THE

PROCEEDINGS

OF THE

COLORADO

SCIENTIFIC SOCIETY

VOL. VIII

1905, 1906, 1907

CONTENTS

ABSTRACT OF MINUTES FOR THE YEARS
1904, 1905, 1906 and 1907

THE TWO HUNDRED AND EIGHTH REGULAR MEETING.

June 4th, 1904.

In the Society Rooms, Chamber of Commerce Building.

There being but four members present, it was decided to hold a meeting of the Executive Committee, instead of the regular meeting, and "Rules Governing the Withdrawal of Books from the Library," were adopted.

THE TWO HUNDRED AND NINTH REGULAR MEETING.

July 2nd, 1904.

In the Society Rooms, Chamber of Commerce Building.

Past President Regis Chauvenet in the Chair

There were fifteen members present.

COMMUNICATIONS.—"Hoisting in Deep Shafts," by Charles W. Comstock.

THE TWO HUNDRED AND TENTH REGULAR MEETING.

August 6th 1904.

In the Society Rooms, Chamber of Commerce Building.

First Vice-President Brownlee in the Chair

There were twelve members present.

COMMUNICATIONS.—"A Contribution to the Planetesimal Theory," by Dr. Franklin R. Carpenter.

THE TWO HUNDRED AND ELEVENTH REGULAR MEETING.

September 3rd, 1904.

In the Society Rooms, Chamber of Commerce Building.

Past President Cannon in the Chair

There were nineteen persons present.

COMMUNICATIONS.—"The Use of Crude Oil for Fire Assaying," Illustrated, by F. C. Bowman.

THE TWO HUNDRED AND TWELFTH REGULAR MEETING.

October 1st, 1904.

In the Society Rooms, Chamber of Commerce Building.

Past President Cannon in the Chair

There were twenty-two persons present.

COMMUNICATIONS.—"Informal Discussion."

THE TWO HUNDRED AND THIRTEENTH REGULAR MEETING.

November 5th, 1904.

In the Society Rooms, Chamber of Commerce Building.

Past President G. C. Hewitt in the Chair

There were twenty-one persons present.

COMMUNICATIONS.—"The Drift Apron of the Front Range," by Professor George L. Cannon.

THE TWO HUNDRED AND FOURTEENTH REGULAR MEETING.

December 3rd, 1904.

In the Society Rooms, Chamber of Commerce Building.

President Lee in the Chair

There were twenty-five members present.

COMMUNICATIONS.—"Tables for the Miscroscopical Determination of Rock Analysis," by Mr. James Underhill.

The following persons were nominated for Officers and members of the Executive Committee:

President.....................Phillip Argall.
First Vice-President.....Charles W. Comstock.
Second Vice-President....Howard C. Parmelee.
Treasurer..............Chester W. Purington.
Secretary....................John W. Finch.

EXECUTIVE COMMITTEE.

Members of the Executive Committee:

Victor C. Alderson.	Harry A. Lee.
Thomas L. Wilkinson.	E. Lyman White.
A. W. Warwick.	G. C. Hewitt.

R. D. George.

THE TWENTY-SECOND ANNUAL MEETING.

December 19th, 1904.

In the Society Rooms, Chamber of Commerce Building.

———

President Harry A. Lee in the Chair

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There were twenty-one members present.

COMMUNICATIONS.—Annual Reports, Election of Officers and Executive Committee.

The following Officers and Executive Committee were elected for the year 1905:

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

EXECUTIVE COMMITTEE.

George L. Cannon.   Charles W. Comstock.
W. A. Johnston.   William F. R. Mills.
                Howard C. Parmelee.

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THE TWO HUNDRED AND SEVENTEENTH REGULAR MEETING.

February 4th, 1905.

In the Society Rooms, Chamber of Commerce Building.

———

President Brownlee in the Chair

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There were twenty-five members present.
COMMUNICATIONS.—"Informal Discussion."

THE TWO HUNDRED AND EIGHTEENTH REGULAR MEETING.

March 4th, 1905.

In the Society Rooms, Chamber of Commerce Building.

President Brownlee in the Chair

There were twenty-seven members present.

COMMUNICATIONS.—"The Geology of the Hot Springs in Colorado, With Some Speculation as to Their Origin and the Cause of Their Heat," by Professor Arthur Lakes.

THE TWO HUNDRED AND NINETEENTH REGULAR MEETING.

April 1st, 1905.

In the Society Rooms, Chamber of Commerce Building.

Past President Cannon in the Chair

There were twenty-seven members present.

COMMUNICATIONS.—"Informal Discussion."

THE TWO HUNDRED AND TWENTIETH REGULAR MEETING.

May 6th, 1905.

In the Society Rooms, Chamber of Commerce Building.

Mr. T. L. Wilkinson in the Chair

There were seventeen members present.

COMMUNICATIONS.—There being no papers for the evening an "Informal Discussion" was entered into, after which the meeting adjourned to partake of a "Dutch Lunch."

THE TWO HUNDRED AND TWENTY-FIRST REGULAR MEETING.

June 3rd, 1905.

In the Society Rooms, Chamber of Commerce Building.

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President Brownlee in the Chair

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There were twelve persons present.

COMMUNICATION.—"Examination of Incrustation formed on Rable Plate of a McDougall Furnace," by Dr. William P. Headden.

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THE TWO HUNDRED AND TWENTY-SECOND REGULAR MEETING.

July 1st, 1905.

In the Society Rooms, Chamber of Commerce Building.

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President Brownlee in the Chair

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There were seven members present.

COMMUNICATIONS.—"Informal Discussion."

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THE TWO HUNDRED AND TWENTY-THIRD REGULAR MEETING.

August 5th, 1905.

In the Society Rooms, Chamber of Commerce Building.

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President Brownlee in the Chair

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COMMUNICATIONS.—"Informal Discussion."

There were fifteen members present.

THE TWO HUNDRED AND TWENTY-FOURTH REGULAR MEETING.

September 2nd, 1905.

In the Society Rooms, Chamber of Commerce Building.

Past President Cannon in the Chair

There were fourteen members present.

COMMUNICATIONS.—"Mineralogical notes, No. II," by Dr. William P. Headden.

THE TWO HUNDRED AND TWENTY-FIFTH REGULAR MEETING.

October 7th, 1905.

In the Society Rooms, Chamber of Commerce Building.

Past President Cannon in the Chair

There were eighteen members present.

COMMUNICATIONS.—"Scientific Principles of Electric Storage Batteries," by Dr. Rudolf Gahl.

THE TWO HUNDRED AND TWENTY-SIXTH REGULAR MEETING.

November 4th, 1905.

In the Society Rooms, Chamber of Commerce Building.

President Brownlee in the Chair

There were thirteen members present.

COMMUNICATIONS.—"Some Recent Conglomerates Near Denver, Colo.," by Professor Cannon.

The new Constitution was adopted.

THE TWO HUNDRED AND TWENTY-SEVENTH REGULAR MEETING.

December 2nd, 1905.

In the Society Rooms, Chamber of Commerce Building.

Dr. William P. Headden in the Chair

There were ten members present.

COMMUNICATIONS.—"Informal Discussion."

NOMINATION OF OFFICERS AND EXECUTIVE COMMITTEE.

The following persons were nominated for officers and members of the Executive Committee:

President......................Phillip Argall.
First Vice-President...........T. E. Schwarz.
Second Vice-President.........D. W. Brunton.
Secretary....................W. A. Johnston.
Treasurer.................George L. Cannon.
Cor. Sec. and Librarian.....Thomas G. Smith.

Executive Committee—Six to be elected:

Mr. J. W. Richards.	Mr. D. W. Brunton.
Mr. W. F. R. Mills.	Mr. E. L. White.
Mr. H. C. Parmelee.	Mr. R. D. George.
Mr. E. N. Hawkins.	Mr. James Underhill.
Mr. Regis Chauvenet.	Mr. J. W. Finch.
Mr. N. C. Bonnevie.	Mr. A. W. Warwick.

THE TWENTY-THIRD ANNUAL MEETING.

December 16th, 1905.

In the Society Rooms, Chamber of Commerce Building.

President Brownlee in the Chair

COMMUNICATIONS.—Annual Reports, Election of Officers and Executive Committee.

NOMINATION OF OFFICERS AND EXECUTIVE COMMITTEE.

The following Officers and Executive Committee were elected for the year 1906:

President.................Mr. Phillip Argall.
First Vice-President.......Mr. T. E. Schwarz.
Second Vice-President.....Mr. D. W. Brunton.
Secretary...............Mr. W. A. Johnston.
Treasurer.................Mr. G. L. Cannon.
Cor. Sec. and Librarian..Mr. Thomas G. Smith.

EXECUTIVE COMMITTEE.

Edwin N. Hawkins.   Regis Chauvenet.
D. W. Brunton.   H. C. Parmelee.
W. F. R. Mills.   J. W. Richards.

THE TWO HUNDRED AND TWENTY-EIGHTH REGULAR MEETING.

February 3rd, 1906.

In the Society Rooms, Chamber of Commerce Building.

President Argall in the Chair

There were eighteen members present.

COMMUNICATIONS.—"The Electrical Separation of Copper Ore," by Mr. W. G. Swart.

THE TWO HUNDRED AND TWENTY-NINTH REGULAR MEETING.

March 3rd, 1906.

In the Society Rooms, Chamber of Commerce Building.

President Argall in the Chair

There were ten members present.

COMMUNICATIONS.—"Notes on Ore Deposits in the Magdalena District," by Mr. Phillip Argall.

THE TWO HUNDRED AND THIRTIETH REGULAR MEETING.

April 7th, 1906.

In the Society Rooms, Chamber of Commerce Building.

President Argall in the Chair

There were fourteen members present.

COMMUNICATIONS.—"Areal Geology of Lower Clear Creek," by Mr. James Underhill.

"Notes on Mining Conditions in a Section Across the Sierra Madre Mountains, in Old Mexico," by A. W. Warwick.

THE TWO HUNDRED AND THIRTY-FIRST REGULAR MEETING.

May 5th, 1906.

In the Society Rooms, Chamber of Commerce Building.

Professor George L. Cannon in the Chair

There were ten members present.

COMMUNICATIONS.—"A Pipe Line in Mexico," by Mr. Thomas L. Wilkinson.

THE TWO HUNDRED AND THIRTY-SECOND REGULAR MEETING.
June 2nd, 1906.
In the Society Rooms, Chamber of Commerce Building.

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President Argall in the Chair

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There were sixteen members present.
COMMUNICATIONS.—"Informal Discussion."

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THE TWO HUNDRED AND THIRTY-THIRD REGULAR MEETING.
July 7th, 1906.
In the Society Rooms, Chamber of Commerce Building.

————

President Argall in the Chair

————

There were eight members present.
COMMUNICATIONS.—"Mineralogical Notes, No. 3," by Dr. William P. Headden.

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THE TWO HUNDRED AND THIRTY-FOURTH REGULAR MEETING.
October 6th, 1906.
In the Society Rooms, Chamber of Commerce Building.

————

Dr. Regis Chauvenet in the Chair

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There were thirteen members present.
COMMUNICATIONS.—"Informal Discussion."

THE TWO HUNDRED AND THIRTY-FIFTH REGULAR MEETING.

November 3rd, 1906.

In the Society Rooms, Chamber of Commerce Building.

President Argall in the Chair

There were fourteen members present.

COMMUNICATIONS.—"Informal Discussion."

THE TWO HUNDRED AND THIRTY-SIXTH REGULAR MEETING.

December 1st, 1906.

In the Society Rooms, Chamber of Commerce Building.

Professor George L. Cannon in the Chair

There were twelve members present.

COMMUNICATIONS.—"Ore Deposits of the Joplin District," by Mr. F. L. Clerc.

"The Fossil Footprints in the Flagstones of Denver," by Professor George L. Cannon.

NOMINATION OF OFFICERS AND EXECUTIVE COMMITTEE.

The following persons were nominated for Officers and members of the Executive Committee:

President............Mr. Thomas L. Wilkinson.
First Vice-President.......Mr. D. W. Brunton.
Second Vice-President.....Mr. James Underhill
                              or Mr. George E. Collins.
Treasurer.............Mr. George L. Cannon.
Secretary...........Mr. William A. Johnston.

Executive Committee—To serve three years:

Mr. J. W. Richards.   Mr. George E. Collins.
                Mr. James Underhill.

THE TWENTY-FOURTH ANNUAL MEETING.

December 15th, 1906.

In the Society Rooms, Chamber of Commerce Building.

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Professor George L. Cannon in the Chair

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There were twelve members present.

COMMUNICATIONS.—Annual Reports, Election of Officers and Members of the Executive Committee.

THE ELECTED OFFICERS AND EXECUTIVE COMMITTEE.

The following Officers and Executive Committee were elected for the year 1907:

President..........Mr. Thomas L. Wilkinson.
First Vice-President.......Mr. D. W. Brunton.
Second Vice-President....Mr. James Underhill.
Secretary...........Mr. William A. Johnston.
Treasurer...........Mr. Geeorge L. Cannon.

Executive Committee—For three-year term:

Mr. J. W. Richards.   Mr. George E. Collins.

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THE TWO HUNDRED AND THIRTY-SEVENTH REGULAR MEETING.

February 2nd, 1907.

In the Society Rooms, Chamber of Commerce Building.

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President Wilkinson in the Chair

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There were twelve members present.

COMMUNICATIONS.—"Air Hammer Rock Drills," by H. L. Sinclair.

THE TWO HUNDRED AND THIRTY-EIGHTH REGULAR MEETING.

March 2nd, 1907.

In the Society Rooms, Chamber of Commerce Building.

———

President Wilkinson in the Chair

———

There were twenty-seven members present.

COMMUNICATIONS.—"The Examination of Some Coals in Routt County, Colorado," by Dr. William P. Headden.

"The Topographic Development of the Chalk Bluff and Pawnee Buttes." Illustrated with lantern slide views," by Mr. Junius Henderson.

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THE TWO HUNDRED AND THIRTY-NINTH REGULAR MEETING.

April 6th, 1907.

In the Society Rooms, Chamber of Commerce Building.

———

President Wilkinson in the Chair

———

There were twenty-two members present.

COMMUNICATIONS.—"A Study of Some Colorado Coals— A Comparison of Some Coals from Boulder, Routt and Delta Counties," by Dr. William P. Headden.

"The Spontaneous Combustion of Coal and its Effects on the Surrounding Strata," by Arthur A. Lakes.

THE TWO HUNDRED AND FORTIETH REGULAR MEETING.

May 4th, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were fourteen members present.

COMMUNICATIONS.—"Commercial Water Softening and Purification," by Charles M. Hampson.

THE TWO HUNDRED AND FORTY-FIRST REGULAR MEETING.

June 1st, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were seventeen members present.

COMMUNICATIONS.—"Notes on Local Quarternary Phenomena." Informal Talk by Professor George L. Cannon.

SPECIAL MEETING.

July 22nd, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were twenty-seven persons present.

This was a joint meeting with the Western Association of Technical Chemists and Metallurgists, called for the discussion of bills drafted for a State Geological Survey and to

approve of one for enactment by the State Legislature now in session.

THE TWO HUNDRED AND FORTY-SECOND REGULAR MEETING.

September 7th, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were sixteen members present.

COMMUNICATIONS.—"Reénforced   Concrete."   Informal Talk by Charles W. Comstock.

THE TWO HUNDRED AND FORTY-THIRD REGULAR MEETING.

October 5th, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were fifty-one members present.

COMMUNICATIONS.—"The Iron Ores and System of Mining a Sunrise Mine, Wyoming," by B. W. Vallat.

THE TWO HUNDRED AND FORTY-FOURTH REGULAR MEETING.

November 2nd, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were fifty-one members present.

COMMUNICATIONS.—"Steps in Cyanidation," by Phillip Argall.

THE TWO HUNDRED AND FORTY-FIFTH REGULAR MEETING.

December 7th, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were thirty-nine members present.

COMMUNICATIONS.—"Some Mattes Formed in Melting Zinc—Box Precipitates—Their Composition and What it Suggests," by Dr. William P. Headden.

NOMINATION OF OFFICERS AND EXECUTIVE COMMITTEE.

The following persons were nominated for Officers and Members of the Executive Committee:

President..........Mr. Thomas L. Wilkinson.
First Vice-President.......Mr. D. W. Brunton.
Second Vice-President....Mr. E. N. Hawkins.
Secretary..............Mr. W. A. Johnston.
Treasurer............Mr. George L. Cannon.

EXECUTIVE COMMITTEE.

Mr. B. W. Vallat.   Mr. Stephen Rickard.

THE TWENTY-FIFTH ANNUAL MEETING.

December 21, 1907.

In the Society Rooms, Chamber of Commerce Building.

President Wilkinson in the Chair

There were ten members present.

COMMUNICATIONS.—Annual Reports, Election of Officers and Members of the Executive Committee.

The following Officers and Executive Committee were elected for the year 1908:

President..........Mr. Thomas L. Wilkinson.
First Vice-President.......Mr. D. W. Brunton.
Second Vice-President.....Mr. E. N. Hawkins.
Secretary..............Mr. W. A. Johnston.
Treasurer................Mr. G. L. Cannon.

EXECUTIVE COMMITTEE.

Mr. B. W. Vallat.   Mr. Stephen Rickard.

PERSONS ELECTED TO MEMBERSHIP IN THE COLORADO SCIENTIFIC SOCIETY DURING THE YEARS 1904, 1905, 1906 AND 1907, WITH THE DATE OF ELECTION AND NAMES OF PRESIDING OFFICERS.

Elected.	Member.	President.	Secretary.
1-16-04	Kyle, T. D.	Harry A. Lee.	E. N. Hawkins.
2- 4-04	Richards, John W.		
2- 4-04	Williams, Fred T.		
2- 6-04	Bonnevie, N. C.		
2- 6-04	Young, L. E.		
2-25-04	James, Harry C.		
2-25-04	Keim, Edward T.		
3- 7-04	Josephi, S. A.		
4- 2-04	Chase, Charles A.		
4- 2-04	Herron, John.		
4- 2-04	Wells, Bulkeley		
5- 7-04	Evans, Mark G.		
8-19-04	Morton, Roscoe		
9- 3-04	Bliss, C. M.		
12- 3-04	Morley, Frederick H.		
1- 5-05	Bancroft, Geo. J.	A. G. Brownlee.	E. N. Hawkins.
1-13-05	Wetherill, W. C.		
2- 3-05	Gates, J. Wilson.		
2- 7-05	Gahl, Rudolph.		
2-13-05	Snedaker, James A.		
3- 4-05	Bruce, Stuart S.		
3- 4-05	Fielding, Thomas		
3- 4-05	Gehrmann, Chas. A.		
3- 4-05	Swickheimer, David		
4-27-05	Cunningham, P. H.		
4-27-05	Wallace, J. P.		
5-25-05	Callbreath, Jas. F.		
6- 2-06	Ballard, Charles.	Phillip Argall.	W. A. Johnston.
6- 2-06	Bowman, F. C.		
6- 2-06	Lennox, L. C.		
6- 2-06	Mayer, Lawrence L.		
6- 2-06	Moffat, F. G.		

