCK.

DENVER,
PUBLISHED BY THE SOCIETY
JULY, 1904.

HOISTING IN DEEP SHAFTS.

BY CHARLES W. COMSTOCK.

Read at the meeting of the Society, July 2, 1904.

The great extent and remarkable continuity of values of the gold bearing reefs of South Africa have brought engineers face to face with the mechanical problems presented by mining at extreme depths. In the *Engineering and Mining Journal* of September 16, 1899, there appeared an abstract of a paper entitled "Mining on the Witwatersrand to 12,000 Feet Deep," read before the South African Association of Engineers by Mr. John Yates. In this paper the possibility of working the gold bearing reefs of South Africa to a vertical depth of 12,000 feet is discussed, and Mr. Yates concludes that it is entirely practicable from an engineering standpoint and, from a commercial point of view, likely to be profitable. Several questions are involved in this study, the most important ones being temperature, ventilation, rock pressure, drainage and hoisting.

The hoisting problem attracted my attention. Mr. Yates thinks that with the quality of steel wire at present available, single stage hoisting from a greater depth than 6,000 feet cannot be considered practicable. His final solution is by means of a vertical shaft 5,000 feet deep and an incline 14,000 feet long, the hoisting being done in four stages in the incline and one stage in the vertical shaft. He gives a number of comparative estimates supporting his decision that this arrangement is on the whole preferable to a vertical shaft reaching the same depth.

More recently Mr. Hans C. Behr has read before The Institution of Mining and Metallurgy in London an elaborate paper

containing an exhaustive study of the hoisting problem as applied to great depths. This paper I have not had an opportunity to read. Abstracts of the discussions of it by Prof. Robert Peele and Messrs. Hennen Jennings, A. M. Robeson and H. H. Webb, together with Mr. Behr's reply, have appeared in the *Engineering and Mining Journal*. None of these gentlemen have considered the possibility of single stage hoisting from a greater depth than 6,000 feet.

Without attempting to controvert Mr. Yates' conclusion as to the advantages of the combination of vertical shaft and incline over the single vertical shaft, I think it can be shown that the hoisting problem is more easily solved in the vertical shaft of 12,000 feet than in the combination proposed by him. That single stage hoisting from a depth of 12,000 feet is practicable with the means now at hand and without the necessity of new inventions or radical changes in present processes of manufacture, can be demonstrated.

It is necessary to inquire first as to the quality of wire which can be readily obtained. In this connection we may note that the Washburn & Moen Manufacturing Co., of Worcester, Mass., in a letter written in 1894 to the Board of Engineer Officers appointed to investigate the maximum practicable span for suspension bridges stated that "the present standard of steel rope wire is somewhat as follows:

Size of Wire	Tensile strength in lbs. per sq. inch	
	Crucible Cast Steel	Pione Steel
No. 6 to No. 8	160,000 to 180,000	225,000 or more
No. 9 to No. 16	160,000 to 180,000	240,000 or more
No. 16 to No. 1	170,000 to 190,000	270,000 or more
No. 18 and finer	180,000 or more	270,000 or more

In Europe wire having a tensile strength of 180 kgs. per sq. mm. (257,000 lbs. per sq. in.) is in common use for mine ropes. The Compagnie de Châtillon-Commentry manufactures five grades of steel rope wire of which the tensile strengths are respectively 75, 90, 130, 150 and 210 kgs. per sq. mm. (107,000 to 299,000 lbs. per sq. in.).

We may, therefore, assume that wire with a tensile strength of 270,000 lbs. per sq. in. is readily obtainable and proceed to design a rope on this basis.

For moderate depths wire ropes with constant cross sections are commonly used. A moment's thought will show that this is out of the question for the extreme depth now under consideration. Ropes as now made with a hemp center weigh about two pounds per foot for each square inch of nominal cross section. The area, F , of the section of a cylindrical rope competent to lift 8,000 lbs. (5,000 lbs. of rock in a skip weighing 3,000 lbs.) is determined by the equation

$$8000 + 2 \times 12000 \times F = 25000F,$$

allowing a stress of 25,000 lbs. per sq. in. on the nominal section of the rope (about 40,000 lbs. per sq. in. on the actual section). This gives an area of 8 sq. ins., corresponding to a diameter of 3.2 inches and a weight of 16 lbs. per ft. One rope would thus weigh 96 tons and would cost—at 12 cts. per lb.—about \$23,000 at the factory. All this rope to raise a paltry two and a half tons of rock is clearly absurd. A tapering rope must, therefore, be adopted. Of all possible tapered ropes the one in which the unit stress is the same on all cross sections is the lightest for a given unit stress and lifting capacity. The construction of such ropes is an accomplished fact. "The factory at Brandeisl in Bohemia has installed a plant capable of furnishing the exact profile of equal resistance."* The diameter, d , of such a rope at the lower end is determined by the load to be lifted. The diameter at a distance x from the lower end is

$$d = d_0 E^{\frac{\delta x}{2t}} \quad (1)$$

where δ is the weight per cubic unit of the rope, t is the unit stress

**Cours d'Exploitation des Mines*, by Haton de la Goupilliere, second edition, vol. 2, p. 10, foot note.

and E base of the natural system of logarithms. The weight of a length x of this rope is

$$W = (Q + q) \left(E^{\frac{\delta x}{t}} - 1 \right) \quad (2)$$

where Q is the weight of the rock lifted and q the weight of the skip or cage. These formulæ are given in all text books on the mechanics of materials and are well known.

To lift a load of 24,000 lbs. (15,000 lbs. of rock in a skip weighing 9,000 lbs.) requires an area at the lower end of one square inch if a unit stress of 24,000 lbs. be allowed. This gives a diameter of 1.13 inches at the lower end. The diameter at the upper end would be

$$d_1 = 1.13 \sqrt{2.71828} = 1.87 \text{ inches.}$$

The weight of 12,000 feet of this rope would be

$$W = 24000 \times 1.71828 = 41240 \text{ lbs.}$$

and the cost at 15 cts. per lb.—allowing 25% increase over the cost of cylindrical ropes for increased difficulty in construction—about \$6,200.

If the rope at the lower end consists, as is usual, of a hemp core and six strands of nineteen wires each, the diameter of each wire will be

$$\frac{1.13}{13.55} = 0.084 \text{ inches} = 2.13 \text{ mm.}$$

Additions to the section are made by increasing the number of wires as the distance from the lower end increases, or by cutting the wires and brazing on larger ones at short intervals.

The smallest diameter of drum on which the rope should be wrapped may be taken at 1500 times the diameter of the wire. In this case this diameter is

$$1500 \times 0.084 = 126 \text{ inches} = 10.5 \text{ feet.}$$

The actual stress in the wire under working conditions may now be calculated. The area of metal at the lower end is

$$114 \times \frac{\pi}{4} (0.084)^2 = 0.632 \text{ sq. in.}$$

The resulting unit stress is

$$\frac{24000}{0.632} = 38000 \text{ lbs. per sq. in.}$$

This must be increased by about one-seventh of itself to allow for the inclination of the wire to the direction of the load. The result is 43,430 lbs. per sq. in. This must be multiplied by 1.67 to take account of the effect of friction and acceleration, chiefly the latter. This operation gives 72,400 lbs. per sq. in. This stress will be the same at all points of the rope. Where the rope winds onto the drum there will be an additional stress due to the bending of the wire. With the ratio of diameter of drum to diameter of wire at 1500 and modulus of elasticity of the wire assumed at 32,000,000 lbs. per sq. in. this additional stress is 21,300 lbs. per sq. in. The total unit stress in the wire due to all causes is then 93,700 lbs. per sq. in. or a little more than one-third of the ultimate strength.

The rope manufacturers recommend one-fifth of the ultimate strength as a working load without taking any account of the increased stress due to acceleration of the load or bending of the wire around sheaves and drums. The figures here given then do not constitute a departure from established practice.