6- 2-06—Sinclair, H. L.
6- 2-06—Wolcott, E. R.
7- 2-06—Thomas, Chas. S., Jr.
9- 1-06—Keely, Thomas
11- 3-06—Allison, Wm. F.
12-15-06—Bosco, Francis W. Phillip Argall. W. A. Johnston.
12-15-06—Decker, W. H.
12-15-06—Morse, Bradish P.
12-15-06—Morse, George G.
1- 5-07—Proctor, Olin S. T. L. Wilkinson. W. A. Johnston.
2- 2-07—Carpenter, L. G.
2- 2-07—Cox, William J.
2- 2-07—Giles, Branch H.
2- 2-07—Hitchman, H. S.
2- 2-07—Parker, Richard A.
2- 2-07—Vallat, Benjamin W.
2- 2-07—Wiles, Edwin L.
3-21-07—Bishop, Leo D.
3-21-07—Dewey, Chauncey E.
3-21-07—Hendryx, Wilbur A.
3-21-07—Sclater, W. L.
3-21-07—Skinner, J. D.
3-21-07—Smale, F. S.
3-21-07—Thatcher, Hugh
4-26-07—Brodhead, Albert G.
4-26-07—Herrick, R. L.
5- 1-07—Hendrie, E. B.
5- 4-07—Crebbin, Alfred
5- 4-07—Harlow, W. P.
9- 7-07—Backus, George S.
9- 7-070—Dalzell, T. J.
9- 7-07—Powell, George F.
9- 7-07—Smith, Carson W.
10- 5-07—Dinsmoor, W. P. J.
11- 2-07—DeSollar, Tenney C.
11- 2-07—Forster, Arthur O.
12- 7-07—Tonge, Thomas.
4- 2-07—Guiterman, Franklin. Restored to membership.
4- 2-07—John Kebler. Restored to membership.

ANNUAL REPORT OF THE PRESIDENT.

Dec. 21, 1907.

GENTLEMEN OF THE SOCIETY:

Another year has gone by and you have heard the reports of the Secretary and Treasurer, which show the present condition and progress of the Society.

At the beginning of the year I said that three things to be accomplished stood out most prominently—a decided increase in the membersship, the presentation of one or more papers at each monthly meeting and the raising of sufficient money to purchase the Hill Collection of Minerals. I may say that we have been entirely successful in the first two, and I believe that had it not been for the present financial situation we would have been successful in the third undertaking. I see no reason for departing from the policy that has been pursued the past year. A large membership is necessary for financial reasons. Papers for presentation, discussion and distribution to the membership must necessarily be procured. This is the hold upon the members who live at a distance and can rarely attend the meetings. It is not always possible to have all that is presented before the Society printed. It is desirable that the discussions be revised and printed as a part of the paper discussed. It is very often that many valuable features of a paper are brought out to better advantage by thorough disgussion. If we were in a position to have the papers printed and put in the hands of the members before the meeting at which they are to be presented, no doubt the discussion would be of a more thorough character. However, until the finances are in better condition this cannot be done.

The present mode of sending out the Proceedings—paged and ready for binding, has been criticised and perhaps with some reason. This method was adopted on account of our finances. Our printing bills are large. When the Proceedings are sent out throughout two or three years, which go to make

up a volume, and when the volume is entirely reprinted for distribution, the expense becomes too much of a burden.

I would recommend that as soon as the financial condition of the Society warrants, that Volume I and two parts of Volume II, be reprinted. There is considerable demand for these two volumes. It is also hoped that the later members will see the need of having all the Proceedings of the Society. With the exception of volumes I and II, these may be purchased from the Society at cost.

It must be remembered that the Officers give what time they can spare from their business and professional work. It would be a great aid to the Secretary for the members to assist him in the canvass for papers as well as new members. Each member should put his shoulder to the wheel and do his part. We are all working for results, not glory. This Society has an honorable record of twenty-five years back of it. The papers have been of the same high standard that the founders set. I have great faith in the possibilities of this Society and of its increase in usefulness and influence.

In the last twenty-five years we have been housed in several places. Through the courtesy of the Chamber of Commerce we have now been a member of their household for five years. Perhaps at this time our hopes for a permanent home of our own are too far distant. Nothing has been gained without work. I hope the idea of a permanent building will take a hold on each member of the Society and that he will not only think about it, but talk about it and work for it. The value that this Society has given to the mining and metallurgical industries of this State alone, by reason of the information given through the Proceedings, has been such that those who benefited thereby are amply able to contribute to the endowment of a building for the use of this Society.

I congratulate the Society on a good year's work. The work has been harmonious and your Secretary, Treasurer, Executive Committee and Assistant Secretary, deserve the commendation of the Society.

For myself, I wish most heartily to thank the members of the Society for the honor of having chosen me as your President for the past year. It is a difficult thing to live up to the standards of the men who have occupied this position. Had I not had the generous support of the whole Society the results of the year would not stand out so well. I hope to prove myself a more worthy and efficient member in the work of the coming year. I appreciate the honor you have done me in re-electing me to the Presidency of the Society. From my own personal stand-point I would rather have seen this office bestowed on another. However, in this re-election and a renewal of your confidence, I take it that the members endorse the policy of this year. That being the case I cannot too strongly urge upon you to secure new members. The increase this year of about fifteen per cent. can be duplicated in the coming year—which will make a membership of about three hundred (300). I ask your loyal co-operation in this work. An income from three hundred members means that more books may be added to the library, many that should be bound, and many other advantages given the Society which it cannot now enjoy.

I cannot refrain from a word about the two members we lost by death this year. Mr. George C. Hewett, your President in 1903. Mr. Hewett did splendid work for the Society. It was he who interested General William J. Palmer in the needs of the library and his generosity was the means of placing the library in its excellent condition today. Mr. Hewett, if I am not mistaken, attended every meeting during his term of office, coming to each meeting from Colorado Springs for that particular purpose. During his term of office more members were brought into the Society than in any other one year during its existence. It is a sad thing that such men as Mr. Hewett should be cut down when many more good years should be theirs. In his death the Society lost a most valuable member. I hope that at no distant time a picture of Mr. Hewett will adorn the walls of this room.

Mr. John T. Kebler was the manager of the coal department of the Colorado Fuel & Iron Company, and at the time of his death was thirty-nine (39) years old. When he first came west and entered the employ of the above named company he came under the direction and influence of Mr. R. C. Hills, and did considerable work for the Society in the early days. For several years he took no part in the Society's work, but early this year he expressed a desire to re-enter the Society, which he did, but soon afterward, on April 12th, he died in Trinidad, of ptomaine poisoning.

It is very possible that this building will be sold in the near future and we shall again be compelled to seek other quarters. In that case, what shall the Society do? At this time considerable space is needed for the Collection and Library. It is a question which must be met. The Executive Committee has not as yet considered it, but it must be done. In other times the Society has been complled to make changes and no doubt it can do so again.

In closing I wish to express my appreciation of the honor you have done me, of your unselfish and loyal support in every way. And I ask, that in the coming year, the same spirit of loyalty to the objects and purposes of the Society be given by you all, in which case we need not fear for results.

<div align="right">THOMAS L. WILKINSON,
President.</div>

REPORT OF THE SECRETARY OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR 1907.

Nine regular meetings and one special meeting, the latter being a joint meeting with "The Western Association of Technical Chemists and Metallurgists," with the object of discussing bills drafted for a "State Geological Survey," and to adopt one for presenting to the State Legislature for enactment, were held, the average attendance, not including the special meeting, being 24.6. Ten papers were presented and read, the titles and authors of which were as follows:

"The History of the Air Hammer Drill."—H. L. Sinclair.

"An Examination of Some Coals from Routt County, Colorado."—Dr. William P. Headden.

"Topographic Developments of Chalk Bluffs and Pawnee Buttes," Illustrated.—Junius Henderson.

"A Study of Some Colorado Coals—A Comparison of Some Coals from Boulder, Routt and Delta Counties."—Dr. William P. Headden.

"The Spontaneous Combustion of Coal and Its Effects on the Surrounding Strata."—Prof. Arthur Lakes.

"Commercial Water Softening and Purification."—Charles M. Hampson.

"The Iron Ores and System of Mining at Sunrise Mine, Wyoming."—B. W. Vallat.

"Steps in Cyanidation," Illustrated.—Phillip Argall.

"The Great Tunnels of the World."—C. W. Comstock.

"Some Mattes Formed in Zinc Box Precipitates, Their Composition and what It Suggests."—Dr. William P. Headden.

In addition to these ten papers a very interesting talk on "Reénforced Concrete" was given by Mr. C. W. Comstock. And Professor George L. Cannon gave an informal and very interesting talk on "Local Quarternary Phenomena." Following the precedent established last year no meetings were

held during July and August and the "Annual Dinner" took the place of the January meeting. In addition to the above meetings, on December 14th the Society celebrated the Twenty-fifth Anniversary of its organization by a special meeting in the Assembly Hall of the Chamber of Commerce, and about three hundred attended, including members and their invited guests. The meeting was opened by President Wilkinson introducing Mr. E. N. Hawkins who, in a very appropriate manner, presented a "Silver Gavel," a gift of Mr. John W. Richards, to the Society. This was followed by a very learned and scientific paper by Dr. John C. Shedd entitled "Lightning and Lightning Protection," with lantern slide illustrations. As the Proceedings of this meeting with the paper of Dr. Shedd, will be distributed through the regular publication of the Society, no further reference is necessary in this report.

The meetings have been well attended, averaging 24.6, which compared with previous years is very satisfactory, indicating a growing interest in the progress and usefulness of the Society.

Our membership has shown a steady growth, increasing from 207 to 245, or about 15 per cent. We have lost two members by death and two by resignation. Of this increase in membership two were added by restoration and the balance by election. Of the total number 133 reside in Denver, 56 outside of Denver, 46 outside of Colorado and 5 outside of the United States.

At our November meeting Dr. Regis Chauvenet and Dr. William P. Headden, were raised in grade from Fellows to Honorary Fellows, and the grading at present stands as follows: One Life Member, 7 Honorary Fellows, 14 Fellows, 167 Members and 56 Associate Members. During the year death claimed two of our valued and esteemed members. Mr. Hewett, who was President of the Society for the year 1903, died at his home in Colorado Springs, August 12th, and Mr. John T. Kebler died April 9th, at the age of 39 years.

It gives me pleasure to speak in the highest commendation of your Executive Committee, who have labored zealously for the welfare of the Society. There were nine regular meetings held, besides a number of informal meetings, at all of which a deep and painstaking interest in all subjects discussed was manifested. The fruits of this labor are shown in the orderly and judicious manner in which the business of your Society has been managed.

Library—In the report of the Secretary for 1906 it was stated that the Library contained 2,369 volumes. Since there has been added by donation 14 volumes and by purchase 72 volumes, bringing the total at this date to 2,400 volumes. The donations were as follows:

"Annals of the Lowell Observatory," Volume 2. Rev. F. F. Kramer.—Presented by Prof. G. L. Cannon.

"Annual Report of the Portland G. M. Co."—Mr. V. G. Hills.

"Twenty-fifth Annual Report of the Bureau of American Ethnology."—Smithsonian Institute.

"Colorado Volunteers in the Civil War, The New Mexico Campaign in 1862." (State Historical and Natural History Society.)—Mr. Charles R. Dudley (Secretary).

"Eighteenth Report of the Missouri Botanical Garden."—Mr. Wm. Trelease (Director).

"Geological Survey of New Jersey, Annual Reports from 1900 to 1906, inclusive."—Mr. H. B. Kummel (Geologist).

"Paleontology," Volume 4. Text and Plates.—Mr. H. B. Kummel.

"Pliocene and Pleistocone." (Maryland Geological Survey).—Mr. Wm. B. Clark (Geologist).

"Report of Experiments with Coal Burning Locomotives Made on the Pennsylvania Road, April to August, 1859."—Mr. Wm. J. Palmer.

"Report of Geological Survey of St. Mary's and Calvert Counties, Maryland," with Maps.—Mr. W. B. Clark (Geologist).

"Transactions of the American Institute of Mining Engineers," Volume 37.—Mr. E. LeNeve Foster.

"Report of the Librarian of Congress and of the Superintendent of Buildings and Grounds for 1906."—Mr. Chas. R. Dudley (Secretary State Historical and Natural History Society).

"The Metallurgy of Steel."—Mr. A. B. Frenzel.

"Wisconsin Geological and Natural History Survey."— Mr. A. E. Birge (Director).

The volumes purchased were:

"Copper Smelting," by Edward D. Peters.
"Cyanide Practice," by Alfred James.
"Geology," by Chamberlain & Salisbury.
"Hand Book of Matellurgy," by Dr. Carl Schnabel.
"Metallurgy of Gold," by T. K. Rose.
"Metallurgy of Lead," by H. O. Hofman.
"Metallurgy of Cadmium and Zinc," by Walter R. Ingalls.
"Mineral Industry," Volume XV.
"Ore Dressing," by Robert H. Richards.
"The Nature of Ore Deposits," by Dr. R. Beck.
"Watt's Dictionary and Chemistry."

It has been the desire of the Executive Committee to keep the library up to the highest standard, and only lack of funds has prevented a much larger addition. We hope and expect to place more volumes on our shelves during the coming year.

The "List of Publications" on the reading table has shown increase and also the "Exchange List" has been added to.

The number of visitors to the Library and Museum, registered, was about the same as last year, the last three months showing a very decided increase as compared with the same period last year.

Hill Collection—In the beginning of the year it looked as though the purchase of the "Hill Collection" would be completed, but the general financial depression has put a damper

on our labor in this line, however, our efforts to acquire this valuable collection will continue with unabated zeal.

The policy of the coming year will be so thoroughly out-lined in the President's Address that no suggestions are left for the Secretary.

<div align="center">WM. A. JOHNSTON,</div>

<div align="right">Secretary.</div>

TREASURER'S REPORT FOR 1907.

RECEIPTS.

From dues	$1,820.00
From dinner fees	130.00
From sale of publications	26.85
From balance from 1906	38.97
	$2,015.82

EXPENDITURES.

Printing	$ 620.55
Salary of assistant secretary and janitor	432.75
Periodicals	95.10
Books	113.20
Dinner expenses	268.95
Postage	125.51
Light and water	72.00
Telephone	40.00
Insurance	47.70
Expressage	4.44
Lecture expenses	102.62
Stationery	7.50
Certificates of membership	8.80
Repairs	8.76
Sundry expenses	5.48
	$1,953.36
Receipts	$2,015.82
Expenditures	1,953.36
Balance	$ 62.46

GEO. L. CANNON, Treasurer.
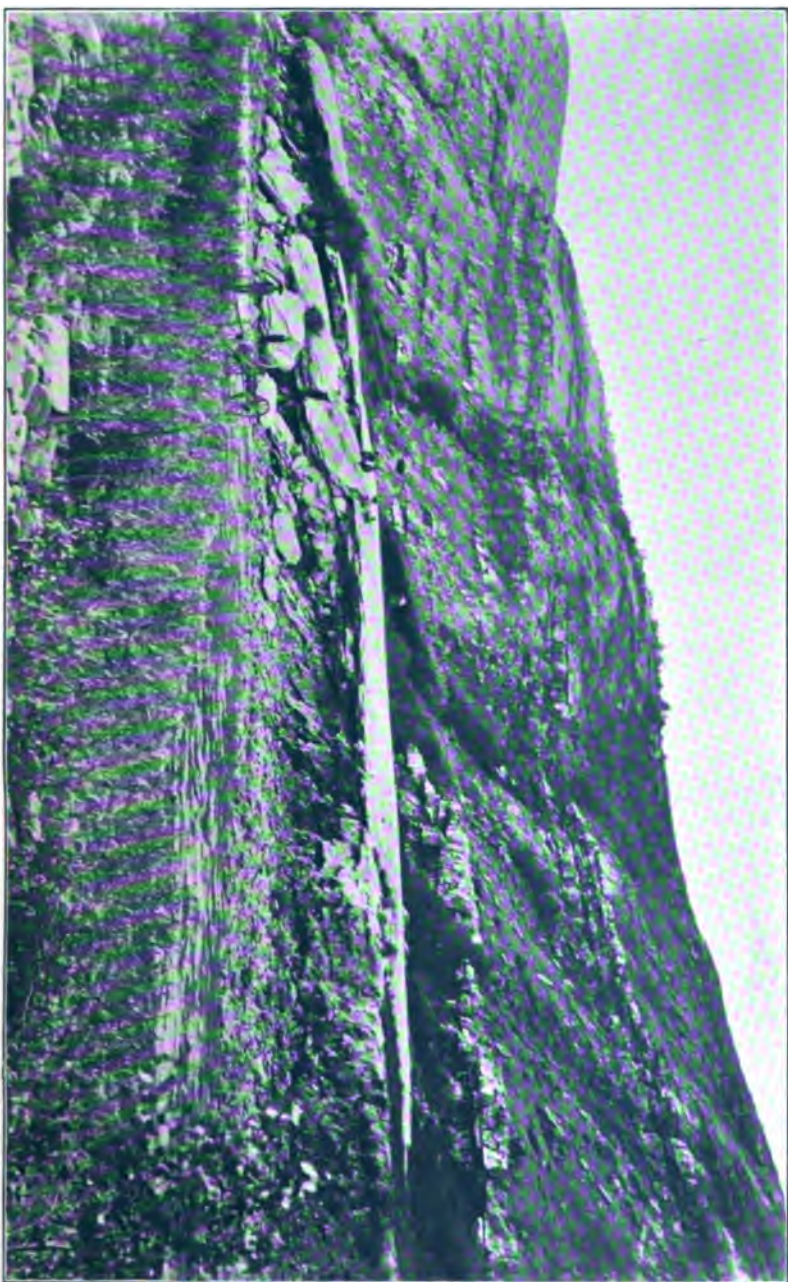
General View of the Springs, showing River, Sinter Bed and Cliff. View looking westward.

THE DOUGHTY SPRINGS, A GROUP OF RADIUM-BEARING SPRINGS ON THE NORTH FORK OF THE GUNNISON RIVER, DELTA COUNTY, COLORADO.

By WM. P. HEADDEN.

About two years ago my friend Mr. Mathews called my attention to a group of springs, which even at this time is wholly unknown to the public, and is but a little more than an object of curiosity to the people of that neighborhood.

The first thing which would probably attract the attention of the average visitor would be the decided odor of hydrogen sulfid, which can be observed for sometime before one reaches the place, but the quite extensive bed of sinter would be much more suggestive to those who have a greater acquaintance with mineral springs. A superficial examination of the surroundings, particularly of the face of the cliff, which rises immediately behind the springs to a height of one hundred and thirty feet, would suggest even more strongly than the sinter bed that the waters of these springs, or waters from some other source were heavily charged with salts and are now acting upon the sandstone and shales of the cliff to a very readily observed extent.

The bed of sinter forms a level area 400 feet long by 147 feet wide, measured at the widest part, the average width is probably

not far from 115 feet and the height above the river bed, or thick-
ness of the sinter, 20 feet.

The springs are all situated near the base of the cliff, and
with one exception have not built up any cones about their points
of issue. There is no marked evidence that these springs are add-
ing rapidly to the mass of sinter at the present time. The sinter
bed is a little higher as we approach the cliff than along the river
front and there is a general deposition going on. There is but
one instance of cone building, and the little streams which flow
across the surface of the bed have not formed elevated margins to
mark their course.

The formation of the cone in the case of the one spring is
easily explicable and furnishes an interesting example of the influ-
ence of accidental agencies. The water of this spring does not
differ sufficiently from that of the others to cause it to lay down
the sinter in a different manner. The explanation of the fact that
it does, is very simple, i. e., the weathering of the cliff has given
rise to a talus which, due to the trampling of cattle and the constant
flow of water through it, has spread out around the spring and
formed a soil which has been taken possession of by a rank grow-
ing grass whose leaves and stems falling around the spring, catch
the sinter forming material and retain it until cemented into a
compact sinter. This sinter will be discussed in some detail in
another paragraph.

The sinter bed occupies practically the entire area between
the foot of the cliff and the river, which, owing to changes in the
river bed whereby the current has been thrown against the lower
portion of the sinter bed, has already encroached upon it for many
feet. There are remnants of pieces which have broken off, due to
undermining by the river, as much as 25 feet in width.

The cliff at a point immediately behind the springs rises per-
pendicularly to a height of 130 feet, but attains a greater height at
points both up and down the river; in structure it presents an
alternation of sandstone and shales with a stratum of conglomer-
ate near the top. The series of strata forming the face of the cliff
probably belong to the upper portion of the Dakota.

There are no evidences that this group of springs has ever been materially more active than at the present time, nor that they represent older but no longer active springs as is the case at a locality some 12 or 15 miles further down the river, where we find several rather small springs, which are the representatives of what must at some time have been quite an extensive group; to whose activity a mass of sinter extending up the face of the quite steep hill for 60 feet or more and long benches of similar material extending back from the river for a considerable distance bear conclusive evidence. No such evidence of change in the number or size, and I may add character of the springs is present at the place which we are describing.

The flow of the springs aggregate a considerable volume, but there is no one spring which furnishes a notably large flow. The large number of small springs in the group is probably due to impeded outflow, whereby the waters are forced to find various passages for their escape. According to my information one spring issues in the bed of the river. Gas, in moderate quantities, escapes from all of the springs. In addition to the actual dis- charge of the springs, small streams are issuing from the face of the sinter bed along the river front at very many places, in fact, almost throughout its entire length. Assuming that this water, the very much larger portion of it at least, comes from the springs, the aggregate amount discharged by them must be quite large. A question, however, may arise in regard to the quantity of water, if any at all, that may flow in from the large area of irrigated land lying above and back of them. It is a fact that there are many little streams flowing out of the face of the cliff, and water is oozing out at almost every point, while the projecting portions of the rocks carry their deposits or incrustations. The country immediately back from the edge of the cliff is a flat area, strongly alkalized by the seepage from the still higher lying, irrigated land. The volume of the off-flow and seepage waters due to irrigation is, at times, sufficient to give rise to a small stream which reaches the river at a point a little below the springs. It is not probable

that the surface waters in the immediate vicinity of the springs influence them in the least. These springs were here in their present size very long before irrigation was practiced, and even if the surface waters penetrated the strata the latter dip down the river and away from it. In order that surface waters should form part of the outflow of these springs they would have to enter the outcrop at some remote point and take their course along the strata to the point of outflow. While this may be the case I know of no fact to indicate it. There is no doubt in my mind but that the waters coming from the cliff, including some surface water, do in a very small measure find their way into the springs under the present conditions, but the amount of this water is wholly insignificant and without influence upon the character of the springs. On the other hand it seems to me very probable that many of the springs represent waters coming from considerable depths, but which are forced to commingle, probably near the surface, because the separate springs have at this time no free channel through which their waters may issue and are consequently forced to find many points of outflow, and in doing so meet and mingle with waters from other springs. A fuller inquiry into this point was out of the question at the time, and in fact did not suggest itself until the work presented in this paper was so well advanced that I would not have undertaken it even if it had been within the scope of this study. This much, however, may be said, i. e., there are certainly three types of waters represented by the analyses, which I shall subsequently present for consideration, but there is a considerable number of springs, how many I do not know, whose waters are, so far as I can now judge, intermediate in character between two of these types.

These springs discharge moderate quantities of gases which, much to my regret, I have not been able to submit to even a qualitative examination. I regret this very much indeed, for I am of the opinion that these gases would, on examination, prove to be of very great interest, as you shall presently learn to be the the case with the waters and their deposits.

These springs are, so far as I know, wholly unknown by the general public and have no individual names, but are spoken of collectively as the Doughty Springs.

It is true that one of them is called the Black Spring, because the water appears black as it lies in the basin just beyond the spring proper. Another is called the Bath Tub because of its size and convenient depth for bathing. It is certain that the Indians made use of it for this purpose whether they knew it under this name or not, for the mud which had gradually collected in the bottom of the spring was found upon cleaning it out to contain an abundance of beads and Indian trinkets, supposed to have been lost by the bathers. The Indians are believed to have attributed great medicinal virtues to this and to the other springs also. A third spring is known under the name of the Drinking Spring, because its waters are preferred to those of the other springs for this purpose. I do not know the reason, real or supposed, of this choice, but the preference is for the waters of this spring, and those who are accustomed to it drink it very freely. This is a curious fact for which I can see no good reason, as some of the other spring waters are as attractive in appearance and taste and smell no stronger of hydrogen sulfid, and yet this is probably another instance in which the unbiased general judgment arrives at a sound and correct scientific conclusion based upon some effect which it either cannot or never troubles itself to formulate. You will later see that this is, in fact, the most remarkable water in the group, and constitutes one of the three types to which I have alluded.

There are but three springs in the group whose waters are clear. They are the Black Spring, the Drinking Spring, and another which I have not mentioned before, the Alum Spring. All the other springs show a pronounced milkiness. The first and most reasonable explanation offering itself is that the milkiness is caused by the sulfur set free by the decomposition of the hydrogen sulfid. This would, according to our almost universal observation, be the case in a spring of the dimensions of the Bath Tub whose diameters are 19 feet and 27 feet respectively and whose

flow is apparently small, while it is constantly receiving a moderate supply of gas. Some of the smaller springs, however, with a comparatively free discharge of water, carbon dioxid and hydrogen sulfid, conditions tending to prevent the decomposition of the latter substance in the spring, are more turbid even than the Bath Tub, and suggest that there is another cause for the milkiness which is really the case. I shall subsequently give the reason for the statement which I now make, i. e., that this turbidity or milkiness is mostly due to the separation of baric sulfate and in a very slight degree only to the separation of sulfur set free by the decomposition of hydrogen or any other sulfid.

The Black Spring is clear, but this spring, so far as I now know, is not depositing any, or at most a very small amount of sinter and the little deposit, which has formed on the shale forming the rim of the spring, is practically pure sulfur. This spring has a basin contiguous to it, but the deposit forming in this is black (from which fact the spring obtains its name), and consists essentially of ferrous sulfid with a little manganous and a trace of zinc sulfid. This basin is also used as a bathing place and is 10 or 12 feet in diameter.

I believe that the separation of the baric sulfate in these waters before they actually come to the point of their discharge is due to the mingling of different waters, whereby the conditions of solution are so changed as to lead to the formation of this salt. The mingling may and probably does take place near to the surface. The precipitated baric sulfate is in an extremely fine state of division, and the movement of the water is sufficient to keep it in suspension and produce the milkiness.

The considerations which lead me to this conclusion are the following:

The Drinking Spring is perfectly clear and contains a very marked quantity of barium in solution. This is probably the typical water of the group; it is depositing a baritic sinter outside of the spring:

The other springs are turbid or milky, their waters contain after the milkiness has subsided or disappeared only a very minute trace of barium, and these springs are all depositing within and about the springs baritic sinters.

A spring, designated in my notes as Spring No. II "Birds' Nest," is building a cone around its vent, consisting very largely of baric sulfate precipitated within the spring and being washed up and out by the outflowing gases and water.

A small amount of deposit was obtained from five gallons of water dipped from the Bath Tub. This deposit contained in round numbers 22 per cent of baric sulfate with a minute quantity of sulfur. The fine impalpable mud from the bottom of the Bath Tub contained almost 40 per cent of baric sulfate.

The foregoing facts, together with observations made at the springs, convince me that the explanation offered to account for the milkiness of the springs is correct. It further seems to follow that water of the type, if not identical with that of the Drinking Spring, is the source of the barium, while the precipitant is probably a water of the type of the Black Spring, as rich in mineral constituents or even more so than the Drinking Spring itself. If the precipitation takes place very near to the surface, then the water held within the rocks and possibly of surface origin, may be the precipitant.

I cannot attempt to give the number of springs in this group. The strip, extending from the Drinking Spring to the Black Spring, seems to be an area of a sort of a diffused discharge caused by the accumulation of talus material. I have taken samples of six springs which I have designated as follows: No. I or Black Spring; No. II, Birds' Nest, situated east and north of Black Spring; No. III, a larger spring west and north of Bath Tub; No. IV, Alum Spring almost north of No. I; No. V, Bath Tub; No. VI, Drinking Spring east and north of the Bath Tub.

The waters of these springs are not equally acceptable to the palate, and the average person would have to acquire a taste for them. The characteristic in the taste of these waters is not due

to the presence of hydrogen sulfid, for the writer is very fond of a certain sulpho-carbonated water, while he cannot truthfully acknowledge any great preference for those of the Doughty Springs as drinking waters. I do not dislike them and they pro- duce no unpleasant effects when drunk in large quantities, on the contrary their effect is agreeable, but their taste is not pronouncedly pleasant to me. I do not know to what one can liken it, especially the taste of No. VI or the Drinking Spring, which suggests to me simultaneously the taste of hydrogen sulfid and that of hydrogen peroxid. All of the springs of this group, with the exception of the Alum Spring, furnish drinkable waters, but the preferred ones are the Drinking Spring and the Black Spring. The Alum Spring is so astringent that its character becomes apparent to one immediately upon tasting it, and there is no temptation to drink thereof.

No. I or Black Spring.

This is the most westerly spring of the group of any size; its diameters are 30″ for the shorter and 48″ for the longer. The flow is not very strong, and is accompanied by a continuous but moderate discharge of gas. The water is clear with a temperature of 17·5°C (63·5°F). It is to my taste the most agreeable drink- ing water of the whole group.

The name given to this spring, Black Spring, alludes to the apparent color of the water, as it collects in the basin which may be considered a part of the spring. The water is, as a fact, color- less and quite clear. The apparent black color is due to the pre- cipitation of ferrous sulfid due to the presence of an alkaline sulfid in the water. The source of the iron is probably the water of the Alum Spring, which is a short distance (30 feet?) north of it. This Alum water spreads out on the surface of the ground, and a sufficient amount of it finds its way into this basin from the sur- face to account for the small amount of ferrous sulfid actually formed. The precipitation of ferrous sulfid from the water, satu-

Black Spring, with Basin or Pool in foreground.

rating the upper portion of the bed, can be observed just above the spring in question.

The presence of the following substances is not noted in the analyses: Sulfids other than hydrogen sulfid, titanic, phosphoric, and dithionic acids. I could not examine the waters until the samples had become so old that the determination of the sulfids, and the dithionic acid would have been of but little or no value. I determined the dithionic acid in the water of the Black Spring in a comparatively fresh sample; its value is, however, not great. Phosphoric acid was repeatedly tested for and is present in minute traces; titanic acid is also probably present, but the reactions obtained were very faint and may have been erroneously inter-preted. I detected neither caesium nor rubidium in the amount of the samples used which, in these cases, was from three to six litres.

RESULTS OF ANALYSIS OF SPRING No. I OR BLACK SPRING.

CALCULATION OF CATIONS.

$$Na............1\cdot1978+ \quad 23\cdot05=0.051964\times1=0\cdot051964$$
$$K............0\cdot0589+ \quad 39\cdot15=0\cdot001504\times1=0\cdot001504$$
$$Li. ....0\cdot0016+ \quad 7\cdot03=0\cdot000224\times1=0\cdot000224$$
$$NH_4... ....0\cdot0013+ \quad 18\cdot08=0\cdot000074\times1=0\cdot000074$$
$$Ca....... .....0\cdot1261+ \quad 40\cdot10=0\cdot003152\times2=0\cdot006304$$
$$Ba....... ...... \qquad\qquad None$$
$$Sr. ....0\cdot0035+ \quad 87\cdot60=0\cdot000039\times2=0\cdot000078$$
$$Mg............0\cdot0609+ \quad 24\cdot36=0\cdot002500\times2=0\cdot005000$$
$$Fe............0\cdot0012+ \quad 55\cdot90=0\cdot000021\times2=0\cdot000042$$
$$Al............0\cdot0046+ \quad 27\cdot10=0\cdot000168\times3=0\cdot000504$$
$$Mn.... ....0\cdot0040+ \quad 55\cdot00=0\cdot000072\times2=0\cdot000144$$
$$Zn............ \qquad\qquad Trace$$
$$Sum.... ......1\cdot4599 \qquad\qquad\qquad 0\cdot065839$$

CALCULATION OF ANIONS.

$$Cl............0\cdot8157+ \quad 35\cdot45=0\cdot023009\times1=0\cdot023009$$
$$Br.... ....0\cdot0147+ \quad 79\cdot96=0\cdot000184\times1=0\cdot000184$$
$$I.............. \qquad\qquad Trace$$
$$SO_4............0\cdot2731+ \quad 96\cdot06=0\cdot002843\times2=0\cdot005686$$
$$SiO_3...........0\cdot0235+ \quad 76\cdot40=0\cdot000308\times2=0\cdot000616$$
$$BO_2............0\cdot0001+ \quad 43\cdot00=0\cdot000003\times1=0\cdot000003$$
$$S_2O_3...........0\cdot0108+112\cdot12=0\cdot000096\times2=0\cdot000182$$
$$Sum............1\cdot1379 \qquad\qquad\qquad 0\cdot029680$$

Sum of Cations..............................0·065839
Sum of Anions..............................0·029680

Excess of Cations..........................0·036159

The excess of cations corresponds to CO_2 anions expressed in monovalent ions.

0·036159÷2=0·018079=CO_2 bivalent ions.

0·018079×60=1·084740 CO_2 in grms., corresponding to 0·794439 CO_2.

Total CO_2 found............................2·5660
CO_2 combined as simple carbonates......:....0·7944

1·7716

CO_2 combined as bicarbonates................0·7944

CO_2 wholly free per litre.....................0·9772

The wholly free CO_2 corresponds to 496·84 c.c. at 0°C and 760mm pressure. Hydrogen sulfid considered as wholly free is 0·0492 gram or 32·12 c.c.

Specific gravity at 16°.............. ....1·00400
Total solids............. .... 3·6825

SPRING No. II. BIRDS' NEST.

This spring is eliptical, the shorter diameter is 18 inches, the long 24 inches. The escaping gas is quite abundant, more so than in No. I. The water of this Spring is quite turbid, and the formation of the sinter cone is due to the fact that the precipitate which is suspended in the water is caught by the leaves and stems of the grass, which grows abundantly about the spring, and which is well shown in the photograph. Observation at the spring and the sample of sinter exhibited, show conclusively that this is the manner in which this sinter is being built up into a cone.

Birds' Nest.   Showing cone of Barltic Sinter.

RESULT OF ANALYSIS OF SPRING No. II.—BIRDS' NEST.
CALCULATION OF CATIONS.

Na............1·2736÷ 23·05=0·055254×1=0·055254
K.............0·0661÷ 39·15=0·001688×1=0·001688
Li.............0·0049÷ 7·03=0·000697×1=0·000697
NH₄...........0·0017÷ 18·08=0·000092×1=0·000092
Ca............0·1186÷ 40·10=0·002959×2=0·005918
Ba............   Minute trace
Sr............0·0035÷ 87.60=0·000040×2=0·000080
Mg...........0·0543÷ 24·36=0 002230×2=0·004460
Fe............0·0003÷ 55·90=0·000005×2=0·000010
Al............0·0005÷ 27·10=0·000018×3=0·000054
Mn...........0 0022÷ 55·00=0·000041×2=0·000082
Zn............   Trace
Sum..........1·5257   0·067335

CALCULATION OF ANIONS.

Cl............0·8615÷ 35·45=0·024302×1=0·024302
Br............0·0095÷ 79·96=0·000119×1=0·000119
I.............   Trace
SO₄...........0·1417÷ 96·06=0·001475×2=0·002950
SiO₃..........0·0213÷ 76·40=0·000280×2=0·000560
BO₂...........0·0079÷ 43·00=0·000183×1=0·000183
Sum..........1·0419   0·028114

Sum of Cations..........................=0·067335
Sum of Anions ....=0·028114
Excess of Cations.......................=0·039221

The excess of cations corresponds to the CO_3 anions expressed in mo-
novalent ions

0·039221÷2=0·0196105=CO_2 bivalent ions 0·0196105×60=CO_3 in
grams=1·176630 corresponding to 0·862823 CO_2

CO₂ found................................. 2·6316
Less CO₂ combined as carbonates .... 0·8628
                                           1·7688
Less CO₂ combined as bicarbonates .... 0·8628
CO₂ entirely free......................... 0·9060
0·9060 CO₂ equals 450. 68 c.c. at 0° and 760mm. pressure.
Hydrogen sulfid considered as wholly free =0·0387358 =25·39 c.c.
Total solids.................................... 3·7442 per litre.
Specific gravity at 16°c...............................= 1·00393.

Spring No. III. is the second largest spring in the group, and is almost circular, being about 4 feet in diameter. The escape of gas is free enough to keep the water quite turbid, due to the constant throwing up of the sand from the bottom of the spring. The deposit formed about this spring, perhaps I should say the sample collected proved to be almost pure sulfur, and the residue was free from calcium, strontium and barium, but lithia was relatively abundant in the ignited residue. This spring is not shown in any of the photographs.

Results of Analysis of Spring No. III.
Calculation of Cations.

$$Na\dots\dots\dots1\cdot2002 \div\ 23\cdot05 = 0\cdot052071 \times 1 = 0\cdot052071$$
$$K\dots\dots\dots0\cdot0632 \div\ 39\cdot15 = 0\cdot001614 \times 1 = 0\cdot001614$$
$$Li\dots\ \dots\dots0\cdot0068 \div\ \ 7\cdot03 = 0\cdot000974 \times 1 = 0\cdot000974$$
$$NH_4\dots\dots\ \dots0\cdot0011 \div\ 18\cdot08 = 0\cdot000058 \times 1 = 0\cdot000058$$
$$Ca\dots\dots\dots0\cdot1204 \div\ 40\cdot10 = 0\cdot003001 \times 2 = 0\cdot006002$$
$$Ba\dots\dots\dots\qquad\qquad Trace$$
$$Sr\dots\ \dots\dots0\cdot0033 \div\ 87\cdot60 = 0\cdot000038 \times 2 = 0\cdot000076$$
$$Mg\dots\ \dots\dots0\cdot0552 \div\ 24\cdot36 = 0\cdot002267 \times 2 = 0.004534$$
$$Fe\dots\ \dots\dots0\cdot0035 \div\ 55\cdot90 = 0\cdot000006 \times 2 = 0\cdot000012$$
$$Al\dots\dots\ \dots\dots0\cdot0004 \div\ 27\cdot10 = 0\cdot000014 \times 3 = 0\cdot000042$$
$$Mn\dots\dots\dots0\cdot0023 \div\ 55\cdot00 = 0\cdot000046 \times 2 = 0\cdot000092$$
$$Zn\dots\ \dots\dots\qquad\qquad Trace$$
$$Sum\dots\dots\dots1\cdot4564 \qquad\qquad\qquad\qquad 0\cdot065475$$

Calculation of Anions.

$$Cl\dots\dots\ \dots\dots0\cdot8200 \div\ 35\cdot45 = 0\cdot023131 \times 1 = 0\cdot023131$$
$$Br\dots\dots\ \dots\ \dots0\cdot0042 \div\ 79\cdot96 = 0\cdot000053 \times 1 = 0\cdot000053$$
$$I\dots\dots\ \dots\dots\qquad\qquad Trace$$
$$SO_4\dots\dots\ \dots\dots0\cdot2004 \div\ 96\cdot06 = 0\cdot002086 \times 2 = 0\cdot004172$$
$$SiO_2\dots\dots\ \dots\dots0\cdot0197 \div\ 76\cdot40 = 0\cdot000258 \times 2 = 0\cdot000516$$
$$BO_2\dots\dots\dots\dots0\cdot0100 \div\ 43\cdot00 = 0\cdot000231 \times 1 = 0\cdot000231$$
$$Sum\dots\dots\dots1\cdot0544 \qquad\qquad\qquad\qquad 0\cdot028103$$

Sum of the Cations......................=0·065475
Sum of the Anions...... ....=0·028103

Excess of Cations........... ....0·037372

The excess of cations corresponds to the CO_3 anions expressed in monovalent ions

The Bath Tub. The Drinking Spring is shown indistinctly by the rocks to the right and in front of the cowboy.