Assuming then that a tapered rope with a diameter of $1\frac{1}{2}$ inches at the lower end and $1\frac{7}{8}$ inches at the upper end is to be used the question of what to wind it on arises. Although the minimum diameter around which the wire can be wrapped with safety has been fixed at $10\frac{1}{2}$ feet, it is clear that a cylindrical drum of this diameter will not be satisfactory because of the great length necessary to enroll 12,000 feet of rope. In fact a cylindrical drum of any diameter will not be advisable because of the great variation in the load on the engine resulting from the variable weight of rope acting with a constant lever arm. If R be the radius of such a drum, then with the weights given above the twisting moment on the engine shaft at the time of starting the load would be

$$(24000 + 41240)R - 9000R = 56240 R.$$

At the passing point of the skips it would be $15000 R$ and when the load arrived at the top

$$24000R - (9000 + 41240)R = -26240 R.$$

This range of 550% of the mean work is obviously not conducive to the economic operation of an engine. The remedy for this is to construct a drum of such a profile that the twisting moment on the engine shaft shall be constant. The determination of this profile for a rope of constant section has been the subject of many papers and is well known. The following analysis serves to determine the proper form of drum to wind a rope of constant strength with a uniform twisting moment on the engine shaft.

Consider the conditions at the instant when the skips pass in the shaft. The drums at the points of suspension of the ropes have equal radii and everything is balanced except for the weight of rock in the ascending skip. Let R be the radius of each drum corresponding to this position.

After n revolutions the loaded skip has ascended and the weight of rope between it and the point of suspension has decreased. Let p_n be this weight. The empty skip has descended and the weight of rope attached to it has increased. Let p_{-n} be this weight since it is the same as the weight which would be attached to the loaded skip if the engine had made $-n$ revolutions. Designate by Q the weight of rock lifted and by q the weight of skip or of cage and car as the case may be. Let the radius from the extremity of which the loaded skip is suspended be ρ_n and the corresponding radius for the unloaded skip be ρ_{-n} .

The condition that the twisting moment on the engine shaft shall be constant is then expressed by the equation

$$(Q+q+p_n) \rho_n - (q+p_{-n}) \rho_{-n} = QR. \quad (3)$$

If the engine had made $-n$ revolutions, that is n revolutions in the opposite direction, the corresponding equation would be

$$(Q+q+p_{-n}) \rho_{-n} - (q+p_n) \rho_n = QR. \quad (4)$$

Adding equations (3) and (4) we have

$$\rho_n + \rho_{-n} = 2 R. \quad (5)$$

showing that the radius at the point of passing is the arithmetical mean of any two radii of simultaneous enrollment.

Multiply equation (5) through by ω , the angular velocity of the drum. The result is

$$\rho_n \omega + \rho_{-n} \omega = v_n + v_{-n} = 2 R \omega. \quad (6)$$

where v_n and v_{-n} are the linear velocities of the ascending and descending skips respectively. Equation (6) shows that the relative velocity of the two skips is constant provided the speed of

the engine is constant. The ascending skip has of course an increasing and the descending skip a decreasing velocity.

Let h_n be the depth of the ascending skip below the point of suspension and h_{-n} the corresponding quantity for the descending skip. Then

$$v_n = -\frac{d h_n}{d t} \quad \text{and} \quad v_{-n} = +\frac{d h_{-n}}{d t},$$

h_n decreasing with t and h_{-n} increasing with t . Making these substitutions and writing

$$\omega = 2\pi \frac{d n}{d t}$$

equation (6) becomes

$$\frac{d h_{-n}}{d t} - \frac{d h_n}{d t} = 4 \pi R \frac{d n}{d t}.$$

Integrating

$$h_{-n} - h_n = 4 n \pi R + C.$$

The left member of this equation is the distance between the skips. When $n=0$ the skips are together so that $C=0$ and we have

$$h_{-n} - h_n = 4 n \pi R \tag{7}$$

which shows that the distance between the skips is proportional to the angular motion of the drum, and this is true for any pair of compensating drums.

If the number of revolutions necessary to bring the ascending skip to the top (and the descending skip to the bottom) is N , equation (7) becomes for this particular value of n

$$h_{-N} - h_N = 4 N \pi R.$$

The left member of this equation is the total depth of the shaft, H , and we, therefore, have

$$H = 4 N \pi R \quad \text{or} \quad N = \frac{H}{4 \pi R} \quad (8)$$

Equation (8) shows that the total number of turns necessary for one trip is the same as would be necessary if cylindrical drums having the radius R were used.

Return now to equation (3) and rearrange it as follows, at the same time substituting for ρ_n its value from equation (5).

$$p_n \rho_n + p_n (\rho_n - 2R) + (Q + 2q) (\rho_n - R) = 0. \quad (9)$$

From equation (2) we find

$$p_n = (Q + q) \left(E^{\frac{\delta h_n}{t}} - 1 \right)$$

and from equations (2) and (7)

$$p_n = (Q + q) \left\{ E^{\frac{\delta}{t} (h_n + 4 n \pi R)} - 1 \right\}.$$

Substituting these values in equation (9) and rearranging terms we get

$$E^{\frac{\delta h_n}{t}} \left\{ (Q + q) \rho_n + (Q + q) (\rho_n - 2R) E^{\frac{\delta}{t} (4 n \pi R)} \right\} - Q (\rho_n - R) = 0. \quad (10)$$

Divide this equation through by $(Q + q)R$ and substitute $y_n = \frac{\rho_n}{R}$. The result is

$$E^{\frac{\delta h_n}{t}} \left\{ y_n + (y_n - 2) E^{\frac{\delta}{t}(4n\pi R)} \right\} - \frac{Q}{Q+q} (y_n - 1) = 0. \quad (11)$$

This may be written

$$E^{\frac{\delta h_n}{t}} = \frac{\frac{Q}{Q+q} (y_n - 1)}{(y_n - 2) E^{\frac{\delta}{t}(4n\pi R)} + y_n}. \quad (12)$$

After $n+1$ revolutions have been made this equation becomes

$$E^{\frac{\delta h_{n+1}}{t}} = \frac{\frac{Q}{Q+q} (y_{n+1} - 1)}{(y_{n+1} - 2) E^{\frac{\delta}{t}(n+1)4\pi R} + y_{n+1}}. \quad (13)$$

Dividing equation (12) by equation (13) and rearranging we obtain

$$E^{\frac{\delta}{t}(h_n - h_{n+1})} = \left\{ \frac{y_n - 1}{y_{n+1} - 1} \right\} \frac{y_{n+1} \left(E^{\frac{\delta}{t}(n+1)4\pi R} + 1 \right) - 2 E^{\frac{\delta}{t}(n+1)4\pi R}}{y_n \left(E^{\frac{\delta}{t}(4n\pi R)} + 1 \right) - 2 E^{\frac{\delta}{t}(4n\pi R)}} \quad (14)$$

$h_n - h_{n+1}$ is the amount of rope enrolled during one revolution and is approximately equal to the circumference of a circle of

radius ρ_n . Although this is not exact the maximum error does not exceed seven-tenths of one per cent. With this approximation

$$h_n - h_{n+1} = 2\pi\rho_n = 2\pi R y_n \quad \text{and} \quad E^{\frac{\delta}{t}(h_n - h_{n+1})} = E^{\frac{\delta}{t} 2\pi R y_n},$$

For brevity let

$$E^{\frac{\delta}{t} 2\pi R} = A.$$

With these substitutions equation (14) becomes

$$\begin{aligned} y_{n+1} & \left\{ y_n \left(A^{2n} + 1 \right) - 2A^{2n} \right\} A^{y_n} - \left\{ y_n \left(A^{2n} + 1 \right) - 2A^{2n} \right\} A^{y_n} \\ & = y_{n+1}(y_n - 1) \left\{ A^{\frac{2(n+1)}{+1}} - 2(y_n - 1)A^{2(n+1)} \right\}, \quad (15) \end{aligned}$$

from which follows

$$\begin{aligned} y_{n+1} & = \frac{\left\{ y_n \left(A^{2n} + 1 \right) - 2A^{2n} \right\} A^{y_n} - 2(y_n - 1)A^{2(n+1)}}{\left\{ y_n \left(A^{2n} + 1 \right) - 2A^{2n} \right\} A^{y_n} - (y_n - 1) \left\{ A^{\frac{2(n+1)}{+1}} \right\}} \quad (16) \end{aligned}$$

Equation (16) gives each radius in terms of the preceding one and known constants. Beginning, therefore, at any point successive radii may be calculated by applications of this formula. By systematizing the work the numerical computation can be accomplished without excessive labor. Following are two calculations as actually carried out, showing the necessary numerical work.