0·037372÷2= 0·018686= CO$_3$ in bivalent ions 0·018686×60= 1·121160 grams of CO$_3$ 1·121160 CO$_3$=0·822207 gnn CO$_2$

Total CO$_2$ found.................................. 2·8868
CO$_2$ combined as carbonates............... 0·8212
                                                                   ———
                                                                   2·0646
CO$_2$ combined as bicarbonates...............9·8222
                                                                   ———
CO$_2$ wholly free............................ 1·2424

The free CO$_2$ in solution, 1·2424 grms= 631·73 c.c. carbon dioxid at O°C and 760mm pressure.

The hydric sulfid found was 0·0385= 25·23 c.c.

Specific gravity............................. 1·00393 temp 16°
Total solids...3·6320

Spring No. V. The Bath Tub.

This is an irregular shaped basin, 19 feet by 27 feet 3 inches and a little over 2 feet deep, there is evidently a larger supply of water entering this spring than is shown by the surface outflow. The water in this basin is opalescent and there is a moderate, but constant escape of gas. This spring is lined by a very porous baritic sinter, which rapidly passes into a highly calcitic one. I cut into the lining of this spring on the side toward the river, which is at the same time toward the sinter bed. I do not think that there is very much sinter on the opposite side.

This spring is shown in the photograph.

RESULTS OF ANALYSIS OF SPRING No. V. OR THE BATH TUB.
CALCULATION OF CATIONS.

$$Na............1.1639 \div 23.05 = 0.050559 \times 1 = 0.050559$$
$$K............0.0594 \div 39.15 = 0.001516 \times 1 = 0.001516$$
$$Li............0.0034 \div 7.03 = 0.000479 \times 1 = 0.000479$$
$$NH_4............0.0005 \div 18.08 = 0.000025 \times 1 = 0.000025$$
$$Ca............0.1182 \div 40.10 = 0.002948 \times 2 = 0.005896$$
$$Ba............\qquad\qquad Trace$$
$$Sr............0.0029 \div 87.60 = 0.000033 \times 2 = 0.000066$$
$$Mg............0.0648 \div 24.36 = 0.002483 \times 2 = 0.004966$$
$$Fe............0.0005 \div 55.90 = 0.000009 \times 2 = 0.000018$$
$$Al............0.0007 \div 27.10 = 0.000025 \times 3 = 0.000075$$
$$Mn............0.0013 \div 55.00 = 0.000024 \times 2 = 0.000048$$
$$Zn............\qquad\qquad Trace$$
$$Sum............1.4154 \qquad\qquad 0.063648$$

CALCULATION OF ANIONS.

$$Cl*............0.7749 \div 35.45 = 0.021858 \times 1 = 0.021858$$
$$SO_4............0.4786 \div 96.06 = 0.004982 \times 2 = 0.009964$$
$$SiO_3............0.0266 \div 76.40 = 0.000348 \times 2 = 0.000696$$
$$BO_2**$$
$$Sum..........1.2801 \qquad\qquad 0.032518$$

Sum of Cations......................... = 0.063648
Sum of Anions .... = 0.032518

Excess of Cations....................... = 0.031130

The excess of cations corresponds to the CO_3 ions, in this instance only roughly, necessary to form the neutral carbonates expressed as monovalent ions

$0.031130 \div 2 = 0.015565 =$ bivalent CO_3 ions $0.015565 \times 60 = 0.9339$ gram CO_3 corresponding to 0.68482 grm CO_2

The total CO_2 found in the sample was....... 1.3764 gr. pr. L
The CO_2 required to form neutral carbonates. 0.6848
                                                          0.6916
CO_3 required to form bicarbonates 0.6848

CO_2 in solution as wholly free acid 0.0068

The CO_2 remaining in solution in the sample of water at the time the determination was made was

0.0068 equal to 3.45 c.c.

---

* The chlorin includes the bromin.
** The reaction for baric acid was very strong, but the determination was lost.

I did not originally intend to analyze the water of this spring and for this reason I did not determine the CO_2 or the H_2S at the time of taking the sample, and both determinations were made on an old sample.   The analysis is not complete.

Specific gravity of water at...... ....18°C=1·00378
Total Solids............................. ....3·4463 per litre

Spring No. VI.   Drinking Spring.

This is one of the typical springs in the group, and by far the most interesting; its waters are perfectly clear and limpid.   The discharge of gas is moderate, but constant.   There are other smaller springs of the same character in its immediate vicinity. The diameters of this spring are 12 and 18 inches respectively. It is not destinctly shown in any of the photographs.

Results of Analysis of Spring No. VI or Drinking Spring.
Calculation of Cations.

Na.............1·0571÷ 23·05=0·045863×1=0·045863
K.............0·0617÷ 39·15=0·001576×1=0·001576
Li. ....0·0031÷   7·03=0·000446×1=0·000446
NH₄... ....0·0012÷ 18·08=0·000068×1=0·000068
Ca....... .....0·1057÷ 40·10=0·002636×2=0·005272
Ba. ....0·0132÷137·40=0·000096×2=0·000192
Sr. ....0·0066÷ 87·60=0·000075×2=0·000150
Mg.............0·0394÷ 24·36=0·001615×2=0·003230
Fe............. .....0·0007÷ 55·90=0·000013×2=0·000026
Al.............0·0005÷ 27·10=0·000018×3=0·000054
Mn...... ......0·0016÷ 55·00=0·000030×2=0·000060
Zn.............   Trace
Sum..... ....1·2908   0·056937

Calculation of Anions.

Cl.............0·7005÷ 35·45=0·019762×1=0·019762
Br..... ....0·0052÷ 79·96=0·000065×1=0·000065
I...............   Trace
SO₄............0·6254÷ 96·06=0·006511×2=0·013022
SiO₂.......... .....0·0266÷ 76·40=0·000348×2=0·000696
BO₂............0·0075÷ 43·00=0·000174×1=0·000174
Sum...........1·3652   0·033719

Sum of Cations............................0·056937
Sum of Anions............................0·033719

Excess of Cations.........................0·023218

The excess of cations equals CO_3 anions expressed as monovalent ions necessary to form normal carbonates.

0·023218÷2=0·011609=bivalent CO_3 ions.

0·011609×60= CO_3 in grms.=0·69654 grm. corresponding to 0·5108 grm.=CO_2.

Total CO_2 found. ....3·0800
Less CO_2 combined as normal carbonates. ....0·5108

2·5692
Less CO_2 combined as bicarbonates...........0·5108

CO_2 wholly free..............................2·0584

The free CO_2 in solution, 2·0584 grms. corresponds to 1047·53 c.c. at 0°C and 760mm pressure.

The hydric sulfid considered as wholly free equals 0·0471 grm. corresponding to 30·88 c.c. at 0°C and 760mm pressure.

Specific gravity of water at 15·5°=1·00377.

Total solids, per libre=3·3525.

It has already been noted that deposits have been formed abundantly along the face of the cliff the projecting portions of the strata whether sandstone or shale usually protect a mass of material deposited on their under side.

The same is true of the little recesses produced by uneven weathering or by the waters escaping from the strata. Such deposits are nearly all easily soluble salts. Gypsum occurs occasionally but is not abundant. Some of the strata, however, are encrusted with more difficulty soluble material.

The dip and character of the strata suggest that if these salts owe their formation to surface waters, these waters must come from considerable distances. If this is not the case the waters saturating these strata might be spring waters forced into the strata, in this case the character of the deposits would probably bear a close relation to the deposits from the spring waters or to the salts in solution. These considerations motived me to examine a few of the deposits and led to some very interesting observations, as the following statements of the results will show.

An incrustation, occurring on a sandstone stratum between 150 and 200 feet east of the Drinking Spring, was found to contain 2·50 per cent of sulfur and to contain calcium, barium, potassium, lithium and sodium. Though this sample of incrusting material was removed from the face of a solid sandstone stratum four or five feet above the upper margin of the talus soil and a hundred and fifty feet or more east of the nearest observed spring, yet its qualitative composition is very strongly suggestive of the composition of the matter held in solution by the waters of the Drinking Spring. The water forming this incrustation must either come through or from above this stratum, at all events it appears to be identical with or very similar to the Drinking Spring. The appearance of this incrustation on the face of the sandstone suggests a stronger pressure than the outflow of the spring indicates. It also raises a question as to the source of the spring waters, that is, whether they come from greater depths or are supplied by water, percolating through the strata of the Dakota formation. I hold to the view that this water is more probably forced into the stratum from the springs than that the springs are formed by water flowing from the strata of the formation. Another sample of material taken from near the foot of the cliff also indicates, as I interpret it, that some of the water in these strata probably comes from below, i. e., is forced into the strata by hydrostatic pressure. I shall discuss this sample presently.

Another sample was collected 50 feet or more up on the face of the cliff. My notes do not state that this sample was gathered from a stratum of shale, but I think that it was. This sample proved to be the mineral mirabilite, $Na_2SO_4 10H_2O$. It was well crystallized and was not accompanied by other minerals. There is no suggestion that the source of this salt might have been any other than the stratum of shale on which it was found. It is not at all rare to find crystals of this mineral deposited from the alkali waters of some sections as much as five or six inches in length. The abundance of this salt in some of our surface waters suggests this as the possible source of this mineral and of other in-

crustations on these strata.   I have already anticipated this point in my statement of the general conditions showing that this is not the case.

Another deposit collected from the rocks at the foot of the cliff immediately back of Spring No. I, Black Spring, had an entirely different, and under the circumstances a surprising composition.   It was this that led to the examination of the water designated as the Alum Spring.

This deposit occurred in association with well defined crystals of gypsum, it was white, pasty, and astringent to the taste.   When a coil of clean iron wire was brought into its aqueous solution hydrogen was set free quite rapidly.   A solution of aluminic sulfate treated in this manner will liberate hydrogen, but not nearly so rapidly as this solution.   A comparative test showed it to be less than one-fifth as rapid.   This reaction was not due to free sulfuric acid, free in the sense of being in excess of the amount necessary to form salts with the bases present.

The analysis of this sample presented some difficulties, and the footing of the analysis is very considerably in excess of 100. The material did not seem to me to justify the repetition of the analysis and as it will serve its purpose thoroughly well I shall give it without further explanation.   The sample was dried at the temperature of the room for three days; its weight was nearly constant during the last day.   The analytical results obtained were as follows:

Loss on drying in water oven for 10 hours.....	29·61
Loss on drying in air-bath at 147° for 2 hours.	15·35
Insoluble in water......	2·72
SO_3...	32·89
Fe_2O_3.........	1·16
FeO...Trace	
Al_2O_3...............	6·71
CaO...........	0·69
MgO.........................	3·33
Na_2O.....	4·68
K_2O..	0·32
Li_2O.................................Heavy Trace	
Ignition, with addition of lead oxid...........	4·45
	101·91

The reactions of this material are those of an alum, and the composition intermediate between mendozite and pickeringite. The manner of occurrence and physical properties of this mass seemed to me to be inconsistent with its composition. I revisited the locality to obtain, if possible, another sample of the material, to study its occurrence more fully, and especially to try to ascertain whether there is a spring issuing near, or at this point whose waters carry these constituents in solution. As I had already found one incrustation on a sandstone whose qualitative composition is the same as the salts contained in one of the springs success in this case seemed probable. There were abundant indications that ferruginous waters issue at this point, but there was no spring comparable to the dozen which can be found scattered along and within a few feet of the base of the cliff. A spring might have existed here and escaped my notice due to having been covered up by the sliding in of the water-soaked clay and debris forming the talus at the base of the cliff. The occurrence of red and yellow ochre at this point was noticeable, but scarcely enough so to be interpreted as indicating the outflow of an independent spring. I at first thought that this iron came from the talus itself and I still think this possible, but it seems probable that it does not and that an independent spring exists at this point, whose waters carry these substances in solution. During the interval between these two visits heavy rains, following periods of freezing and thawing, had caused very large quantities of material to come down, and the point where I had obtained this sample was covered deeply with mud and rocks, which would have required several days work to remove. We succeeded in digging two holes near together, each deep enough to enable us to dip up the water with a quart pitcher. The water, with some gas, bubbled up freely in one of the holes and quickly became clear. The suspended matter, clay, etc., in the other subsided quickly, but the water was milky, due to the formation of a white precipitate. A sample of water was taken from each of the holes and the perfectly clear one submitted to analysis, which, owing to the fact that the sample

is not from a definitely located spring I did not make as complete as some of the others, it is, however, sufficient for every practical purpose.

RESULTS OF ANALYSIS OF SPRING No. IV. ALUM SPRING.

CALCULATION OF CATIONS.

Na............0·4561÷ 23·05=0·019786×1=0·019786
K.............0·0216÷ 39·15=0·000551×1=0·000551
Ca............0·4089÷ 40·10=0·010198×2=0·020396
Mg.... ....0·1888÷ 24·36=0·007750×2=0.015500
Fe.... ....0·1485÷ 55·90=0·001860×2=0·003720
Al...... ....0·3036÷ 27·10=0·011203×3=0·033609
Sum..........1·5275   0·093562

CALCULATION OF ANIONS.

Cl........ .....0·2790÷ 35·45=0·007869×1=0·007869
SO₄...... .....3·5275÷ 96·06=0·036608×2=0·073216
SiO₃...... .....0·0745÷ 76·40=0·000975×2=0·001950
Sum..........3·9810   0·083035

Sum of Cations..........................=0·093562
Sum of Anions...... ....=0·083035

Excess of Cations........... ....0·010527

    The excess of cations is equal to the CO_3 ions, expressed as monovalent ions, required to form neutral carbonates.
    0·010527÷2=0·005264, bivalent CO_3 ions.
    0·005264×60=CO_3 in grms.=0·315840 grm. which corresponds to 0·231605 CO_2 present in the form of neutral carbonates.
    The specific gravity at 15·5°C=1·00546.
    Total solids dried persistently at 150°=5·6900, found 5·7401.
    Total solids dried at 250° for two hours 5·2740.

If the calcium were removed from this water in the form of calcic sulfate, it could give rise to just such a deposit as we actually found, i. e., gypsum and a double sulfate or a mixture of sulfates of alumina, magnesia and soda, which would naturally contain lithia, as we find to be the case.

The sample which remained. milky was not analyzed, but a portion of it was filtered and the white precipitate examined; it consisted principally of aluminic hydrate.

The analysis of this spring, given in Vol. VIII, p. 20, con-tains several errors which have been corrected in the following statement of it.

ANALYSIS OF SPRING No. IV, ALUM SPRING.

CALCULATION OF CATIONS.

Na............0·4561÷ 23·05=0·019786×1=0·019786
K.............0·0216÷ 39·15=0·000551×1=0·000551
Ca............0·4089÷ 40·10=0·010198×2=0·020396
Mg.... ....0·1888÷ 24·36=0·007750×2=0.015500
Fe.... ....0·1040÷ 55·90=0·001860×2=0·003720
Al...... ....0·3036÷ 27·10=0·011203×3=0·033609

Sum..........1·4830   0·093562

CALCULATION OF ANIONS.

Cl........ .....0·2790÷ 35·45=0·007869×1=0·007869
SO_4 ....3·5275÷ 96·06=0·036722×2=0·073444
SiO_3...... .....0·0745÷ 76·40=0·000975×2=0·001950

Sum..........3·8810   0·083263

Sum of Cations...........................=0·093562
Sum of Anions...... ....=0·083263

Excess of Cations........... ....0·010299

The excess of cations is equal to the CO_3 ions, expressed as monovalent ions, required to form neutral carbonates.
0·010299÷2=0·005149, bivalent CO_3 ions.
0·005149×60=CO_3 in grms.=0·30894 grm. corresponding to 0·226576 grm. CO_2 present in the form of neutral carbonates.
Specific gravity of water at 15·5°C=1·00546.
Total solids per litre, dried persistently at 150°=5·6900, found 5·6729.
Total solids dried at 250° for two hours 5·2740.

There was no white, pasty mineral to be found at this point, as at the time of my previous visit, even the gypsum was missing but an abundance of a mineral crystallizing in two forms—one form was as small, bright scales and the other as white, fibrous masses. This was the mineral alunogen. It appeared to be in place, but I could not satisfy myself whether it had been formed there or not. I am in doubt in regard to this point. On my calling attention to this mineral one of the party informed me that in a gulch, called Alum Gulch, on the other side of the river a similar mineral occurred in such abundance, that it formerly had been hauled away by the wagon load for the purposes of tanning. At my request he mounted his horse, and set out returning in about twenty minutes with excellent samples of these two varieties of this mineral. I already knew of its occurrence at the base of the stratum of conglomerate much more than half way up the cliff and probably 300 feet west of the western end of the sinter bed. The occurrence of alunogen at the base of the conglomerate, and according to my informant, in a similar position, and on a much larger scale in Alum Gulch makes one hesitate to attribute its formation to the action of springs. On the other hand, the composition of the mineral matter dissolved in the sample of water taken, the alum associated with gypsum found on my first visit and the alunogen found on my last visit, indicate that some of it at least has been formed by this agency.

The milky turbidity observed in the water of one of these holes was undoubtedly due to the access of water, containing sodic carbonate which precipitated the aluminic hydrate. This precipitation can be observed in a ditch, which has been cut to carry away the water from the basin of the Black Spring. This ditch serves also to intercept the water, moving from the Alum Spring, or this section of the cliff toward the river, and the water in the ditch is covered on the side toward the cliff, with a thick, white precipitate presumably aluminic hydrate as that in the water was. I will not give the analyses of the samples of alunogen, as they are almost wholly of a mineralogical interest.

As interesting as the deposits found along the cliff proved to be they are much less so than the sinter deposited by these springs, and of which there is probably more than 1,000,000 cubic feet remaining at this time.   The sinter bed has been stated to be 400 feet in length and 147 feet wide at the widest place with a thickness of 20 feet at its thinner edge.   The first photograph exhibited gives a most excellent view of the deposit, showing at the same time that the springs are building up the portion nearer the cliff quite uniformly throughout the length of the bed.   When we consider the mineral constituents contained in these waters, calcic oxid forming about one twenty-fifth of the total, and the mass of the sinter now visible it would seem that the springs must have been richer, and yielded this sinter at a more rapid rate at some previous period than at the present time.

There are no indications at the springs that this has been the case.   The baric oxid contained in the water exceeds a trace in only one case, and in this it amounts to approximately one two hundred and fiftieth of the total solids contained in the water. Such considerations enable us to read the testimony, which the sinter bed bears in regard to the amount of material the springs have brought from their subterranean sources, in order to deposit the minimum of a 1,000,000 cubic feet, and at the present apparent rate of deposit it would require a very long time to accomplish this result.

The first sample analyzed was taken along the face of the bed, where the encroachment of the river gave me a good section through the deposit.   Its analysis awakened my curiosity.   Traces of barium in spring waters have often been reported, but so far as I can find the deposition of baric sulfate by any water has been recorded but once and this was from a mine water.   It would seem that such depositions must have taken place, but I have been unable to find any mention of their having been observed.

The analysis of this sample resulted as follows:

Sand and SiO_2	0·51
Organic Matter	2·29
CO_2	39·39
Cl	Trace
SO_3	Trace
CaO	48·84
SrO	1·16
BaO present in HCl soltuion	Trace
MgO	1·37
Fe_2O_3 } Al_2O_3 }	0·20
MnO	0·62
Na_2O	Trace
Li_2O	Trace
$BaSO_4$ present as such	5·42
	99·80

The hydrochloric acid solution of this sinter contained only a minute trace of sulfuric acid, showing the absence of soluble sulfates. I thought that this was an accident and did not believe that the sample represented the mass of sinter. Mr. Doughty was kind enough to take samples from different points along the edge of the bed, where the waters from the different springs run over into the river. I chose these points, because they are easily located. The following notes on the composition of these samples are full enough for our present purpose. The first set of samples represents 15 feet along the edge of the bed, where the waters from Spring No. I, Black Spring, flow over. The first sample gave 2·07 per cent insoluble, contained $BaSO_4$, the second gave 4·10 per cent, almost wholly $BaSO_4$, and the third 3·27 per cent, largely $BaSO_4$. These samples were pretty pure $CaCO_3$, but contained as much as 4·0 per cent of $BaSO_4$. The fourth sample was taken at a point, where the water from Spring No. III runs into the river, this sample contained 4·48 per cent insoluble, mainly $BaSO_4$. The fifth sample was taken from the edge of the bed, where the water from Spring No. VI runs over into the river. This sample had the following composition: $CaCO_3$ 78·53 per cent, sand 11·72 per cent, $BaSO_4$ 9·75 per cent. These samples not only establish the uniform presence of $BaSO_4$ as a constituent of this sinter but

indicate that Spring No. I, Black Spring, probably contains but little or no barium, and that Spring No. VI, Drinking Spring, is the richest source. Strontia and traces of barium are uniformly present in the HCl solutions of these samples.

The results obtained by the examination of these samples led me to examine samples obtained nearer to the springs, especially the Drinking Spring, as both the analysis of the spring waters and the sinters point to this spring as the principal source of the baric sulfate. I consequently examined two samples from this source: one taken a few feet away from the spring and the other taken at the spring.

The sample taken a few (8–10) feet away from the spring gave the following results:

Organic matter, with a little free sulfur........	3·43
CaCO₃...............................	26·46
BaSO₄...............	66·98
Fe, Mn, Na, K and Li not determined	[3·13]
	100·00

The second sample, taken close to the rim of the spring, within 2½ feet, gave the following:

Organic matter, with a little sulfur...........	3·11
CaCO₃............................	1·84
BaSO₄.....	94·62
Mg, K, Na and Li...........................	Trace
	99·57

Upon examination, I find that the Bath Tub and Birds' Nest springs present an interesting phase of this deposition of baric sulfate, despite of this, the deposition by the Drinking Spring is the more typical, and I believe the only instance in which we have a simple case of deposition from the water issuing from the spring, i. e., it is the only one that brings the barium to the surface in solution. The Bath Tub, however, furnishes even finer samples of baric sulfate than any of the others, its cellular sinter shows very beautifully, by its increasing compactness and change of color, the rapid increase in the amount of CaCO₃ in the sinter as one passes back

from the outer surface of the spring into the mass of sinter. The
sinter lining the spring is quite pure baric sulfate. The sample
which I used as the source of baric sulfate for analysis was not so
pure as either of the two last samples, but it was nearer an aver-
age of the sinter occurring near the springs. The sample used
gave the following results:

Soluble in acetic acid, moderate effervesence..	15·46
Soluble in concentrated HCl....................	1·33
Insoluble, BaSO₄............................	83·21
	100·00

The baric sulfate thus obtained was then analyzed, with the
following results:

SiO_2................................	3·25
SO_3..	32·25
Al_2O_3, Fe_2O_3...............................	0·80
BaO*..............................	63·00
CaO..	0·30
SrO.. ..	0·45
MgO.......................................	Trace
K_2O.....................	0·17
Na_2O, with heavy trace of Li_2O..............	0·29
	100·51

This analysis establishes the character of the portion insolu-
ble in acids and shows that it is an almost pure baric sulfate, but
that it, like other precipitated baric sulfate, carries down and
tenaciously retains some other substances.

The sinter which is being formed by Spring No. II, the
Birds' Nest, differs from those of the Drinking Spring and the
Bath Tub, in that it is richer in $CaCO_3$; a sample taken from
the conical mass surrounding the spring gave the following figures:

Organic matter, etc..........................	7·82
$CaCO_3$...........................	43·39
$BaSO_4$......	48.70
Sr, K, Na and Li...........................	Trace
	100·00

*The barium determination is probably a little too high, the chromate precipiate should
have been reprecipitated again.

A sample collected a little way, perhaps 12 feet, from the spring and along the course of the water flowing away from it was very dense and hard, and according to Mr. Douglass's determination contained only about one-half as much $BaSO_4$, viz.: 26·51 per cent. Strontia, soda, and lithia showed strongly in the spectrum obtained from the HCl solution of this sinter.

The examination of these samples of sinter developed the fact that its composition passes from that of a limestone containing an admixture of a few per cent of baric sulfate, at what is now its outer edge, to practically pure baric sulfate at some of the springs.

These springs are not equally active in forming deposits, nor are they all making deposits of the same kind. The only deposit occurring about Spring No. I, Black Spring, is certainly due to the decomposition of the escaping hydrogen sulfid. A sample of this material proved to consist of sulfur 83·57 per cent, and nonvolatile 16·43 per cent, which consisted of disintegrated shale and sandstone. The deposit forming about Spring No. III, is still richer in sulfur than that being formed by No. I. The sample examined contained 94·22 per cent of sulfur: the remaining 5·8 per cent contained no calcium or barium, but the alkalies, potash, soda, and lithia were present in unusual abundance. The general absence of sulfur deposits about these springs is more a matter for comment than these two distinct occurrences, for all of the springs are emitting hydrogen sulfid. The escaping CO_2, however, seems to carry it out of the water and protect it in a measure from the action of the air. The firm sinter does not contain calcic sulfate or any notable quantity of free sulfur, in the samples tested there were only traces of it present.

I have now presented the striking features of these springs, considered either from the standpoint of the chemist or geologist and whatever further I may present must be either in the nature of general comments or an extension of my work in a different direction; it shall be both. The deposition of practically pure baric sulfate by a mineral spring is, so far as I have been able to find, a unique fact. I find mention made of a mine water in

England which deposited baric sulfate in a launder. Frequent mention is made of the occurrence of barium in mineral springs, but I have found no other mention of the deposition of baric sulfate than the one just given.

I have stated that I regret that I have thus far been unable to examine the gases escaping from these springs, and this expression gives no hint of the intense desire that I have had to examine them. Helium has been found in the gases escaping from several springs, and why should it not be found in these which, as I have already shown, are very unusual springs. I believe that helium is present in the gases, and I shall now show you that radium is present in these waters in comparatively abundant quantities.

The well-known property of baric sulfate to carry other substances down with it, and the fact, which is now almost as well-known, that the close relationship between barium and radium renders it almost impossible to effect a complete separation almost assures us that if radium exists in these waters, the whole of it will probably be removed with the barium salt, especially if the latter is sufficiently abundant. The problem presented itself to me in the following form, helium, the transmutation product of radium, has been demonstrated to be present in the gases of several springs; other springs have been proven to be radio-active, among them are the Glenwood Springs and the Hot Springs of Arkansas; radium possesses the property of rendering things radio-active; barium and radium are closely related; barium carries radium down with it when precipitated from a solution as a sulfate. We have here the unusual fact of the precipitation of. baric sulfate from a mineral water; if the water is radio-active, the radium should be found in the baric sulfate. I tried it and I shall now present the results of my experiments.

I had no means of testing the sinter, except by its action on the photographic plate. This is neither the most sensitive nor the best perhaps, but it possesses the great merit of being within the reach of every one. I for one had to depend upon it as my guide.

I did quite an amount of work in this line with photographic plates before I permitted myself to accept the results obtained with this sinter. My results in some of these experiments were baffling in the extreme. I would hesitate to present them in detail lest you should be perplexed to determine in your own minds the degree of my responsibility or verity of my statements. The results, however, obtained with the different samples of sinter were so positive and so consistent that I determined to attempt the preparation of a radiferous baric chlorid, which should show this property of radium in a stronger degree.

When it is remembered that tons of pitchblende or the residue obtained in the process of treating this ore is required for the obtaining of a very small quantity of a strongly radiferous baric chlorid, it could not be expected that I would be able to obtain a very strong preparation from any quantity of the sinter, that I would be able to work up in the short time at my disposal, using an H-sand crucible in which to do my fluxing. This is still more apparent when you consider that pitchblende, at least that from Gilpin County, is very much stronger in its action on the plate than this baritic sinter.

Before proceeding I will answer a misgiving which may present itself to some of you in this connection, i. e., whether ordinary baric salts may not always possess this property. Mme Curie tested baric chlorid to determine this question and obtained negative results, and barite is not given in the list of radio-active minerals, tested by means of the electroscope, a method many times more sensitive than the photographic plate, which is acted on by the beta and gamma rays, while the electroscope responds to the alpha rays. The beta and gamma rays which possess the property of penetrating black paper and acting on the plate are absent from a freshly prepared radiferous baric chlorid, and are not reestablished in their maximum strength until the lapse of about 30 days. These are perhaps all the facts relative to the rays that act on the photographic plate, which it is well to cite in this connection.

Radiograph taken with Pitchblende from Gilpin County, Colorado. The plate was exposed for two and a half days; the distance between plate and mineral 0·25 to 0·50 centimeters.

The first experiments made with these sinters gave very faint impressions on the plates, and required a period of five days to produce them.   The distance between the film and the mineral may have varied from $\frac{1}{2}$ to $1\frac{1}{2}$ centimeters.

With pitchblende from the Wood Mine, Gilpin County, we obtained a strong but blurred impression on the plate through one thickness of black paper, one of orange paper and the bottom of a dry plate box, paste board about 1–16 inch thick, in five days. With the baritic sinter under exactly the same conditions and in the same time (the experiments were made simultaneously), we obtained a very faint impression, best seen, while developing the plate, but scarcely visible when fixed and dried.   These starting points may serve, first to establish the fact that the sinter acts on the plate the same as pitchblende but in a much less degree, second as standards by which to judge of the results obtained.

As I have no facilities for treating large quantities of mate- rial I could only hope to effect a concentration of the radium into a preparation which would, at the best, simply be more active than the original sinter.   The action of the original sinter upon the plate is then the standard by which I judge of the degree of my success.

I took 13 pounds of the sinter.   It was not all collected from the same spring, but was a mixture from Springs II, V and VI, or the Birds' Nest, the Bath Tub and the Drinking Springs.   I fluxed it with sodic carbonate washed and dissolved in hydro- chloric acid, separated the silicic acid and iron by usual methods and separated the baric from calcic chlorid by crystallization.   The yield of crude baric chlorid was eight pounds.   This baric chlorid, after the removal of the last of the iron present, was subjected to fractional crystallization, four crops of crystals being removed from each solution.   A little practice sufficed to enable me to recover two-thirds of the quantity dissolved in the first three crops of crystals.   This was continued until the weight of the three crops when united was two ounces.   The last crystallizations were made from hydrochloric acid solutions.   I make no pretence to having

extracted all of the radium in the sinter. I know on the contrary that my mother liquors and reserve salts contain radium, but I believed that the requirements of my present work did not demand the recovery of all of the radium. The crystals of radiferous baric chlorid were at first colorless, but have gradually acquired a yellow tinge. This is an observation which has been repeatedly made.

After allowing the sample to stand 15 days to accumulate its power to act on the plate, I submitted a photographic plate to its action for $2\frac{1}{2}$ days. The plate was covered with two thicknesses of black paper. The distance between the film and the salt was between 0·25 and 0·5 centimeter. The result was a strong, sharp negative, comparable in its density to negatives obtained with pitchblende or carnotite and not at all with those obtained with the original sinter. A detailed account of other experiments made with this material would only be tedious and would simply add proof of the same character as that already adduced, showing the presence of radium in the sinter and consequently in the springs.

I herewith finish the presentation of the results of my study of this group of springs, which I believe to be the most remarkable group, which it has been the privilege of any chemist to make known to the public, and it may not be improper for me to express the hope that in the future many persons may reap great benefits as the result of the work which is herein recorded.

Radiograph taken with Radiferous Baric Chlorid prepared from the Baric Sinter of the Doughty Springs. Time of exposure two and a half days; distance between plate and salt, 0·25 to 0·50 centimeters. The preparation was 15 days old.

GEOLOGY OF THE HOT SPRINGS OF COLORADO AND SPECULATIONS AS TO THEIR ORIGIN AND HEAT.

BY A. LAKES.

The subject of springs, and especially hot springs, is so germain to the origin of mineral veins that it is one of considerrable interest to the mining man and student of mining geology.

In Colorado we have a vast number and variety of springs, from those icy cold to others of 168 degrees F., and from those of almost chemically pure water to others charged with nearly every known chemical or mineral ingredient to be found in springs.

Nearly all the hot springs in Colorado are in the mountains, either on the flanks or more generally deep into the heart of the ranges. They are all associated with areas of great disturbance sometimes characterized by more or less volcanic activity. The rocks in which they occur are highly tilted and often folded and faulted. Some of the rocks are metamorphic or show signs of incipient metamorphism, a few are strictly igneous and volcanic. It is a popular notion that hot springs derive their heat directly from a deeply buried volcanic source, such as from lavas once poured out on the surface and cooled, but still retaining their heat at considerable depths. Undoubtedly this is true in regions of very recent or present volcanic activity, such as the geysers and hot springs of Iceland, but we doubt if the heat of Colorado hot springs can be attributed to any such direct volcanic source, but rather to the great depths of the fissures in fault planes caused by mountain movements, irrespective of any immediate or great exhibition of volcanic activity.

We know that in regions of active volcanoes a high internal temperature is still found in springs of hot water in what is known as the solfataric period or decline of a volcanic eruption, and that these hot springs may continue for centuries to maintain their heat.

The neighborhood of large masses of lava or of recent volcanic activity may raise the subterranean temperature much above its normal condition and this may not disappear for many thousand years after the volcanic activity has wholly ceased. The cooling down of so notoriously bad a heat conductor as a subterranean mass of lava is a very slow process. But can we think that lavas like those of the Table Mountain, at Golden, and the dikes at Rallston and Valmont, which were erupted so long ago as in late Cretaceous or early Tertiary times, if followed down to a great depth would be found now in so heated or semi-molten a condition that water percolating down to and coming in contact with them would be returned to the surface through profound fissures in a boiling state? (We may observe that in our experience springs ascending alongside of volcanic dikes are generally cold), or may we suppose that these dike-filled fissures, at profound depth, are no more molten or eruptive in character than the granite surrounding them.

So many of our Colorado hot springs appear to have so little direct connection with past, or comparatively recent, volcanic activity that we are inclined to look for the source of their heat in the depth to which their fissures may extend, in other words, to the progressive downward increase of heat in the earth.

The influence of seasons upon the earth's temperature descends to a limit. In the tropics it is but a few feet; in Germany at eighty-two feet it is 48·20 degrees; in Siberia, frozen soil is found at 260 feet. Careful observation in various parts of the world give an average increase of temperature, somewhere between one degree for every sixty-four feet, one degree for every 101 feet, one degree for every 110 feet.

Some of our hot springs occur in the immediate vicinity of noted mining camps and would appear like living modern examples, or object lessons, of the methods and forces which made and filled the old fissure veins of the district. The hot soda waters of Idaho Springs is one of these. Hot Springs also occur at Ouray, in the San Juan mining district, not far from the American Nettie and other celebrated mines.

The Chalk Creek hot springs in the Sawatch Range, near Buena Vista and Salida, occur in the granite not far from the mines and veins in that region.

Again some mining districts where we might most expect them are singularly without hot springs. Cripple Creek, for example, whose mines are located in the heart of an old volcano, is destitute of hot springs. When the fissure veins of Cripple Creek were in process of forming and filling, the region was doubtless steaming with hot springs, but these have long since exhausted their energies in filling fissures with quartz and ore and are passed into the crystallized state.

If the Cripple Creek volcano still retains its heat at a moderate depth from the surface and within reach of percolating surface waters, we might naturally expect hot springs to rise and appear, or that the waters which so greatly trouble Cripple Creek's deep mines would show some elevation of temperature. Might we not also expect occasional earthquakes and earth tremors if the Cripple Creek volcano is still hot below, or again, are we to assume that these old volcanoes are, at depth, no hotter or more eruptive in character than the granite surrounding their throats, and that the volcanic heat and forces have left them for other regions and for pastures new.

As an example that hot springs are not necessarily connected with direct manifestations of volcanic energy, but may derive their heat from their depth, we may mention the long zone of hot springs, which runs for miles parallel with the steep scarp of the Western face of the Wahsatch Mountains in Utah. These hot springs are along the line of a profound fault at the base of the

mountains, not characterized by any great volcanic display or eruption of lava.

A brief review of the geological conditions and surroundings of some of the best known hot springs in Colorado, will, we think, show that these springs derive their heat more from the great depth of their fissures, or from latent heat caused by folding or faulting of the rocks, than from any direct volcanic source.

Along the Eastern foothills of Colorado there are few springs that rise above the normal temperature. At the entrance of South Boulder Canon is a warm spring with the temperature 83 to 84 degrees F., near the surface. This spring, or zone of springs, occurs at the juncture of the overlying impervious marly beds of the Jurassic, with the underlying coarse, porous and much fractured quartzite beds of the Triassic. The district is noted for the occurrence of some great mountain faults, such as have produced the twin peaks of South Boulder. The throw of one of these faults is estimated at 3500 feet. It is a reverse fault, due to great compressive force and everywhere the rocks give evidence of such compression by being intensely jointed and checked up. The enormous thick and lofty body of the Triassic quartzite shows evidence of metamorphic heat in its uplift, being locally changed from a normal sandstone or conglomerate to a hard red quartzite. There are no volcanic rocks in the neighborhood nearer than the Dike of Valmont, some six or eight miles east.

Passing from the foothills to the heart of the mountains at Glenwood, on Grand River, we find a number of hot springs issuing from the bed and bank of the river. These hot springs were formerly much higher up than at present, as shown by the hallowed out fissures and joints and little caverns high on the cliffs above the river. The cutting down of the canon by the river lowered the surface exit and position of the springs. These springs occupied a much compressed, sheared and faulted zone of of Paleozoic rocks. There is no volcanic rock in immediate association with them though the little Dotsero crater is on the other side of the mountain, about twenty miles distant, at the junction

of the Grand and Eagle Rivers, and some distance south of the springs the hills are covered with fresh looking lava. In the Dotsero crater it is worthy of note there are no springs of any kind. We think, however, that the heat o these springs is attributable more to the depth of these fissures than to the neighboring manifestations of volcanic energy.