$$n = -40$$

$$y_n = 0.6146 \quad A^{2n} = 0.5134 \quad A^{2(n+1)} = 0.5220$$

$$1 + A^{2n} = 1.5134$$

$$\log A^{2(n+1)} = \frac{0.7104720 - 1}{72382} = 0.7177102 - 1$$

$$\log 1.5134 = 0.1799537$$

$$\log y_n = \frac{0.7885793 - 1}{0.9685330 - 1}$$

$$\frac{0.0036191}{0.6146} = 217148$$

$$-2A^{2n} = \frac{0.9301}{1.0269} = -0.9067$$

$$\log A^{y_n} = \frac{36191}{144764} = 0.00222423886$$

$$\log 0.9067 = 0.9854235 - 2$$

$$1 + A^{2(n+1)} = 1.5220$$

$$\log A^{y_n} = \frac{0.0022243}{0.9876508 - 2}$$

$$\log 1.5220 = 0.1824147$$

$$\log (y_n - 1) = \frac{0.5859117 - 1}{0.7683284 - 1}$$

$$B = -0.0972$$

$$0.3854$$

$$\frac{0.5866}{-0.0972} = 0.4894$$

$$\log (y_n - 1) = 0.5859117 - 1$$

$$\log 2 = 0.3010300$$

$$\log A^{2(n+1)} = \frac{0.7177102 - 1}{0.6046519 - 1}$$

$$\frac{0.4024}{-0.0972} = 0.3052$$

$$\log 0.3052 = 0.4845845 - 1$$

$$\log 0.4894 = 0.6896640 - 1$$

$$\log y_{n+1} = 0.7949205 - 1$$

$$y_{n+1} = 0.6236$$

$$n = -39$$

$$y_n = 0.6236 \qquad A^{2n} = 0.5220 \qquad A^{2(n+1)} = 0.5308$$

$$1 + A^{2n} = 1.5220$$

$$\log A^{2(n+1)} = \frac{0.7177102 - 1}{72382} = 0.7249484 - 1$$

$$\log 1.5220 = 0.1824147$$

$$\log y_n = \frac{0.7949205 - 1}{0.9773352 - 1}$$

$$\frac{0.0036191}{0.6240} = \frac{217146}{72382}$$

$$-2A^{2n} = \frac{0.9492}{-1.0440} = -0.9048$$

$$\log A^{y_n} = \frac{144764}{0.0022583184}$$

$$\log 0.9048 = 0.9768063 - 2$$

$$1 + A^{2(n+1)} = 1.5308$$

$$\log A^{y_n} = \frac{0.0022583}{0.9790664 - 2}$$

$$\log 1.5308 = 0.1849185$$

$$\log (y_n - 1) = \frac{0.5751878 - 1}{0.7601063 - 1}$$

$$B = -0.0953$$

$$\frac{0.5756}{-0.0953} = +0.4803$$

$$0.3760$$

$$\log (y_n - 1) = 0.5751878 - 1$$

$$\log 2 = 0.3010300$$

$$\log A^{2(n+1)} = \frac{0.7249484 - 1}{0.6011662 - 1}$$

$$\frac{0.3992}{-0.0953} = +0.3039$$

$$\log 0.3039 = 0.4827307 - 1$$

$$\log 0.4803 = 0.6815126 - 1$$

$$\log y_{n+1} = 0.8012181 - 1$$

$$y_{n+1} = 0.6327$$

In the table on page 327, which shows the principal numerical results of these calculations, the expression

$$\left\{ y_n \left(\frac{2n}{A+1} \right) - 2A \right\} \frac{2n}{A}$$

is represented by B . All values of this expression are negative.

Returning for a moment to equation (4), let us write it for the instant when the loaded skip is at the top, that is for $n=N$.

$$(Q+q+p_N)\rho_N - (q+p_N)(2R-\rho_N) - QR = 0. \quad (17)$$

If we neglect the weight of rope between the head sheave and the landing $p_N=0$, and equation (17) gives

$$R = \rho_N \frac{Q+2q+p_N}{Q+2q}. \quad (18)$$

ρ_N is arbitrary, being the radius of the small end of the drum. The smallest diameter about which a rope should be bent may be taken as fifteen hundred times the diameter of the wire composing the rope. This gives

$$2\rho_N = 1500 \times 0.084 = 126 \text{ inches} = 10.5 \text{ ft.}$$

ρ_N is the weight of 12,000 feet of rope and has been determined to be 41,240 lbs. Q has been taken as 15,000 lbs. and q as 9,000 lbs. With these figures we find

$$R = \frac{74240}{33000} 5.25 = 11.81 \text{ ft.}$$

and from equation (5) we get

$$\rho_N = 23.62 - 5.25 = 18.37 \text{ ft.}$$

n	y_n	$2n$ A	$2(n+1)$ A	B	y_{n+1}
60	0.4445	0.3679	0.3741	0.1283	0.4524
59	0.4524	0.3741	0.3804	0.1270	0.4605
58	0.4605	0.3804	0.3867	0.1256	0.4686
57	0.4686	0.3867	0.3932	0.1241	0.4768
56	0.4768	0.3932	0.3999	0.1226	0.4851
55	0.4851	0.3999	0.4066	0.1212	0.4933
54	0.4933	0.4066	0.4134	0.1198	0.5015
53	0.5015	0.4134	0.4204	0.1185	0.5098
52	0.5098	0.4204	0.4274	0.1171	0.5182
51	0.5182	0.4274	0.4346	0.1156	0.5268
50	0.5268	0.4346	0.4419	0.1140	0.5353
49	0.5353	0.4419	0.4493	0.1125	0.5439
48	0.5439	0.4493	0.4569	0.1109	0.5526
47	0.5526	0.4569	0.4646	0.1093	0.5612
46	0.5612	0.4646	0.4723	0.1078	0.5699
45	0.5699	0.4723	0.4803	0.1061	0.5788
44	0.5788	0.4803	0.4884	0.1043	0.5876
43	0.5876	0.4884	0.4966	0.1026	0.5966
42	0.5966	0.4966	0.5049	0.1009	0.6055
41	0.6055	0.5049	0.5134	0.0991	0.6146
40	0.6146	0.5134	0.5220	0.0972	0.6236
39	0.6236	0.5220	0.5308	0.0953	0.6327
38	0.6327	0.5308	0.5397	0.0935	0.6419
37	0.6419	0.5397	0.5488	0.0915	0.6513
36	0.6513	0.5488	0.5580	0.0894	0.6605
35	0.6605	0.5580	0.5674	0.0874	0.6699
34	0.6699	0.5674	0.5770	0.0854	0.6790
33	0.6790	0.5770	0.5866	0.0837	0.6882
32	0.6882	0.5866	0.5965	0.0818	0.6976
31	0.6976	0.5965	0.6065	0.0798	0.7069
30	0.7069	0.6065	0.6167	0.0779	0.7162
29	0.7162	0.6167	0.6271	0.0760	0.7255
28	0.7255	0.6271	0.6376	0.0741	0.7352
27	0.7352	0.6376	0.6483	0.0716	0.7449
26	0.7449	0.6483	0.6592	0.0692	0.7543
25	0.7543	0.6592	0.6703	0.0673	0.7639
24	0.7639	0.6703	0.6816	0.0650	0.7735
23	0.7735	0.6816	0.6930	0.0629	0.7829
22	0.7829	0.6930	0.7047	0.0609	0.7927
21	0.7927	0.7047	0.7165	0.0585	0.8026
20	0.8026	0.7165	0.7286	0.0558	0.8122
19	0.8122	0.7286	0.7408	0.0536	0.8222
18	0.8222	0.7408	0.7533	0.0507	0.8322
17	0.8322	0.7533	0.7659	0.0478	0.8419
16	0.8419	0.7659	0.7788	0.0455	0.8519
15	0.8519	0.7788	0.7919	0.0425	0.8618
14	0.8618	0.7919	0.8052	0.0398	0.8717
13	0.8717	0.8052	0.8187	0.0371	0.8818
12	0.8818	0.8187	0.8325	0.0340	0.8916
11	0.8916	0.8325	0.8465	0.0314	0.9016
10	0.9016	0.8465	0.8607	0.0284	0.9114
9	0.9114	0.8607	0.8752	0.0257	0.9217
8	0.9217	0.8752	0.8899	0.0221	0.9317
7	0.9317	0.8899	0.9048	0.0191	0.9414
6	0.9414	0.9048	0.9200	0.0164	0.9511
5	0.9511	0.9200	0.9355	0.0140	0.9603
4	0.9603	0.9355	0.9512	0.0124	0.9693
3	0.9693	0.9512	0.9672	0.0112	0.9797
2	0.9797	0.9672	0.9835	0.0073	0.9898
1	.....	.....	.....	.....	1.0000
0	1.0000	.....	.....	.....	.....

All quantities in the first and fifth columns of this table are negative.

From equation (8)

$$N = \frac{12000}{4\pi \times 11.81} = 80.85,$$

that is, the entire trip requires 161.7 revolutions of the drum. As this number of turns would require a very long drum, I have assumed $N=120$ which results in

$$R=15.9155, \quad \rho_{-N}=7.0745 \quad \text{and} \quad \rho_N=24.7565.$$

While a drum diameter of nearly fifty feet may at first sight seem excessive, it should be remembered that the whole undertaking is entirely unprecedented in point of magnitude and unusual dimensions are to be expected. There are now in operation in Europe several drums with diameters between ten and eleven metres, the double conical drum at Tamarack No. 3 shaft in Michigan has a diameter of thirty-six feet, and that at Sydney Harbour Colliery in Australia a diameter of thirty-eight feet, so a fifty-foot drum can hardly be considered impracticable.

The increase in diameter of the small end of the drum from 10.5 feet to 14 feet has the further advantage of decreasing the bending stress on the wires from 21,300 lbs. per sq. in. to 15,800 lbs. per sq. in.

The quantity δ for steel ropes with hemp centers is 288 lbs. per cu. ft. and t is taken at 24,000 lbs. per sq. in. or 3,456,000 lbs. per sq. ft. With these figures we find

$$\frac{2\delta\pi R}{t} = 0.008333$$

and

$$E \frac{\delta}{t} 2\pi R = A = 1.008368.$$

The successive radii can now be readily calculated, beginning with ρ_{-v} . Only sixty of the one hundred and twenty calculations need be made as the other values can be quickly obtained from equation (5) by simple subtraction.

The exact width of drum required cannot be determined without a detailed design, but it would not be far from twenty-four feet. Such drums could not, of course, be set side by side without giving an excessive lead to the rope from the head sheave. They should be set one behind the other, on separate axes which may be connected by vertical walking beams as arranged by Poussigue at the Ronchamp collieries in France or operated by double bell cranks after the plan adopted by Tomson at the Preussen shaft in Westphalia. By this arrangement the planes of the mean radius of the drums can be made to coincide with the planes of the head sheaves and the rope leads reduced to a minimum. By Tomson's plan also it is possible to revolve the drums in opposite directions and thus wind both ropes over instead of one under and one over. This will prolong the life of one rope appreciably. The high speed and enormous dimensions would probably preclude the use of spur gearing to connect the drum shafts.

The capacity of this shaft depends directly on the hoisting speed and an average speed of 3,000 ft. per minute has been adopted, this being within the range of present practice. The velocity of a skip at the bottom would then be 1,310 ft. per minute and at the top 4,690 ft. per minute. The mean circumference of the drum being 100 ft., a hoisting velocity of 3,000 ft. per minute corresponds to an engine speed of thirty revolutions per minute. The engine should be brought up to this speed in the shortest practicable time and should then run at constant speed until one skip nears the surface when the retardation should be as rapid as possible. In this way the desired average hoisting velocity can be attained without an excessive maximum.

It is then necessary to determine what the greatest practicable acceleration is. The limit is fixed by the descending skip. If it fell freely its acceleration would be 32 ft. per second. It has, how-

ever, to drag after it a certain amount of rope and, in doing so, to impart a velocity to the head sheave; it has to overcome friction on the guides and the air resistance in the shaft. Taking these things into account I have assumed that the descending skip cannot safely have an acceleration exceeding 16 ft. per second. Since the rope attached to this skip is wound on a radius of 24.76 ft., this linear acceleration corresponds to an angular acceleration of the drum of 0.65 radians per second.

The ascending skip, being attached to a rope wound on a radius of only seven feet at starting, has an acceleration of only 4.5 ft. per second and the increase in stress due to this cause is, therefore, only about fourteen per cent. of the weight lifted. In the design of the rope a factor of 1.67 was used in allowing for friction and acceleration. It now appears that 1.30 would have been sufficient. Using this factor and the decreased bending stress due to the use of the larger drum the total stress on the wire is only 72,260 lbs. per sq. in. instead of 93,700 as originally calculated. This is but little more than one-fourth of the ultimate strength of the wire.

It is now possible to determine the proportions of the engine necessary to operate these drums. Two phases of the case must be considered. First, the steam pressure and dimensions of the steam cylinders must be sufficient to start the load and impart the desired acceleration; second, the arrangement must be such that the engine will run economically at the normal speed of thirty revolutions per minute under the static and friction loads only.

The moment necessary to start the engine may be thought of as consisting of three parts, viz., that necessary to accelerate the drums with the rope wound on one of them, the moment necessary to accelerate the skips and the rope hanging in the shaft, and the static moment. To these should properly be added the moment of shaft and engine frictions, that necessary to accelerate the head sheaves and the moment equivalent to the acceleration of the moving parts of the engine other than the drums. In the final calculations for a detailed design these would have to be considered

but, in view of the overwhelming effect of the acceleration of the drums, they may safely be neglected in this preliminary calculation.

The first part is equal to the product of the angular acceleration by the moment of inertia of the drums. This moment of inertia cannot be determined exactly without a complete design of the drum. For the purposes of this paper, however, I have assumed that it would be equivalent to a steel shell having the form of a frustrum of a cone with radii of seven and twenty-five feet, an altitude of twenty-four feet and a thickness of metal of two inches. The moment of inertia of such a shell referred to its geometrical axis is 2,022,000 and its weight 193,000 lbs. The actual drum would undoubtedly weigh more than this but its moment of inertia probably would not be greater. If the rope, weighing 41,240 lbs., is assumed to be distributed uniformly over the surface of this shell (this is not quite true since the larger end of the rope is wound on the smaller end of the drum) its moment of inertia will be 430,000. At the time of starting one drum is empty and the other is filled with rope. The moment of inertia of the mass to be accelerated is then

$$2 \times 2022000 + 430000 = 4474000.$$

The angular acceleration being 0.65 the moment of the starting forces must be

$$0.65 \times 4474000 = 2908100 \text{ ft. lbs.}$$

The second part must be subdivided into two. On the ascending side the load to be accelerated consists of the rope hanging in the shaft and the loaded skip, a total of 65,240 lbs. This must receive an acceleration of 4.5 ft. per second requiring an increased tension in the rope of 9,100 lbs. This with a lever arm of seven feet gives a moment of 63,700 ft. lbs.

On the descending side the empty skip weighing 9,000 lbs. receives an acceleration of 16 ft. per second, resulting in a

decrease in rope tension of 4,500 lbs. This with a lever arm of twenty-five feet gives a moment of 112,500 ft. lbs. The total moment due to acceleration of loads in the shaft is then 176,200 ft. lbs.

The static moment is constant and is the product of the unbalanced load, 15,000 lbs., into the mean radius of the drum, sixteen feet, or 240,000 ft. lbs.

The total required starting moment is the sum of these three parts which is 3,324,300 ft. lbs. Assuming that steam follows full stroke and neglecting the obliquity of the connecting rods the available starting moment is one-half the product of the unit steam pressure and the cylinder volume. Adopting a steam pressure of 150 lbs. per sq. in. and equating this product to the required starting moment, the necessary cylinder volume is found to be 307.8 cu. ft.

The mean twisting moment imparted to the drum shaft by two cranks at right angles with steam following full stroke would be $\frac{4}{\pi}$ or 1.27 times the product of the pressure on one piston into the crank radius. The applied moment would of course vary from point to point of the stroke and with it would vary the angular acceleration. The excess of twenty-seven per cent. which the mean twisting moment has over the required moment is, however, ample to compensate for the neglected shaft and engine friction and acceleration of head sheaves and engine parts, so that the desired angular acceleration of 0.65 radians per second would certainly be attained.

It is proposed to mount at each end of the drums a double bell crank operated by a two cylinder compound engine. Since one engine may be on a dead center when it is desired to start, either engine must be capable of starting the load. By admitting steam at boiler pressure to both cylinders for starting, the engines may be kept within such limits of size as to enable them to work economically under the normal load. With a ratio of cylinder volumes of six to one, a high pressure cylinder 32" \times 96" and a low pressure cylinder 78" \times 96" give the required total volume. With

the acceleration mentioned above the machine would be up to speed at the end of five seconds. Steam would then be cut off and the engine worked compound. With steam at one hundred and fifty pounds each pair of cylinders would develop about eleven hundred indicated horse-power with one-quarter cut off in the high pressure cylinder and a vacuum of twenty-six inches, assuming adiabatic expansion and neglecting the drop between cylinders. This last could easily be overcome by superheating in the receiver. Under these conditions about sixty per cent. of the work would be done in the high pressure cylinder, but the division would be more nearly equal as the cut-off was increased.