At Steamboat Springs, Routt County, are some thirty hot springs emanating from fissures in much folded and faulted Cretaceous rocks, unaccompanied by any prominent signs of volcanic action in the immediate neighborhood.

At Pagosa, in Western Colorado, are a series of hot springs 148 F., one of which issues from a deep crater-like hole full of dark green boiling water. These springs occur in a zone of fissures in much folded Cretaceous rocks which can be followed for miles by springs of various temperatures parallel with the west flank of the Conejos Range. Paralleling the springs, but at some distance from them, is a zone of narrow basaltic dikes; otherwise the area is not remarkable for extraordinary volcanic manifestations.

The hot soda water of Idaho Springs, with temperature 80 to 120 degrees F., issues from fissures in granitic rocks like those now occupied and filled with quartz and ore, forming the gold and silver veins of the district. There is no prominent porphyry or other volcanic rock in direct association with the springs.

The Chalk Creek Springs, of Chaffee County, issue from the white feldspathic granite of the Sawatch Range, with a temperature of 150 degrees F. At Poncha Pass are 100 springs with temperatures 80 to 168 degrees F. Hot Sulphur Springs, in Middle Park, have temperatures of 117 degrees F. Trimble Hot Springs, with temperature of 130 F., issues from the folded and fissured Paleozoic rocks of the Animas Canon. Springs at Wagon Wheel Gap, with temperature of 140 to 150 degrees F., issue from essentially volcanic rocks of the San Juan Mountains. Hot Springs at Ouray occur in a region of much faulted Paleozoic rocks adjacent to the volcanic overflow of San Juan.

Hartzells Springs, in South Park, issue from the tilted hog-back of the Dakota Cretaceous toward the Southern and most volcanic part of the Park. The temperature is 105 degrees F.

In most of these cases cited, the volcanic element is either absent or inconspicuous, whilst that of the folding, faulting and fissuring of the rocks is the most prominent feature and seems to have most to do both with the origin and heat of the springs.

If we assume a downward increase of heat of one degree for every 64 or 100 feet it is possible, from the temperature of the springs at the surface, to form a rough approximate estimate of the depth of the fissure from which they rose.

Thus the Moffat Springs, at South Boulder Canon, with temperature 84 F., would rise from a fissure, at the rate of 64 feet per increase of 1 degree, 6,000 feet, or an increase of 1 degree per 100 feet would make the fissure 8,400 feet deep.

Temperature.				At 64 Feet Per 1 Degree. Depth of Fissure.		At 100 Feet Per 1 Degree. Depth of Fissure.
Pagosa Springs,	148	degrees	F.	9,600	to	14,800
Idaho Springs	128	"	F.	7,700	"	12,000
Chalk Creek Springs,	150	"	F.	9,700	"	10,000
Poncha Springs	168	"	F.	10,800	"	16,800
Hot Sulphur Springs, Middle Park,	117	"	F.	6,500	"	11,700
Trimble Hot Springs,	130	"	F.	8,400	"	13,000
Wagon Wheel Gap,	150	"	F.	9,700	"	15,000
Hartzells Springs,	105	"	F.	6,700	"	10,500

Some profound fault fissures are known to exceed even the greatest depth here given.

The above estimates, however, are merely to show what would result if we applied the assumed rate of one degree for every 64 or 100 feet descent. But these estimates must be taken only in a most broadly approximate sense. Personally, I am inclined to think many, if not all are too deep. There are so many other

factors to be considered which might materially alter or shorten the depth, such, for instance, as chemical reactions, producing local heat at a very moderate depth, or heat retained at moderate depths resulting from rock crushing or slipping, or even in some cases from actual buried volcanic heat.

We have treated the subject from a purely geological stand-point; we should like now to turn it over to the chemist and see what he has to say.

In an able article on the Geysers of the Yellowstone, and on hot springs generally, in Hayden's Geological Survey of the Territories, the matter is summed up thus:

"The heat of hot springs may be due, First—To the internal heat of the earth, which meteoric waters acquire by penetrating the rocks, after which they come to the surface as thermal springs.

"Second—Ordinarily, this heat is simply due to the regular downward increase of heat of the earth of one degree temperature for every 60 feet. The temperature may be lower or higher according to the depth penetrated.

"Third—In regions of mountain corrugation thermal springs are of higher temperature than in undisturbed regions, probably because mechanical movement attending plication increases the amount of heat, and fractures caused allow water to penetrate to greater depths.

"Fourth—Thermal springs occur pre-eminently in regions of eruptive rocks, recent or ancient, and no boiling springs are found outside of volcanic areas, proving that in such area downward increase of heat in rocks is greater.

"Heat increases with depth generally, but may be to a certain extent independent of depth.

"The mere presence of volcanic rocks is not sufficient to cause thermal springs. There are large areas of volcanic rocks in Idaho and Arizona that are destitute of thermal springs. In these cases we may suppose that hot springs that once existed may have cooled and become extinct."

EXAMINATION OF INCRUSTATION FORMED ON RABLE PLATE OF A McDOUGALL FURNACE.

BY WM. P. HEADDEN

Read at the meeting of the Society, June 3, 1905.

In the summer of 1903, I received from Mr. Finch, who, at that time was visiting Anaconda, a small piece of material which had formed on a rable or plow of a McDougall furnace. I subsequently learned from Mr. E. P. Mathewson that this material was considered to be an artificial calcopyrite. This classification of the material was based upon determinations made in the company's laboratory.

The material received from Mr. Finch had a dull brassy color, metallic lustre, and a conchoidal fracture but, as this portion breaks off in scales, it is difficult to judge whether this was its real fracture or whether this apparently conchoidal fracture was due to the manner in which it had been formed. I believe that it was due to the latter cause, and represented a particular form in which it can break owing to the manner of its formation.

The analysis which I made of this small piece excited my curiosity as it was evident that this material, if it represented any definite chemical compound, did not represent any known mineral, but approached more nearly to the mineral cubanite, than to any other with which I was acquainted.

The material on which this preliminary analysis was made, was not homogeneous and the amount received was really too small for a complete analysis had it been fitted for this purpose in other respects, which it was not. As I had become interested in the matter I addressed a letter of inquiry to one of the officers of the company which was answered by Mr. E. P. Mathewson, Superintendent, who subsequently sent me one of the rable plates which showed the deposit formed on it by the action of the roasting ore in a most satisfactory manner. The plate was sawed in two, parallel to its sides and cutting through the thickest portion of the incrustation; this gave me a section of the incrusted plate.

The incrustation on the front edge and corner is about $\frac{3}{8}$ of an inch in thickness and on the ground surface appears to be composed of three layers, but when the incrustation has been broken from the plate it is difficult to satisfactorily distinguish more than two, the innermost one is at all times easily recognized, but the middle and outermost layers merge into one another, especially where the layers are thin, and one is compelled to be content with flaking off the very outermost portion as representing the third layer without in reality being able to separate it into two layers, except in the thickest portions.

The innermost layer separates very easily from the iron plate and also from the middle layer. This fact enabled me to obtain very good material to represent this portion of the deposit. In order to obtain material to represent the middle layer, I had to confine my choice to the thicker portions. It is probable that this layer is essentially uniform in composition and that the sample selected will correctly give the composition of the compound or compounds formed within this zone, so far as an analysis of such material may give any light upon such questions as may arise in this connection. I did not use the outermost layer as separated from the middle layer, but used only such portions as flaked off during the separation of the whole mass from the iron plate. In this way I obtained apparently homogeneous material.

I do not know the conditions under which this incrustation was formed, either in regard to the character of the ore roasted, the supply of air, or the temperature. The appearance of the incrustation suggests that a thin layer of fused material existed on the front corner of the plate, it being set obliquely, were this the case, however, one would expect to find a larger amount of slagged material, included quartz, etc. So it seems probable that this appearance is deserving of but little consideration.

In giving the analyses, I shall begin with the innermost, which being next to the iron, I shall designate as the first layer. This layer is dark gray, rather fine granular in structure, with highly reflecting points, probably due to the presence of graphite. It shows no signs of having been fused, is not very hard and is non-magnetic. The powdered material shows a very small portion which is magnetic, or perhaps the material itself is very feebly magnetic.

Spe. gr. at 21° C...... ....4·0073
      Insoluable.......................................10·42
      SiO_2... 1·01
      S..20·00
      Fe...55·65
      Cu .... 0·38
      C Total... .... 6·61
      O... 5·07
      Mn........ ....Trace
                                    Total...................99·14

That sulfur attacks hot cast iron much less readily than it does wrought iron or steel is a fact known to every student of chemistry, still an inspection of this analysis leads forthwith to the inference that this portion of the incrustation is essentially ferrous sulfid.

That it is not pure is evident from the presence of oxygen, also by the disengagement of H_2S in small quantity when ignited in hydrogen gas.

An interesting fact in this connection is the concentration of the carbon in this layer. The filings from the plate contained

3·05 per cent. of carbon, while this layer next to it or, at most, sep-
arated from it by a very thin layer of material, contains 6·61 per
cent. It is also a matter of note that oxygen is present in this layer
in a considerable amount, 5·07 per cent. The oxygen was deter-
mined by heating the material in an atmosphere of dry hydrogen
and collecting the water formed in a calcic chlorid tube. There
was a small quantity of hydrogen sulfid given off which probably
indicates the presence of a higher sulfid of iron.

I did not attempt to determine whether the carbon was
present in both forms, graphitic and combined, or not. A very
large amount of carbon failed to be oxidized by persistent treat-
ment with aqua regia.

The middle or second layer has the same fracture that No.
1 has, i. e. fine granular, but it does not show the glistening par-
ticles nearly so prominently as No. 1. Its color inclines to a
bronzy yellow. It is harder than No. 1 and feebly magnetic.

ANALYSIS OF SECOND LAYER.

Insoluble	4·86
S.	30·80
Fe	50·75
Cu	6·18
Zn.	0·27
As, Mn, Ca, Mg	Traces
O.	3·56
C.	(3·58)
	100·00

This sample was tested for the presence of SO_3, but none
was found.

This sample is clearly a mixture of compounds—at least of
two. If we wholly neglect the oxygen, we observe that this is
probably a mixture of FeS which makes up essentially the whole
mass of No. 1 with a little sulfid of copper, or perhaps better,
a ferrous sulfid which has taken up a little, six per cent. copper
in place of part of the iron.

THE THIRD OR OUTERMOST LAYER—ARTIFICIAL CUBANITE.

The third or outermost layer is wholly different in color and texture from the other layers. Its color is a bronzy yellow which tarnishes in pavonine tints. Its fracture is conchoidal, and its hardness about equal to that of the middle layer, less than six.

ANALYSIS OF THE THIRD, OUTERMOST LAYER.

Sp. gr. at 20° Centigrade.. 3·9381
Insoluble .... 6·18
S... 31·54
Cu.... .... 21·74
Fe.... .... 39·93
Ca. Mg. O. C.................................... Traces
                                              _____
                                               99·39

Calculating Cu, S, and Fe to 100, we have

	Analysis	Theoretical for Cubanite
S.................	.33·84	35·4
Cu................	23·32	23·3
Fe................	42·84	41·3
	100·00	100·00

This analysis corresponds fairly well to the formula $CuFe_2 S_4$ or cubanite.

These results indicate that the products of the action of the roasting ore upon the iron of the rable plate is to sulfurize it, converting it into FeS. This is a result which we would expect, as we know that FeS_2, when heated under proper conditions yields sulfur—either free or in combination. If the vapor of sulfur comes into contact with iron, even cast iron, we can easily understand that it would unite with it forming FeS. It is not so easy to account for the presence of oxygen in the first or innermost layer, but it was present. Any explanation which suggests

itself to me has no better foundation than plausibility. That the outer coating of the deposit contains oxygen is very probable, it is evident to the eye. If the incrustation has increased in thickness by addition from the outside alone, then a failure to completely reduce this film of oxid might account for the presence of the oxid. I do not see how this can apply to the innermost layer, No. 1, whose small content of copper as well as its position seem to me to militate against the assumption that the incrustation has increased by additions to the outer surface only. The presence of even one quarter of one per cent. of copper in the innermost layer suggests that it has probably passed through the outer layers to be absorbed in this. The outer layer is both interesting and conclusive in showing that it is a product of the reactions taking place either through the agency of fusion or volatilization. I have previously stated that while the outer surface has the appearance of having been fused, it does not seem probable that this has actually taken place. If this be correct, then the copper must get into the first and second layers at least by a sort of solution, solid solution.

The occurrence of cubanite, as the outer layer, points to a total rebuilding of the molecules forming the mineral, had it been chalcopyrite, a common ore, it might have been an accident due to the adhering of the chalcopyrite particles to the hot and perhaps softened surface; but the molecule is a new one and the mass has not been formed by agglutination.

ACTION OF PHOSPHATES ON PLATINUM WHEN HEATED WITH IT IN THE PRESENCE OF CARBON.

PLATINUM AND PHOSPHORUS.

Chemists who have many determinations to make, either of phosphoric acid or magnesia, in which the precipitated ammonic magnesic phosphate is ignited in a platinum crucible, have noticed that the crucible is attacked, being converted into a brittle crystalline condition and finally cracking so badly that it has to be made over. The explanation offered is that the carbon of the filter, at the high and prolonged temperature which is often required to burn the precipitate white, especially if the precipitate was not perfectly dry before ignition, acts upon the phosphate reducing the phosphoric acid, setting a portion of the phosphorus free which unites with the platinum to form a brittle crystalline alloy. This explanation may not be explicitly. given in any text book. It is, however, an established fact that finely divided platinum, heated to dull redness in the vapor of phosphorus burns brilliantly, forming diphosphid—a gray mass with a metallic lustre and a specific gravity of 8·77. It is insoluble in hydrochloric acid but easily soluble in aqua regia, (*Schroetter*). Pelletier obtained this compound by heating sodic metaphosphate, platinum, and carbon together—E. Davy obtained it by heating platinum or ammonic chloroplatinate with phosphorus. It is easily fusible and crystallizes in cubes.*

This constitutes about all of the information that I have been able to find touching upon this subject. These facts are to be found in other works of reference, but the statements made are the same and add nothing to the above.

The platinic diphosphid is said to fuse more easily than silver.

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*Gmelin-Kraut, Handbuch der Anorganischen Chemie, pp. 1073

This is not the case with crucibles which have been attacked by continued use in the manner stated, so it is not probable that the change in the platinum has proceeded far enough to produce this compound.

As I have had several experiences showing how readily platinum ware can be injured, even ruined; by the action of phosphorus, I thought I would imitate some of them and see what results would be produced.

One of my earlier experiences with this subject happened about fifteen years ago. I wished to expose an object to a high temperature—I had no blast lamp, no gas, not even a Hoskins furnace, but I did have an anthracite fire in the stove which heated my room. I lined a small sand crucible with magnesia as I now recall it, and placed my platinum crucible within this—the crucible cover, owing to its having a rather long projecting portion, would not go inside of the crucible, so the top of the platinum crucible was brought up just enough higher than the top of the sand crucible to permit the cover to close it snugly and the cover of the sand crucible was put on top of this. In order to be able to place and handle the crucible and also to keep it from coming in contact with the burning anthracite coal, I placed the sand crucible with its charge inside a larger one, and in order to hold it firmly in place and prevent the displacement of the platinum crucible, I filled in a portion of the space between the two sand crucibles with bone ash, but in such a manner that it did not touch or even come near to the projecting portion of the cover of the platinum crucible. It did not occur to me that there was any great probability that phosphoric acid would be set free and reduced, but I was mistaken. When the platinum crucible was removed that portion of the cover, the handle, which projected beyond the containing sand crucible was distinctly crystalline and so brittle that I could rub it off with my fingers. The material of the sand crucible had evidently set some phosphoric acid free, from which enough phosphorus had been reduced by the gases, for

there was no carbon as such within the crucible, to ruin the cover of my crucible.

Another experience was with the incineration of some seed in a platinum dish. The temperature did not appear to be very high, but the carbon of the charred seed acting on the phosphates of which the ashes of seeds consist, liberated phosphorus enough to render the heated portion of the dish, the bottom, so brittle that holes were broken through it in cleaning it and it had to be made over.

The crucibles in my laboratory seem to wear out very rapidly, becoming brittle and cracking so badly that they need to be repaired. These facts led me to make the following experiments to see whether the reduction of the phosphoric acid and the absorption of the liberated phosphorus by the platinum takes place so easily as it appears to, or whether, in my case, the flame used might not, in part, be the cause. I made three experiments:

First, with calcic phosphate $Ca_3 (PO_4)_2$ commercial.

Second, with alfalfa seeds, essentially, $Ca_3 (PO_4)_2$ and $K_3 PO_4$.

Third, with powdered animal charcoal.

The phosphates were placed in a porcelain crucible, mixed with charcoal, if not already present, and the platinum buried in the mixture so that it was not in contact with the crucible, which was then placed inside a larger crucible and heated in a Hoskins furnace.

In the first experiment the platinum was attacked and fused to small globules. The glazing of the porcelain crucible was not attacked so far as one could judge from its appearance.

In the second experiment the platinum was likewise attacked and fused. In this and the preceding experiment pieces of platinum foil were used.

In the third experiment the platinum used had been precipitated as a sulfid and ignited. The heat used was as high as I could attain, the glazing of the crucible was attacked by the basic

charge, bone black. The platinum was attacked but not wholly melted as in the preceding cases. The basic character of the charge, due to calcic and magnesic carbonates, was evidently not so favorable to my object as the neutral one. The platinum was partly melted into globules, and the rest of it resembled coke in structure. The globules in this instance showed under the magnifier a beautiful case of sprouting.

I submitted the results of the first two experiments to analysis but I will only give one of them.

$$
\begin{array}{ll}
\text{P.} & 2{\cdot}301 \\
\text{Ca} & 0{\cdot}095 \\
\text{Zn.} & 0{\cdot}088 \\
\text{Fe} & 0{\cdot}085 \\
\left.\begin{array}{l}\text{Pt}\\\text{Ir}\end{array}\right\} & 97{\cdot}431 \\
\hline
 & 100{\cdot}00
\end{array}
$$

The reduction seems to have proceeded rather differently in the presence of the platinum than one would expect.

The calcium was in the alloy and not due to adhering particles of calcic phosphate, for the alloy, if such it be, was washed with hydrochloric acid in which it was insoluble.

The fused globules were not smooth, but quite rough; they were hard and brittle enough to admit of being powdered in a diamond mortar.

The statement is made that the platinic diphosphid is easily soluble in aqua regia. This alloy is not. It required eight days to bring a little less than two grams of the powdered alloy into solution, using two and sometimes three fresh portions of aqua regia, 40 cc. each, daily. Each portion was allowed to stand in contact with the powdered alloy for several hours, then evaporated to dryness, hydrochloric acid added, digested, and finally decanted. The final solution was evaporated to dryness to separate any silicic acid which might be present. I did not observe any. The trace of zinc undoubtedly came from the commercial calcic phosphate.

This alloy differs altogether from the platinic diphosphid described by Schroetter and others. It contains only a small amount of phosphorus, and is very difficultly soluble in aqua regia.

I did not use magnesic phosphate, for the simple reason that I did not find out that I had no magnesic phosphate in stock until I was ready to make the experiments, when I substituted the lime for the magnesic salt. The results, however, show clearly that the phosphates, even the normal orthophosphates, do cause platinum to be attacked when heated with charcoal, due to the liberation of phosphorus which unites with the platinum. They further show that the presence of comparatively small amounts of phosphorus suffice to render the platinum fusible, crystalline, and brittle; in other words, to ruin our platinum ware.

SOME REACTIONS DUE TO IRIDIUM.

Iridium is not of such common occurrence as to render it in any measure necessary that the average chemist should have an acquaintance with its reactions, and should a sample of native platinum, osmiridium, etc., fall into his hands he will in almost every case be guided in his determination of it by other characteristics than the reactions of iridium. Still the following notes made in connection with the preceding experiments may be of sufficient interest to justify their presentation.

The presence of a small amount of iridium in platinum imparts to it desirable properties, for which reason it is not always desirable on the part of the platinum worker to go to the trouble to effect a complete separation of the iridium from the platinum. In fact the iridium may be added by the manufacturer for the purpose of improving the quality of the ware. Its presence therefore in the foil used in the experiments was nothing which might not be found in any other piece of platinum ware. The points of interest lie, perhaps, more in the insufficiency of the statements of our text-books than in the facts themselves. This statement is not made for the purpose of cavilling at our text-books, but with a keen appreciation of their general excellence in spite of the extreme difficulty of presenting even the simplest facts so clearly and fully that the whole case shall be presented without making a number of statements incompatible with the limits and purpose of the text-book. We meet the same difficulty even in manuals—where the statements are often reduced to a simple enumeration of facts, rendered necessary by the great number of facts to be given, and a statement of fact which, in chemical work perhaps to a greater extent than in almost any other line, is the briefest possible expression of the result of an extended series of experiments which may have been very far from concordant throughout, and requiring much skill and good judgment in their interpretation. It is a fact that we often have to call personal experience and observation to

our aid in interpreting very simple statements of truth; in other
words, we have to learn, by these means, the comparatively simple
and common things even when they are stated succinctly and ap-
parently plainly. In regard to iridium, for instance, Fresenius
in his qualitative analysis says that hydrogen sulfid first decolorizes
a solution of iridic chlorid with separation of sulfur and the re-
duction of the iridic to iridious chlorid (chlorür), but later throws
down the brown iridium sulfid· This also is the statement made by
other text-books and manuals. In only one simple statement have I
found any hint that the "later" of Fresenius is suggestive of diffi-
culty. In Gmelin-Kraut's Handbuch der Anorganischen Chemie
p. 1060, Vol. III one finds in small type the following statement
regarding the separation of platinum and iridium attributed to
Claus.

"The ammonic platinic and iridic chlorids are heated with a little
water and sulfuretted hydrogen water added. Platinic sulfid precipitates
with the sulfur; iridic sulfid will be precipitated only upon the addition
of a very large excess of hydrogen sulfid water."

In these experiments I had no occasion to consider the sepa-
ration of the members of the platinum group, and consequently
concerned myself only with their removal from the solution. For
this purpose, I passed hydrogen sulfid into the hot, dilute solution
of the chlorids, which contained no nitric acid. When the solu-
tion had become saturated with hydrogen sulfid and quite cold, it
was heated to boiling and again treated with hydrogen sulfid. This
was repeated once more—the platinic sulfid filtered off and the
filtrate and wash waters concentrated. The hydrogen sulfid was
of course expelled by the boiling and $KClO_3$ was added to oxidize
any iron which might have been derived from the phosphates used.
The addition of the $KClO_3$ produced almost immediately a
brownish solution which, when viewed against the walls of the
casserole, had a decided tinge of pink. After the expulsion of free
chlorin, hydrogen sulfid discharged the color with separation of
sulfur, yielding a colorless solution, but produced no precipitate

even on standing 48 hours. On filtering, the precipitated sulfur formed no more than a stain upon the filter; this stain was brownish. The solution was oxidized and sodic carbonate added which again discharged the color, but produced only a small precipitate. Iron, manganese, etc., were removed from this solution by ammonium sulfid. The filtrate was concentrated, HCl and $KClO_3$ added, which reproduced the brown color. The solution was then evaporated to dryness on a water bath; the dried mass was pink, a color not given as characteristic of iridium but of rhodium salts.

It was dissolved in a small quantity of water, KOH added and boiled. The slight precipitate formed was filtered off and subsequently dissolved in HCl. Color of the solution at first was deep green, subsequently brown. The filtrates obtained in the precipitation and purification of the magnesic phosphate were evaporated and the salts present converted into acid sulfates by addition of excess of sulfuric acid. The addition of sulfuric acid produced a pink coloration, and on evaporation and fusion a small precipitate having a brown color; this precipitate dissolved in HCl, I obtained the precipitate a second time by oxidizing, adding H_2SO_4 and proceeding as before. The amount of the precipitate, however, was very minute. A second portion of the platinum-phosphorus compound was treated precisely as the preceding, with the same reactions except that the beer-brown color obtained upon oxidizing with the HCl and $KClO_3$ was even more pronounced, and it was further found that when the filtrate from the $Mg\,(NH_4)\,PO_4$ precipitate was evaporated nearly to dryness, H_2SO_4 added and heated on the sand bath till fumes of H_2SO_4 were given off and the mass had become almost dry, the addition of HNO_3 conc. produced a very pure deep blue color. This color was very beautiful; I know of nothing to which I can compare it. Heating to expel the nitric acid destroyed the color; it was, however, reproduced upon the addition of HNO_3 conc. to the cooled solution. The reactions enumerated are not given, even in our manuals. However, I believe them to be due to iridium. The

substance producing these reactions, whether it is iridium or not, is present in small quantities. It is probable that it is iridium as it is not uncommon for platinum to contain iridium, sometimes intentionally added, because it improves the quality of the platinum. For this reason I submitted the small piece of this foil that I still had to a qualitative examination by dissolving it in aqua regia and proceeding as in the case of the alloy. The readiness with which this foil went into solution in aqua regia compared with the resistance offered by the platinum-phosphorus compound, even though it had been finely pulverized in an agate mortar, was a matter of great surprise; rather more than three grams of the foil went into solution in aqua regia, on being gently heated and allowed to stand over night, whereas less than two grams of the powdered platinum-phosphorus compound required repeated treatment with fresh portions of aqua regia for eight days to effect its solution.

A portion of the solution of the foil, corresponding to exactly one gram, was taken and treated as before; the filtrate from the platinic sulfid was concentrated, oxidized with HCl and $KClO_3$ and evaporated to dryness on the water bath. There was a minute residue insoluble in a strong solution of potassic chlorid which, examined under the microscope, proved to be composed of dark brown, almost black octahedrae, appearing altogether like the potassic iridic chlorid which, when dissolved in water and boiled with the addition of KNO_2 gave a bulky white precipitate. The brown color produced by the oxidation with $KClO_3$ is probably due to the formation of $K_2Ir\,Cl_6$.

The pink color produced on addition of H_2SO_4 to the mass of salts obtained by evaporation of the filtrates and the production of the beautiful blue color produced upon the addition of concentrated nitric acid are not mentioned so far as I can find in the literature of the subject and consequently no explanation is given. As this work is quite beyond the question which I set out to solve, my material insufficient, and other work demanding my time, I will leave the question for others to prosecute.

MINERALOGICAL NOTES, NO. II.

BY WM. P. HEADDEN

PALLADIUM.

The case of the material whose description and composition I shall give in this note is an illustration of the value of obtaining a full description of the sample, together with its complete history, in case it is an artificial product.

The material was given to me by Mr. A. B. Frenzel, who obtained it from Mr. J. Winchester. The sample was given to Mr. Winchester by a casual acquaintance whose name and address he did not obtain, or if so they were lost.

The material would be of very considerable interest if we knew where the ore from which it was obtained occurred, and the process by which it was prepared. Even as it is I think it worth presenting, especially as it is probable that it was obtained from the so-called platinum ore of Wyoming.

The material was soft and black, with a few spots, where it had been rubbed, showing the lustre and color of metallic copper. Upon looking at it casually one would probably take it to be a manganese oxid, the mineral "wad" for instance, but its deportment toward solvents, as well as a closer examination of its physical

properties, reveals the fact that it is not manganese, nor any other mineral, but an artificial product.

I confess that I was at a loss at first to recognize it as an artificial product, or to place it as a mineral, because of its softness, and particularly because of its deportment with strong oxidizing solvents, such as nitric or hydrochloric acid and potassic chlorate, with which it gave a beautiful cinnibar red precipitate. Diligent search for an explanation of this reaction proved fruitless at the time. I had no idea of the cause of this, nor could I find such a reaction mentioned anywhere. The precipitate was not produced by aqua regia, but it appeared immediately upon the addition of potassic chlorate. The inference that the precipitate was a double potassic salt was a most natural one, and proved to be correct. This led to the identification of the precipitate as potassic palladic chlorid. The difficult solubility of this salt in strong nitric or hydrochloric acid seems not to have been mentioned by any of the writers on palladium, though it must certainly have been noticed.

This material was not uniform in composition, and I did not wish to destroy the piece that I had in an endeavor to obtain a sample, so my separate determinations did not agree very well.

The results of my analysis were as follows:

Palladium	11·86
Platinum	0·45
Iridium...	trace
Copper	60·21
Lead	2·52
Iron	2·50
Nickel..	1·25
Arsenic	1·56
Loss on ignition in Hydrogen....................	16·42
Sand	0·28
Sulfuric Acid and Chlorin.......................	(3·38)
Total...........	100·00

In regard to the Wyoming platinum ore, I would say that I have failed to obtain samples of it, though I have made attempts

to do so and have repeatedly been promised fairly large quantities. As I was naturally interested in the source of the material forming the subject of this note, and thinking that it was possibly a sample of the product being obtained from the Wyoming platinum ore, I wrote to Messrs. Baker & Co., of Newark, N. J., for information, if they chanced to possess any, which might throw some light upon this matter. They answered me at some length, kindly giving me such facts as were at that time in their possession. These facts, however, threw no light upon the possible origin of my sample. It did appear from their letter, however, that the Wyoming platinum ore varied greatly in its content and carried palladium rather than platinum.

While I have not succeeded in obtaining the often promised samples of Wyoming platinum ore, I have obtained small samples of the ore, covellite, supposed to carry platinum. I have tested this, using as high as thirty grams at a time,, but have never succeeded in finding platinum; in one sample, however, I did find a trace of palladium.

COLUMBITE—CAÑON CITY, COLO.

This sample of columbite was sent to me by Mr. E. E. Smith, of Cañon City, who informs me that the occurrence is in an unnamed hill about seven miles west of Cañon City. He describes it as occurring in bunches, or kidneys, in a pegmatite, associated with red, green and black tourmalines. The largest pieces are said to weigh six hundred pounds.

The sample received was an inch or more thick, and showed the impress of the inclosing rock on the two natural surfaces. One of these surfaces was quite covered with small mica crystals, the other was spotted by adhering mica. The color is grayish black, with a feeble lustre on the natural surfaces, but some fresh fractures on small pieces show the characteristic lustre of the mineral.

This is a new locality for columbite in Colorado.

COLUMBITE—CANON CITY, Colo.

Specific Gravity, 20°C., 5·6608

		At Equiv.		*At Ratio*
Columbic acid	56·48	42·15		
Tantalic acid	22·12	9·92	52·33	1·81
Tungstic acid	0·45	0·19		
Stannic oxid	0·11	0·07		
Ferrous oxid	8·07	11·20	28·73	1·00
Manganous oxid	12·45	17·53		
Ignition	0·15			
Total	99·83			

This is a highly manganiferous columbite, but otherwise does not differ in any respect from samples previously described. The specific gravity, 5·6608, is rather low for the amount of tantalic acid present, but my observation is that with the percentages of acids remaining the same, a high percentage of manganese corresponds to a slightly lower specific gravity. This sample is no exception in this respect.

COLUMBITE—BLACK HILLS, SOUTH DAKOTA.

This sample is a piece from a lot received by Mr. A. B. Frenzel from the Black Hills. Being myself somewhat familiar with the columbites of this section, and knowing how difficult it is for any one, especially for ordinary collectors, to avoid errors in respect to localities, I am convinced that we cannot with certainty give a more specific locality, but will have to be satisfied with the general one of the Black Hills. The sample has all of the marks of the columbite from the Bob Ingersoll mine, the most characteristic of which are the brilliant sub-metallic lustre, the presence of the pyramidal surface 111, and the specific gravity about five and nine-

tenths. The sample, however, is quite interesting when compared with the one from Canon City.

The sample has an iron black color and a sub-metallic, somewhat brilliant lustre.

COLUMBITE—BLLCK HILLS, S. D.

Specific Gravity at 24°C., 5·90655

		At. Equiv.		At. Ratio.
Columbic acid	54·64	41·77		
Tantalic acid	25·62	11·49	53·36	1·95
Stannic oxid	0·15	0·10		
Ferrous oxid	6·80	9·44	27·20	1·00
Manganous oxid	12·61	17·76		
Total	99·82			

The Bob Ingersoll columbite, which occurred in a mass estimated to weigh at least one ton, was the largest single mass discovered in the Black Hills. This occurrence was first described by Prof. W. P. Blake, in the *American Journal of Science*, and the following analysis of a sample of it was published by the writer in 1890. It will serve well to show the remarkably close agreement of these specimens with the Canon City sample, as well as with one another.

COLUMBITE—BOB INGERSOLL MINE, BLACK HILLS, S. D.

Specific Gravity at 20°C., 5·9005

		At. Equiv.		At. Ratio.
Columbic acid	57·32	42·80		
Tantalic acid	23·43	18·89	55·66	2·00
Stannic oxid	0·09	0·06		
Ferrous oxid	6·29	8·80	27·80	1·00
Manganous oxid	13·55	19·00		
Total	100·68			

The sample sent by Mr. Frenzel and labeled "Black Hills, South Dakota," may not be from the Bob Ingersoll mine; if not, so much the more is it to be regretted that its exact locality cannot

be given, for it is, according to my observation, a rare thing to find three separate crystals of this mineral at the same locality so nearly alike in composition as these three samples are, two of which we know to be from very remote localities.

In the analyses of columbite I have observed that it is common to have an excess amounting to several tenths of one per cent., whereas a slight deficiency is rather to be expected. This excess is partly, if not wholly, to be explained by the fact that the columbic and tantalic acids obstinately retain sulfuric acid, or it may be potassic sulfate if the acids have been fused with acid potassic sulfate. This error can be corrected by heating the ignited acids with ammonic carbonate and washing.

FIBROFERRITE—GREEN RIVER, UTAH.

Mr. E. A. Sutton, a former student in the laboratory, sent me about a pound of material for identification. As received, it consisted of a mass of fine acicular crystals, and a considerable portion of the material was colored by oxid of iron, due to partial decomposition. The inner portions of the larger and some of the smaller aggregations were greenish white, with a silky lustre. Examination under the microscope showed that the apparently acicular crystals were mostly groups of radiating crystals which had probably formed parts of a radiating aggregation; the larger groups were strongly suggestive of this. No terminations could be observed. The mass was not perfectly homogenous, as there were small, greenish-white particles visible under the microscope and easily distinguished from the acicular crystals in form, color and lustre. The latter are more nearly white, with a silky lustre; the former are greenish-white, with a vitreous lustre. While they might be taken for ferrous sulfate, they have not the decidedly green color of this salt, besides the material does not react for ferrous oxid. Fortunately these make up a very subordinate portion of the mass, so that they would not materially affect the formula of the mineral even if they differed somewhat in composition.

The locality is thirty miles southwest from Green River, Utah. The country rock prevailing at this locality is said to be sandstone.

FIBROFERRITE—GREEN RIVER, UTAH.

Specific Gravity Not Determined

		At. Ratios.
Insoluble	0·10	
Water	..87·06	
Sulfur trioxid	81·57	
Ferric oxid	80·22	Iron } Sodium } .... 4·00
Calcic oxid	trace	Sulfur............... 4·00
Magnesic oxid	trace	Oxygen ....88·00
Sodic oxid	0·59	Hydrogen ....41·00
Potassic oxid	none	
Total	99·54	

This gives the formula 2 Fe_2O_3 4 SO_3 20 H_2O, or Fe_2O_3 2 SO_3 10 H_2O. The very slight excess of hydrogen has been neglected.

ENARGITE—PROWERS MINE, WILLIS GULCH, GILPIN COUNTY, COLORADO.

Willis Gulch is a comparatively old locality for this mineral, its occurrence having been mentioned as early as 1868; but the place in Willis Gulch at which it occurred is not given, so far as I know. The probabilities, however, seem to be that the property from which the samples were obtained as early as 1868 was the Hampton, which is very near the Prowers mine, and presumed by some to be on the same vein. I have not been able to learn that this mineral occurs in other properties in this district.

The mineral occurs in lenses associated with iron pyrites and some chalcopyrite, and constitutes the ore produced at the mine. The mineral is crystalline, and I succeeded in finding some individual crystals, but these were in every case incrusted with quartz and sometimes associated with white and purple crystals of fluorspar.

The crystals, when stripped of their incrusting quartz, are iron black, with brilliant metallic lustre, and show the following forms: 100, 110, and 001. I was unable to detect any other forms.

ENARGITE—PROWERS MINE, WILLIS GULCH, GILPIN COUNTY, COLO.

Specific Gravity at 18° C., 4·4263

Sulfur	29·35
Arsenic	16·17
Antimony	3·77
Copper	48·40
Lead	1·83
Iron	0·30
Zinc	0·19
Total	100·01

This enargite carries some gold and silver, as shown by the returns from ore shipped, but the amount of these metals is quite small.

These results agree well with the accepted formula for enargite, which requires sulfur, 32·26; arsenic, 19·1; copper, 48·3 I do not think that the lead appearing in the analysis could have come from admixed galena. I could not detect this mineral in any of the specimens.

ALUNOGEN—DOUGHTY SPRINGS, DELTA CO., COLO.

In describing this occurrence of alunogen I shall consider Doughty Springs and Alum Gulch as practically one locality, though Alum Gulch is on the opposite side of the river and the mineral is found a quarter of a mile or more up the gulch.

In describing the Doughty Springs I raised the question of the origin of the aluminum sulfate occurring in the waters of the Alum Spring. I hoped to be able to obtain some further light on this point by studying the occurrence of the alunogen in Alum Gulch and on the cliff below the springs at the Doughty place.

There are no springs in Alum Gulch that I discovered, so we will have to look to the strata of rocks forming the cliff, respect-

ively the plains into which this gulch is cut, for the source of the alunogen.

The bed of the little creek flowing through Alum Gulch is composed of sandstone. There is a considerable talus at the base of the cliff, varying from ten to twenty-five feet. The best view of a section of these strata that I was able to find, beginning at or near the top of the talus, was as follows: Oxid of iron, five feet or more, which has been opened by some prospector in the hope of utilizing it as an iron ore; shale one and one-half feet; sandstone four to five feet; shale one and one-half to three and one-half feet; sandstone, sixty feet or more. This sandstone shows false bedding in a marked degree and is very irregular in character, it often passing into conglomerate which forms lenses sometimes five to six feet in thickness, and again into shales. The persistent stratum of shale at the base of the sandstones, varying in thickness from one and one-half to three and one-half feet, is rich in alunogen, but I hesitate to designate it as alum shale because I would be justified to even a greater extent in designating the sandstone as an alum sandstone. The alunogen occurs on the face of this sandstone as an incrustation of varying thickness for at least thirty-five feet from its base. As this portion of the cliff is perpendicular, the height at which the incrustation ceases is estimatted, but I have tried to be conservative, and I think that the figures given are rather below than above the fact. The mineral also fills the cavities occurring in the sandstone, or such as have been formed due to unequal weathering.