Running at normal speed the work done, exclusive of friction on guides, stiffness of ropes, etc., is 1,360 H.P. The two compound engines described will develop 1,980 brake horse-power (allowing ten per cent. for engine friction) and this is sufficient to handle the loads with a margin of forty-five per cent. for friction on guides, air resistance, etc.

This plan of introducing boiler pressure steam into low pressure cylinders for starting, and afterward working on the double expansion system is one frequently used on compound locomotives.

If one skip is landed on chairs at the bottom of the shaft the other may still have to be raised in order to empty it, this condition being frequently brought about by the stretching of the ropes. At the instant when this operation is being performed the descending rope is entirely relieved of the weight of the skip and the moment acting on the drum shaft is

$$24000 \times 25 - 41240 \times 7 = 311320 \text{ ft. lbs.}$$

One pair of cylinders with the ordinary boiler and receiver pressures would be more than able to overcome this moment. With boiler pressure steam in both high and low pressure cylinders the machine might be operated with one skip and rope removed though it is not likely that this would ever be desirable.

As the loaded skip approaches the top the engine must be brought to rest. Assuming that this is to be done in the same length of time as required for starting, the necessary retarding moment can be determined as follows: The moment necessary to retard the drums at the rate of 0.65 radians per second is 2,908,100 ft. lbs. The retardation of the ascending skip at the rate of sixteen feet per second results in a decrease of 12,000 lbs. in the tension on the rope, producing a moment of 300,000 ft. lbs. The retardation of the descending skip at the rate of four and a half feet per second produces an increase in the rope tension of 7,000 lbs. and a moment of 49,000 ft. lbs. The total required retarding moment is then 3,257,100 ft. lbs. From this must be subtracted the constant static moment of 240,000 ft. lbs. leaving a net retarding moment of 3,017,100 ft. lbs. If the brake rings have the same diameter as the large end of the drum, viz., 50 ft., the friction on the brake shoes must be 120,684 lbs. If there are two brake rings and two shoes on each ring this amount of friction is easily obtained. This result is theoretically inexact for three reasons. First, the retardation of the ascending skip is somewhat less and that of the descending skip somewhat greater than stated above since the ascending rope is not winding on the largest diameter of the drum nor the descending on the smallest diameter. These two errors are in opposite directions and tend to compensate. Second, the retarding influence of shaft and engine friction has been ignored. Third, the inertia of head sheaves and moving engine parts has not been considered. On the whole it is safe to say that the friction required on the brake rings will be rather less than here calculated.

Generally, however it will be desirable to bring the engine to rest without the use of the brake. The number of revolutions required to stop the machine in this way may easily be calculated. The total kinetic energy of the apparatus consists of the energy of the revolving drums and the energy of the moving skips and rope. This must be equated to the work done in raising the load. The equation is

$$\frac{1}{2}\omega^2 I + \frac{1}{2}M_1 v_1^2 + \frac{1}{2}M_2 v_2^2 = 2 \times 240000 \, n\pi. \quad (19)$$

where ω is the angular velocity of the drum, I the moment of inertia of the revolving parts, M_1 and M_2 the masses and v_1 and v_2 the velocities of the ascending and descending loads respectively, 240,000 the constant static moment and n the required number of revolutions. These quantities have numerical values as follows:

$$\begin{aligned} \omega &= \pi \\ I &= 4474000 \\ M_1 &= \frac{24000}{32 \cdot 2} \\ M_2 &= \frac{50240}{32 \cdot 2} \\ v_1 &= 78 \\ v_2 &= 22 \end{aligned}$$

The solution of equation (19) gives $n = 16 \cdot 2$ revolutions. This result is subject to the same inaccuracies as the one in the preceding paragraph. v_1 is really less and v_2 really greater than the values used in the calculation. The two corrections would be in opposite directions but their net result would be to decrease n . Consideration of shaft and engine frictions would decrease n , while consideration of inertia of moving parts neglected in equation (19) would increase it. The final result would probably be somewhat less than derived from this equation.

The total number of revolutions per trip will be one hundred and twenty. The time consumed in getting up speed will be five seconds and the number of revolutions one and a quarter. In stopping the engine makes sixteen revolutions requiring sixty-four seconds. There remain one hundred and two and three-quarters revolutions at thirty per minute requiring two hundred and five and a half seconds. The total time from start to stop is then four minutes and thirty-four and a half seconds. It seems probable that twenty-five and a half seconds would be sufficient, with proper

arrangements, for loading and dumping. If so the machine would make twelve trips per hour, raising seven and one-half tons per trip or ninety tons per hour. Hoisting twenty hours out of twenty-four the shaft would output eighteen hundred tons per day for each pair of compartments. With some small changes the apparatus could be arranged to handle ten tons per trip instead of seven and a half. So long as the ratio of weight of skip to weight of rock remains the same the form of drums will not change. The weight of rope would increase proportionately to the load raised. The steam cylinders would need to be only slightly increased in size to handle the increased loads. The same cylinders could be used if the steam pressure were increased somewhat. With ten ton skips the output would be twenty-four hundred tons in twenty hours for one pair of compartments. If a seven compartment shaft were constructed and four of these compartments devoted to handling rock, the output would be forty-eight hundred tons per day. With a reasonable allowance for waste the ore hoisted would be fully thirty-five hundred tons, probably enough to keep seven hundred stamps dropping.

No doubt one of the first objections which will be raised against the plan here proposed is the low factor of safety for the rope. In reply to this anticipated objection I will say that the actual factor of safety of most hoisting ropes is not much greater. In the case of the hoisting plant recently established at the Ronchamp collieries in France, for a depth of 3,330 feet, it is stated that the factor of safety at the upper end of the tapered rope is nine. Let us examine the actual figures which, for convenience, I have changed from metric to English measures. The wire has an ultimate strength of 257,000 lbs. per sq. in. The large end of the rope consists of one hundred and twelve wires of 0.11 in. diameter, giving an actual metal section of 1.06 sq. in. The total load including the rope is 32,325 lbs. The nominal stress per square inch of metal is then 30,500 lbs. Adding one-seventh for lay of the wire gives 34,860. Multiply this by 1.30 to allow for friction and acceleration. The result is 45,318. This rope is

wound on a drum eighteen feet in diameter at the small end and the ratio of diameter of drum to diameter of wire is thus 1,960. With a modulus of elasticity of 32,000,000 lbs. per sq. in. the stress in the wire due to curvature is 16,300 lbs. This makes the total 61,618 lbs. per sq. in. The actual factor of safety is then

$$\frac{257000}{61618} = 4.16.$$

The nominal factor of safety is

$$\frac{1.06 \times 257000}{32325} = 8.80.$$

In the rope which I have proposed for a 12,000 ft. shaft and a net load of 15,000 lbs. the actual factor of safety is

$$\frac{270000}{72260} = 3.75.$$

The equalizing drum for a rope of constant section departs so much from the conical form that a conical drum does not produce the desired equalization of the twisting moments. In the case of the tapered rope, however, the drum for exact equalization approaches very closely indeed to the cone and the latter form may, therefore, be used without seriously affecting the conditions under which the engine must work. The great approximation of this drum to the conical form may be seen from an examination of the differences between successive numbers in the sixth column of the table on page 327.

Now a few words as to the other systems which might be considered applicable to the solution of this problem.

The Koepe and the Whiting systems require the use of ropes of constant section and, as pointed out in the early part of this

paper, the use of such ropes is impracticable at a depth of 12,000 feet. Whatever else may be said either for or against them, therefore, they are out of the question in this case.

Flat ropes may be tapered and, being wound on reels, afford a certain degree of equalization which may be sufficient for economical engine operation. Their use would do away with the heavy and expensive winding drums and result in smaller steam cylinders. The objections to the flat rope, however, appear to me serious enough to counterbalance these advantages. The wires rapidly deteriorate at the points where they are crossed by the sewing wires and the life of the rope is, therefore, much less than that of a properly designed round rope. There is also much less certainty about the distribution of the load on a flat rope and the factor of safety must on that account be larger, thus increasing the weight of the rope for a given lifting capacity. Further, the hoisting speed with a tapered flat rope is limited by a consideration which does not enter into the use of round ropes. The taper is principally, if not entirely, in the width and after the coil has been partly built up the width of the rope winding on it is less than the space between the arms of the reel. Consequently there is danger that the rope will slip off the coil and become wedged between it and the reel arms. The greater the speed, the greater this danger and the more serious the consequences if such an accident occurs.

The only other possibility is stage winding. This complicates the shaft construction and arrangement, subdivides the power used, increases the wages account and involves the use of underground hoists. The transmission of power to these underground machines is a serious matter. Each one of them may demand from one thousand to fifteen hundred horse-power. The generation of steam underground is out of the question. The losses involved in the transmission of steam through great distances underground are such as to render this system unworthy of serious consideration. Compressed air is almost equally wasteful and scarcely to be considered unless cheap water power is available for compressing the

air. This is not the case in South Africa. The only remaining method is by electricity. While the desired result can no doubt be accomplished through this agent, there are some serious difficulties involved which, so far as my knowledge extends, have not yet been successfully overcome. Among these are the dangers connected with conductors under high tension or carrying large currents in the restricted spaces available in mine shafts and other passages, and the enormous starting currents required by hoist motors. This last consideration was so serious in one case which came under my notice that a two hundred horse-power hoist on the surface was thrown out as a failure and the central station manager gave thanks when it was out.

Just a word as to the financial problem. There is no doubt but that the proper way to prospect the deeper portions of these gold bearing reefs is through inclines from the bottom of the present vertical shafts. Assuming that this has been done and the grade shown to be sufficient for profitable extraction, it is by no means evident *a priori* that continued working through these inclines is the best way to mine. There are few instances in which it has not been found advisable to abandon the prospecting workings in favor of others more favorably located and arranged for economical mining.

In conclusion let me say to those who may be disposed to discuss this paper that I have made no pretence to a complete design and have carried my calculations only far enough to show that the principal figures are such as to indicate that the proposed plan is practicable.

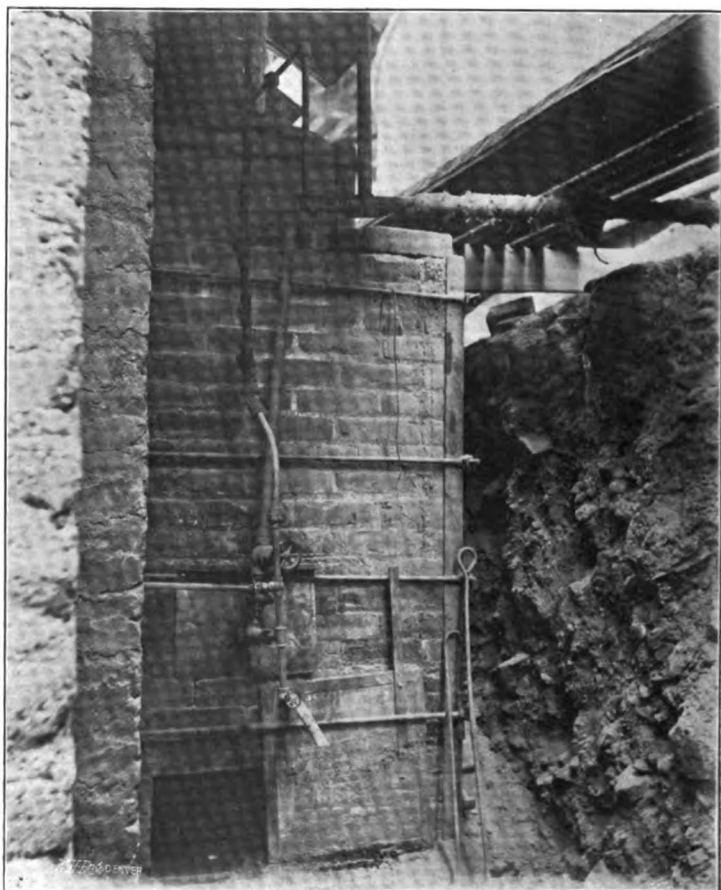
NOTE:—Since this paper was put into type I have had an opportunity to read the valuable paper of Mr. H. C. Behr presented to the Institution of Mining and Metallurgy and extensively discussed in London and in Johannesburg. As Mr. Behr does not consider single stage hoisting from a greater depth than 6,000 ft., I find nothing in his paper or the discussion of it to modify my views as expressed above.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. VII, pp. 341-346.

THE USE OF CRUDE OIL FOR FIRE ASSAYING.

By F. C. BOWMAN.

DENVER,
PUBLISHED BY THE SOCIETY
OCTOBER, 1904



Side of Furnace Showing Burner.



Front of Furnace.

THE USE OF CRUDE OIL FOR FIRE ASSAYING.

By F. C. BOWMAN.

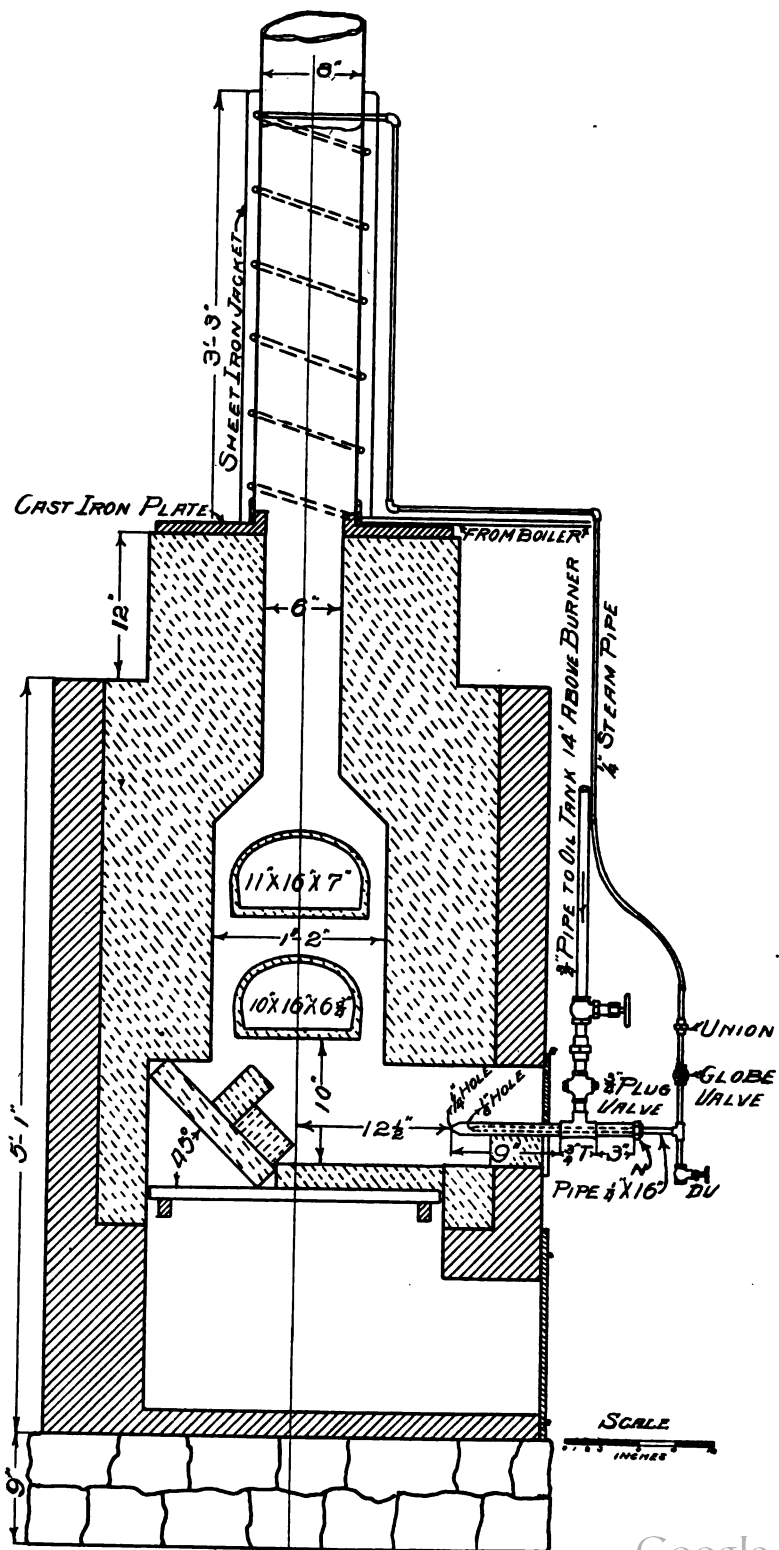
Read at the meeting of the Society, September 3, 1904.

The principal fuels used in assaying are coal and coke, while charcoal and wood are used in special cases and in some portable furnaces gas and gasoline are employed, although it is difficult to obtain the same even heat with the latter as with the coal and coke furnaces. In some portions of the country however, the high cost of these fuels and the difficulty of obtaining a good quality of such fuel often leads one to adopt the gasoline furnace where the work is light.

It was in view of these facts that I was led to experiment with crude oil, which was comparatively cheap, as a fuel although I was informed by a very prominent manufacturer of gasoline furnaces that others had not been very successful in this line.

A new 2-muffle 11"x16"x7" furnace, which was constructed to burn coal, had just been completed as is shown in the accompanying cross sectional drawing. It was rather doubtful at first whether this could be adapted to the burning of oil without very radical changes, but comparatively few additions were found necessary.

There are a great many styles of oil burners on the market, all having their special claims, but the general result arrived at is the breaking of the oil into fine particles by the use of steam or compressed air and at the same time forcing it into the fire box.



Cross Section of Furnace.

The burner which I have adopted, though probably not as efficient as some sold by manufacturers, has proven quite effective and is simple and easily constructed by any one. It is shown in the section of the furnace and consists of a $\frac{3}{4}$ -inch pipe connected by a T with the oil line and through which passes a $\frac{1}{4}$ -inch pipe connected with the steam line. This steam pipe passes through a packing nut (N) which allows of the adjustment of the distance between the opening in the nozzle and the opening in the steam pipe, this distance affecting very materially the flow of the oil even when the inlet valves of both steam and oil are set. A slotted hole was first used in the nozzle but a round one was found to work better in such a small fire box.

The arrangement of fire-brick was only determined by experiment. The grate bars are covered the full width of the fire box and the other brick arranged as shown in the section and extending the full width of the fire box. The successful working of the furnace depends largely on the arrangement of this fire-brick.

In starting the fire a piece of oil waste is lighted in the fire box just back of the burner nozzle. When this is burning well oil and steam are turned on at the same time until the oil ignites and the oil valve set to give the proper flow of oil after which it is regulated by the steam valve. Plenty of waste should be used to furnish a blaze until the furnace is hot enough to ignite the oil, otherwise an explosion is liable to take place from the gases formed by the oil in the partially heated furnace.

The valve DV at the end of the steam line is left slightly open to let the water of condensation drain off, which if passed into the furnace will cool it off and is liable to crack the muffles. To obtain the best results the steam should be absolutely dry, and for this reason the steam is passed through a coil around the stack before going to the burner. A small steam coil is placed in the oil tank to heat the oil and make it flow more evenly and also serves to keep the heavier oils from settling.

About fifteen minutes after the fire is started the muffles are red and after from thirty to forty-five minutes the crucibles are

ready to pour. With this furnace I have run through twenty-five to thirty assays in one and a half to two hours, and from fifty to sixty assays in two and a quarter to three hours, including cupelling. This time is counted from the time the oil is turned on until it is turned off. The amount of oil used varied from 4.2 gallons per hour to 5.3 gallons per hour, varying with different lots of oil and also with the quality of steam furnished. With oil at 8.7 cents per gallon delivered at the burner the cost per assay was 2.2 to 2.8 cents.

In a coke furnace with a single 11"x16"x7" muffle and using forced draft, the average consumption of coke per hour was 34 pounds. The time was counted from the lighting of the fire until the heat was too low to be used for cupellation. With coke costing \$2.25 per cwt. delivered at the furnace, the cost per assay for fuel was 7.1 cents.

In a No. 31 Cary Combination gasoline furnace of F. W. Braun & Co's. make using a 2-inch Cary burner of the same make, the average consumption of gasoline was 0.65 gallons per hour, the gasoline being delivered to the burner under an average pressure of 10 pounds. The time was counted from the time the gasoline was turned on until it was turned off. With gasoline at 40 cents per gallon delivered at the burner, the cost per assay for fuel was 5.2 cents.

DISCUSSION.

C. W. Comstock. —By way of additional information as to fuel consumption in assay furnaces the following may be of interest. Twenty-three heats aggregating 117.25 hours were made in a coal-burning furnace with one muffle. The muffle was 12"x19"x7 $\frac{3}{4}$ ". The grate was 19"x12 $\frac{1}{2}$ " and its upper surface was 17 $\frac{1}{2}$ " below the muffle. Two tons of coal were burned, one ton of Maitland screened nut and one ton run-of-mine from an unknown locality. The grate area was 1.66 square feet. Coal was burned at the rate of thirty-four pounds per hour or twenty and one-half pounds per

square foot of grate surface per hour. No record was kept of the number of assays made during this time. The average time per heat was 5.1 hours, the shortest 3.0 hours and the longest 8.0 hours. Fire was started in a cold furnace at the beginning of each heat.

A No. 37 Cary double muffle furnace made by F. W. Braun & Co. of Los Angeles, consumed gasoline as follows: Two heats aggregating four hours and fifty minutes consumed 6.36 gallons or 1.30 gallons per hour. The air pressure in the gasoline tank was forty pounds. One heat of two hours and twenty-five minutes consumed 2.70 gallons or 1.12 gallons per hour. The pressure was thirty pounds at the beginning but, owing to a leak, ran down to seven pounds at the end. One heat of four hours and twenty minutes consumed 5.95 gallons or 1.37 gallons per hour. The pressure was thirty-five pounds. One heat of two hours and twenty minutes consumed 2.70 gallons or 1.14 gallons per hour. The pressure was twenty pounds. The total consumption was 17.71 gallons in fourteen hours or 1.27 gallons per hour. One of the muffles was 6"x12"x4" and the other was 10"x16"x6 $\frac{3}{4}$ ". The burner was a Cary hydro-carbon burner 2 $\frac{1}{4}$ " in diameter.

INDEX

A

Andesite of West Sugarloaf Mountain, Boulder County, Colorado, 1.
 Andesite, see Mica Andesite,
 Analysis of Mica-Andesite, 11, 16.
 Agents of Ore Deposition, 194.
 Analysis of Arizpe Meteorite, 68.
 Analysis of Mine Air, 175.
 Analytical Chemistry, Uses of Refractometers, 85.
 Analysis of Gas, Happy Thought mine, 167.
 Analyses of Lead Ores, 74.
 Analysis of Tellurium, 143.
 Analysis of White Country Granite, 116.
 Analysis of Flowage of Underground Water, 203.
 Aqueous Solutions and the Deposition of Lode Ores, 193.
 Arizpe Meteorite, 67.
 Argonoid Elements, 70.
 Arsenopyrite and Native Tellurium, 146.
 Assay of Lead Ores, Commercial, 73, 77, 110.
 Assaying, Use of Crude Oil in, 341.

B

Bald Mountain, Boulder County, Colorado, 112.
 Barriers of Flowage of Underground Water, 200.
 Beaver Dam Mountains, 64.
 Boulder County, Mica-Andesite of West Sugarloaf Mountain, 1.

Boulder County, White Country Granite of Sugar Loaf Mountain, 113.
 Boulder County, Mica in, 139.

C

Chemical Asteroids, 69.
 Chemistry, Use of Refractometers in Analytical, 85.
 Chemical Agents in Ore Deposition, 194.
 Chihuahua, Mex., Santa Eulalia Mining District, 117.
 Circulation of Underground Aqueous Solutions, 193.
 Colorado Central Lode, 41.
 Comparative Results of Wet and Fire Methods for Lead, 74.
 Comparative Analyses of Mica-Andesite, 15.
 Conditions to the Absence of the Zone of Underground Water, 205, 212.
 Conditions to the Productiveness of Primary Ore Deposits, 248.
 Contact, Nev., Quaquaversal, 127.
 Copper and Pyritic Smelting, 79.
 Copper in the Dixie Mine, 64.
 Corliss Engine at the Saratoga Mine, Test of, 23.
 Creede, Gases in Mines at, 163.
 Crude Oil in Assaying, 341.
 Criteria for the Recognition of Primary Minerals, 248.
 Crystalline Form, Some Relations of Tetrahedral Combinations to, 19.
 Cuprodescloizite, Arizona, 149.

D

- Death Gulch, 189.
- Deep Shafts, Hoisting in, 313.
- Deposits, see Ore Deposits.
- Development of Pseudomorphs, 103.
- Discharging of Zone of Underground Water, 202.
- Discussion, 136, 173, 289, 344.
- Direction of Flowage of Underground Water, 199.

E

- Economy in Mill Water, 151.
- Effects of Arid Climates on Underground Water, 202.
- Effects of Local Heat and Its Sources on Underground Water, 210.
- Engine at Saratoga Mine, Test of, 23.
- Engine Indicator, Steam, 34.
- Electrons, 71.

F

- Flowage of Underground Water, 198.
- Fire Assaying, Use of Crude Oil in, 341.
- Fire Methods for Lead, 74, 110.

G

- Gases in Metalliferous Mines, 163.
- Gathering Zone of Underground Water, 201.
- Gold from Copper, The Separation of, 79.
- Granite, of West Sugar Loaf Mountain, 111.
- Geology, Santa Eulalia Mining District, 118.
- Geology of Contact Quaquaversal, 127.

Gases in Metalliferous Mines, Tests for, 176.

Gases in Death Gulch, 189.

Gold Mining in Kalgoorlie, W. A., 267.

Genesis of Metalliferous Ore Deposits, 289.

Geology and Vein Formation, the new, 289.

H

- Happy Thought Mine, Gases in, 165.
- Hoisting in Deep Shafts, 313.

I

- Indicator, Tabor Steam Engine, 34.
- Indicator, Tabor Steam Engine, 23.
- Ion, The Chemical Molecule of, 70.
- Iron Ores of Southwestern Utah, 55.

K

- Kalgoorlie, Western Australia, Progress of Gold Mining in, 267.
- Kalgoorlie, Western Australia, Tables Showing Gold Production, 268.

L

- Lead, Loss in Treatment, 78.
- Lead, Wet and Fire Methods, 110.
- Lead Ores, Commercial Assay of, 73, 77, 110.
- Limits of Variations of Underground Water, 201.
- Limits of the Zone of Underground Water, 202, 211.
- Localization of Primary Ore Deposits, 245.

M

- Microscopic Examination of White Country Granite, 113.
- Meteorite, The Arizpe, 67.

Metalliferous Mines, Gases in, 163.
 Mine Air, Analysis of, 175.
 Mica-Andesite, Comparative Analyses of, 15.
 Mica-Andesite, The Microscopic Examination of, 5.
 Mica-Andesite, Analysis of, 8.
 Mica in Boulder County, 139.
 Mica Andesite of West Sugar Loaf Mountain, 1.
 Microscopic Examination of Mica Andesite, 5.
 Mining Law, A Paradox of the, 41.
 Mineralogical Notes, 141.
 Mill Water, Economy in, 151.

N

Native Tellurium, Boulder County, Colo., 142.
 Gunnison County, Colo., 145.
 Associated With Arsenopyrite, Gunnison County, Colo., 146.
 Nevada Quaquaversal, 127.
 Nitrogen in Mines, 163.
 Notes on an Occurrence of Mica in Boulder County, 139.
 Notes on the Santa Eulalia Mining District, Chihuahua, Mex., 117.
 Notes on Southwestern Utah and Its Iron Ores, 55.
 Notes on Vanadium, 297.

O

Oil in Assaying, Use of, 341.
 Ontario Mine, Pumping System of, 30.
 Ore Deposits, 253.
 Ore Deposits, Primary, Conditions to Productiveness of, 248.
 Primary Localization of, 245.
 Ore Deposits, see Vein Formation.

Ore Deposition, Agents of, 194.
 Chemical Precipitants, 197.
 Chemical Solvents, 194.
 Chemical, 194.
 Physical, Meteoric Waters, 194.
 Physical, 194.
 Physical, Gravitation, 194.

P

Paradoxes in the Present Classification of the Elements in Reference to the Periodic Sequence, 69.
 Paradox of Mining Law, The Colorado Central Lode, 41.
 Periodic Sequence, Some Apparent Paradoxes, 69.
 Pseudomorphs, The Development of, 103.
 Primary Minerals, Criteria for the Recognition of, 248.
 Primary Deposits, Causes of Precipitation, 244.
 Conditions to Deposition of, 243.
 Disturbances to Static Conditions, 243.
 Localization of, 245.
 Native to Zone III, 242.
 Pumping Data, Some, 28.
 Pyritic Smelting, 79.

Q

Quaquaversal, The Contact Nevada, 127.

R

Rare Earths, 69.
 Radio-Active Elements, 71.
 Refractometers, Their Use in Analytical Chemistry, 85.
 Routes of Underground Water, 202.

S

- Santa Eulalia Mining District, 117.
- Saratoga Mine, Test of Engine at, 23.
- Secondary Enrichment; Agents and Reactions; Importance of the Zone Commercially, 239.
- Conditions to the Development of ore-shoots, 238.
- Absence of a Belt of Saturation, 239.
- Definitions of, 220.
- Limits and Characteristics of the Zone of Oxidation of, 228.
- Relations With the Water Zone, 222.
- Subdivisions of the Belt of, 224.
- Stages of Vein History, 222.
- Zone of Oxidation and Disintegration of, 225.
- Zone of Reduction and Precipitation of, 229.
- Secondary Minerals, Criteria for the Recognition of, 241.
- Silver Reef Camp, 64.
- Some Pumping Data, 28.
- Some Relations of Tetrahedral Combinations to Crystalline Form, 19.
- Southwestern Utah and Its Iron Ores, 55.
- Steam Engine Indicator, 34.
- Segment of the Cycle of Circulation of Underground Water, 209, 213.
- Smelting, Pyritic, 79.
- Separation of Gold from Copper With Reference to Pyritic Smelting, 79.
- Slimes Settling Tank, 158.

T

- Tabor Steam Engine Indicator, 34.
- Water in Kalgoorlie, 273.

- Tellurite, Gunnison County, Colo., 148.
- Tellurium, Native, 141.
- Temporary and Static Zone of Underground Water, 209.
- Test of the Corliss Engine at the Saratoga Mine, Central City, 23.
- Tests for Gases in Metalliferous Mines, 176, 180.
- Table Showing Consumption of
- Table Showing Labor Cost in Kalgoorlie, 286.
- Table Showing Grade of Ore, Costs, Profits, etc., 287.

U

- Underground Water, Analyses of Flowage of, 203.
- Articulation With Prevailing Theories of, 213.
- Barriers to Flowage of, 200.
- Conditions to the Absence of the Zone of, 205, 212.
- Closer Definition of the Lower Limit of, 217.
- Direction of Flowage, 199.
- Discharging Zone of, 202.
- Effects of Arid Climates on, 202.
- Effects of Local Heat and Its Sources on, 210.
- Flowage of, 198.
- Gathering Zone of, 201.
- Limits of Variations of, 201.
- Limits of Zone of, 202, 211.
- Movement Normally Infinitesimal, 209.
- Routes of, 202.
- Segment of the Cycle of Circulation of, 209, 213.
- Temporary and Static Zone of, 209.
- Zonal Deposition of, 201.

Utah, Notes on Southwestern, 55.

V

Vanadium, Notes on, 297.

Vein Formation, New Geology of,
253, 289.

W

Water, Economy in Mill, 151.

Waters Underground, 194.

West Sugarloaf Mountain, Mica-
Andesite of, 1.

Z

Zonal, Disposition of Underground
Waters, 201.

Zone of Unmodified Primary De-
posits, 242.



UNIVERSITY OF CALIFORNIA LIBRARY,
BERKELEY

**THIS BOOK IS DUE ON THE LAST DATE
STAMPED BELOW**

Books not returned on time are subject to a fine of 50c per volume after the third day overdue, increasing to \$1.00 per volume after the sixth day. Books not in demand may be renewed if application is made before expiration of loan period.

FEB 8 1923

MAY 16 1924

REG. CIR. FEB 177

MAY 19 1930

MAY 18 1930

SEP 12 1976 4 9
STACKS

AUG 12 1977

REG. CIR. AUG 14 78

25m 7.25

18

U. C. BERKELEY LIBRARIES



C054823231

Q11

C63

v. 1

1900