The comparatively small stratum of shale seems to me to be wholly inadequate as a source of the alunogen occurring at this place. The point of outcrop of this shale cannot be specified as the zone at which the alunogen appears; on the contrary, I think that one can correctly state that there is more of the mineral above it than at or below the line of the shale.

On the north side of the river and almost opposite Alum Gulch the alunogen occurs in masses of such size that one could

bar off pieces weighing several hundred pounds, perhaps a thousand pounds. These masses are found either at the base of a conglomerate or a sandstone. The only shale that I found at this point was about twenty feet above the sandstone. I climbed up to this for the purpose of satisfying myself in regard to the probabilities of this stratum furnishing the alunogen. The face of this shale was clean and showed no discoloration or disintegration, and I could not detect any evidence of the presence of alum or other soluble aluminum salts in these shales. There are other strata of shales cropping out immediately back of the Doughty Springs, but the incrustations and deposits occurring on or furnished by these strata are, as I showed in the article on the springs themselves, of an entirely different nature, i. e., sulfates of lime and soda, but no aluminum salt except at the Alum Spring.

While my observations have failed to detect the source of this alunogen, they lead me to believe that it is independent of the shales or any other specific stratum of rocks. There are no springs known to exist in Alum Gulch at this time, and I saw no indication that there had ever been any. The iron ore occurring here is a bedded hematite, and its presence cannot be considered as indicating the source of the sulfuric acid, i. e., oxidation of pyrites.

These are the only localities, of which I have learned, at which alunogen occurs in this vicinity. The mineral occurs in three varieties: massive, fibrous and in micaceous scales.

I found the massive variety more abundant on the north side of the river than in Alum Gulch. It occurs either at the base of the sandstone or conglomerate, well up on the face of the cliff, but not, so far as I have observed, on the face of or at the base of any of the shales. That the varieties should show slight differences is no matter for surprise.

ANALYSIS OF MASSIVE ALUNOGEN—NORTH SIDE OF THE RIVER, 300 FEET
WEST OF THE DOUGHTY SPRINGS

		Soluble Portion Calculated to 100
Insoluble in H_2O	21·30	
SiO_2, soluble in H_2O	0·17	0·22
SO_3	29·17	37·15
Al_2O_3	12·31	15·68
Fe_2O_3	trace	trace
CaO.............................	0·31	0·40
MgO	0·58	0·74
Na_2O...........................	trace	trace
H_2O	35·97	45·81
Total...............	99·81	100·00

MICACEOUS ALUNOGEN.

This variety occurs both at the Doughty Springs and in Alum Gulch, in masses of small, bright, apparently monoclinic scales, having a strong, silky lustre. The analysis resulted as follows:

MICACEOUS ALUNOGEN.

	Alum Gulch.	Doughty Springs.
Insoluble in H_2O..................	0·14	0·71
SO_3	37·12	39·18
Al_2O_3..........................	13·53	14·17
Fe_2O_3..........................	trace	trace
CaO..............................	trace	0·09
MgO	2·90	1·94
Na_2O	1·25	not deter.
K_2O	0·17	" "
Li_2O	trace	" "
H_2O	44·84	43·07
Total...............	99·95	99·16

FIBROUS ALUNOGEN.

	Alum Gulch.	Doughty Springs
Insoluble in H_2O	2·76	1·37
SO_3	38·90	37·26
Al_2O_3	12·51	15·08
Fe_2O_3	trace	1·19
CaO	trace	trace
MgO.............................	3·35	none
Alkalies	not deter.	not deter.
H_2O	41·96	44·84
Total...............	99·48	99·74

The two features of these samples of alunogen are the occurrence of plate like crystals and the presence of magnesia in some of the samples; in fact, the Alum Gulch specimens are quite as near to pickeringite as to alunogen. The plate-like crystals from both places agree in containing magnesia, but the two samples analyzed do not agree well enough to justify any attempt to establish a formula for them. The sample of fibrous alunogen from Alum Gulch carries almost enough magnesia to justify one in considering it as pickeringite. On the other hand, the sample from the Doughty Springs contains no magnesia, and the massive variety from this place contains comparatively little. They appear, as the conditions under which they occur would suggest, to be the same minerals alunogen, with varying amounts of magnesia and carrying more or less alkalies.

DOUGHTYITE.

A HYDRATED BASIC ALUMINIC SULFATE.

This material is formed rather abundantly by the action of the alkaline waters of the Black Spring, one of the Doughty Springs, on those of the Alum Spring, another of the same group, or in general, so far as this locality is concerned, on waters carrying aluminic sulfate in solution. This substance is described in my article on these springs as being formed at the Alum Spring, but more particularly in a drain cut to carry off the flow from the Black Spring, and at the same time intercepting the waters flowing from the Alum Spring and the talus in its neighborhood. In the article referred to, I stated that this white precipitate was presumably an aluminic hydrate. Having subsequently visited the springs, I find that the precipitate is forming at another place, sixty or eighty feet west of this spring, where it covered, at the time of this visit, many square yards of the surface. In places this precipitate was as much as three-quarters of an inch in thickness. I gathered a sample of it, and, after drying it for five weeks in the air, I submitted it to analysis, with the following results:

ANALYSIS OF WHITE PRECIPITATE.

Sand............................. 1·56
SiO$_2$ .... 1·91
SO$_3$ .... 15·00   15·58
Al$_2$O$_3$ .... 39·51   41·02
Fe$_2$O$_3$ .... 0·45
ZnO .... 0·44
MgO .... trace
H$_2$S..............................not deter.
CO$_2$..............................not deter.
H$_2$O .... 41·80   43·40

            Total...............100·67   100·00

S.	0·06232 + 32	1·917= 2	3
Al.	0·21716 + 27	7 670= 8	12
O.	0·67220 + 16	42·000=42	63
H.	0·04822 + 1	48·220=48	72

These ratios correspond to the following formula:

$$Al_2(SO_4)_3 \, 5 \, Al_2(OII)_6 \, 21 \, H_2O.$$

Which requires the following percentages:

$$SO_3, \, 16·00; \, Al_2O_3, \, 40·80; \, H_2O, \, 43·20.$$

I have some doubts whether this substance is entitled to classi-
fication as a mineral species or not, and yet I can see no good
reason why it should be less so than alunogen, alum, ferric hydrate,
or any other compound, simply because its formation is plainly
observable. I tentatively suggest the name of Doughtyite, after
the owner of the springs where it occurs—that is, if it should find
place as a new species.

BISMUTHITE FROM THE PAULINA MINE—NACOZARI, MEXICO,

I am indebted to Mr. Herman Berkhauer, one of the owners
of the Paulina mine, for the samples which form the subject of this
note.

The mineral occurs associated with a highly micaceous hema-
tite, with only an occasional, small crystal of pyrite; the little

druses occurring in the largest piece are lined with crystals of calcite. The samples received show two forms, crystalline and massive.

The crystalline varieties present two types, one consisting cf large, radiating crystals; the other of small ones, which form a compact mass. This, however, is not pure, as it includes some hematite in the interstices of the crystals. The large, radiating crystals attain a length of an inch and a half, with a width exceeding a quarter of an inch, measured in the direction of perfect cleavage, brachydiagonal. The color on these cleavage surfaces is tin white rather than gray, but that on the surfaces corresponding to the less perfect cleavage is dark gray.

The massive form is lead gray in color, and shows, in patches, the iridescent tarnish often observed on this mineral. The massive variety occurs both with the crystallized variety and alone, always, however, in association with hematite.

The vein in which these samples were found is stated to be 18 feet wide, with the mineral occurring abundantly throughout its width. The character of the vein filling is not stated, but, if one may rely upon the indications as given by a single specimen, it must be highly chloritic in character.

None of the samples received, though they were the best to be obtained, constituted ideal materials for analysis. The sample finally chosen was a piece composed of small interlocking crystals. This piece appeared to be almost pure; some hematite, however, could be detected upon close examination, but no calcite was observed.

The specific gravity of this mass was 6·2079 at 23°C, but when correction is made for the impurities it becomes 6·9102, which is probably a close approximation to the specific gravity of this sample of the mineral.

The analysis of the sample resulted as follows:

Bismuth ....69·393
Sulfur ....16·010
Ferric oxid... 8·010
Calcic oxid.. 2·090
Copper .... 0·958
Zinc .... 0·436
Lead.. 0·180
Carbon dioxid..................................... 1·640
Insoluble .... 0·430
Loss at 200°C..................................... 0·100
                                                   ———
                                                   99·257

The footing of this analysis is rather low, but it is almost certain that the zinc should be given as zinc oxid instead of as metallic zinc, because the hematite from this mine contains zinc oxid, even when it is entirely free from bismuth. The same is the case, in part at least, with the copper. I made no attempt to determine the water of hydration, etc., beyond drying at 200°C., after having previously dried the mineral at 110°C. for over an hour. This temperature, 200°, is not sufficient to expel all water of hydration, if any were present, nor to destroy organic matter. Owing to these elements of uncertainty which tend to produce a deficiency in the summation of the analysis, I have not thought it necessary to repeat it, as I believe the determinations to be quite within the allowable limits of error.

If we calculate the bismuth and sulfur to one hundred, neglecting the zinc, copper and lead for reasons already suggested, we obtain:

|	From the analysis	Required by formula Bi_2S_3
Bismuth	81·265	81·25
Sulphur	18·737	18·75
	100·000	100·00

The close agreement between the results obtained from the analysis and those required by the formula for bismuthinite establishes the identity of the mineral. The locality and also the association of hematite with this mineral are new.

Fig. 1.

Set of "Box Plates." Electric
Storage Battery Co.

Fig. 2.
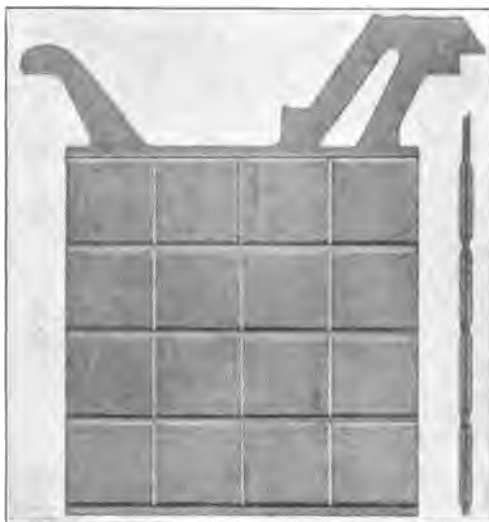
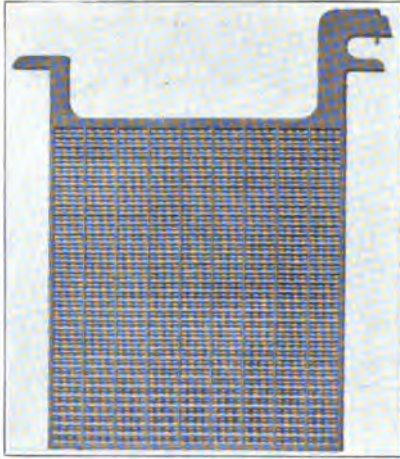Positive Plate.   Willard Storage Battery Co.

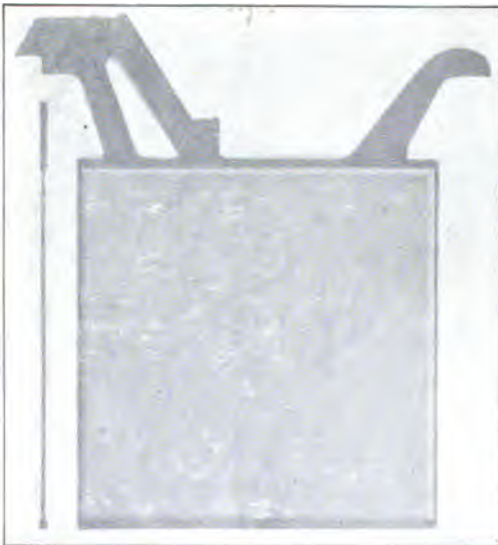Fig. 3.

Positive Plate.   National Battery Co.

Fig. 4.
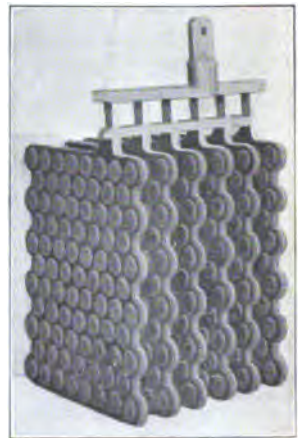

Element in Glass Jar.   National
Battery Co.

Fig. 5.

Lead Grid.   National Battery Co.

Fig. 6.

Negative Plate.   Willard Storage Battery Co.

Fig 7.

Set of Positive Plates.
Electric Storage Battery Co.

SCIENTIFIC PRINCIPLES OF ELECTRIC STORAGE BATTERIES.

BY RUDOLF GAHL, PH.D.

Read at the Meeting of the Society, October 7, 1905.

To the superficial observer the process involved in the operation of electric storage batteries appears very plain. Indeed the main chemical action upon which they are based is simple enough. The lead forming the negative pole and the lead peroxide forming the positive pole are both changed into lead sulphate by the combined effect of the electric current and the sulphuric acid which serves as electrolyte. At the first glance this seems to exhaust the theory of the lead storage cell, but the men who looked deeper found secrets, and the deeper they searched the more they found. Although these problems were attacked by investigators who knew how to handle the weapons furnished by physics as well as analytical and mathematical chemistry, and although their efforts were crowned with success it must be stated that the theory of storage batteries is not yet exhausted.

For this reason it is impossible to give a full account of the theoretical principles of the storage battery, but I will try to develop the most important facts in a way which seems the logical way, in looking backward. It is hardly necessary to mention that the way which now seems the logical one for the development of the accumulator has not been the historical one.

Let us suppose we needed something in which to store electricity and did not know anything about what had been accomplished to solve this problem. What would we do? The first idea would probably be to use a condenser, a Leyden jar; in other words a purely electrical apparatus, but soon we would find out that it is a physical impossibility to construct a condenser which would store such quantities of electricity as practical use requires.

Knowing that an electrical current can be used to produce mechanical energy and that mechanical energy can be transformed into an electric current again, the idea might occur to us to construct a kind of electro-mechanical accumulator. For example, we could use the current to drive a motor which pumps water to a high level; then when it is desired to make use of the current again the water could be made to run down and drive the electrical machine, which will act as a dynamo in this case, and produce current. Such a thing is possible, of course, but would be quite an engineering achievement of probably very low efficiency.

After recognizing that the mechanical storing of electricity is not feasible, the fundamental idea of electric storage battery construction might strike an inventive mind; i. e., to transform electric energy into chemical energy and to try to retransform chemical energy in electric current.

We have to study, therefore, the chemical effects of the electric current. Electric currents passing through a circuit of metals have no chemical effects, except, of course, indirect ones which are caused by the heat produced in wires traversed by electric currents. So metals alone will not do—we have to introduce a non-metallic conductor, or conductor of the second class, as it is sometimes called. We might state, as a principle, that an electric storage battery has to consist of a conductor of the second-class between metallic conductors. It seems self-evident that the storage cell must contain an electrolyte; that is, a substance which when traversed by the current undergoes a chemical change; but, nevertheless, I re-

member to have heard the suggestion to replace the sulphuric
acid in the lead storage cell by mercury because the conduct-
ivity was so much better.

Let us now look at the chemical changes which electro-
lytes undergo and see whether it is possible to make such
chemical action the basis of an electric storage cell. Prob-
ably the best known electro-chemical reaction is the decom-
position of water. When we send a current through an aque-
ous solution it will develop gas on the positive and on the neg-
ative poles, supposing that the electrodes consist of a noble
metal which is not attacked by the electric current. This de-
composition of water is very well known. Hydrogen is de-
veloped on the negative pole, oxygen on the positive pole.
Now the question is, can we make this cell an accumulator?
We can, if we succeed in reversing the process. That would
mean pressing the gases back into the solution, and making
them combine to reproduce again the electric energy which in
the first step was absorbed by the chemical process. This is
quite possible; indeed I might mention that such a cell which
produces electricity from the combination of oxygen and
hydrogen has been used and investigated extensively from a
theoretical standpoint. Attempts have also been made to
make the gas cell a practical accumulator. Great difficulties
must be overcome, however, to accomplish this, the main ob-
stacle being that the reaction between the gases is too slow.
To make them combine with each other it is necessary to ab-
sorb the two gases in the two electrodes. Platinum is the only
metal which will answer the purpose, so at best it is not a very
cheap accumulator. The cell has a voltage of about one volt,
but if any considerable amount of current is taken out the
voltage drops at once. The reason seems to be that accord-
ing to the amount of current taken out from the cell the gases
are removed from the electrodes, and combine so that new
amounts of gases have to be dissolved by the metal to produce
more current. But the process of the dissolution of gases in
metals, even in platinum, acts so slowly that it can not keep

pace with the consumption of gas. The consequence is that the gas contents of the electrodes become very low when current is taken out, and the voltage drops accordingly. As a matter of experience we may state that a practical accumulator cannot be based on gas reactions at present.

Use has been made in several constructions of storage batteries of the chemical decomposition of liquids not connected with gas development. As an example I mention a construction of Dr. Auer von Welsbach, who is better known as the inventor of the Welsbach light. In his cell cerium-sulphate is used as electrolyte, surrounding the positive pole. At the charge ceri-salt is formed; at the discharge it is reduced to cero-salt. But this cell, like all others depending on the same principle, has not proven practical.

Practical success has been met only by experimenting with solid bodies formed, or chemically changed by means of the electric current. In the case of gas reactions the proper method of employing the gases for producing electric current was to make the gases the electrodes themselves. As, of course, it is impossible to form electrodes from gases it was necessary, as I explained before, to absorb the gases in platinum metal in order to make them react. Practically it was already the case of solid bodies reacting which we will consider now. The way to construct an accumulator of this type is naturally to cause the electrodes to react with the liquid electrolyte by means of the electric current.

The simplest case of such a reaction is that of a metal entering into solution, and, indeed, this reaction has been made use of by a great many inventors. When the positive current is sent through a metallic electrode into an electrolyte, which has the power of dissolving the salt formed by the transformation of the metal, a great many metals will go into solution. Very noble metals like platinum or gold do not enter into solution. They have, as the electrochemist says, in accordance with the ideas developed by Nernst, too small a solution tension. Other metals like sodium or potassium enter

into solution without the help of the electric current. Their solution tension is higher than the solution tension of hydrogen, and as a consequence they press the hydrogen from the combination with oxygen, the metal of high solution tension being substituted. It is clear that neither the metals which do not react at all, owing to their small solution tension, nor the metals which react without the help of the electric current are available for storage batteries of this type. Our choice is limited to metals standing in the middle. I will mention zinc, cadmium, iron, lead, copper, mercury, silver, and possibly one or two of the rare elements.

A cell may be composed of two of these metals. If we should take the same metals for both electrodes of course no electromotive force would result, as the solution tensions, which are the origin of the electromotive force, according to Nernst's theory, would be equal and opposed to each other. To construct a cell of high electromotive force it is necessary therefore to take two different kinds of metals and combine them in a cell. The Danniel cell having a zinc kathode, (negative electrode,) and a copper anode, (positive electrode,) is an example of this type. Zinc has the higher solution tension of these two metals. If there is a possibility given of transporting electricity through a wire by a circuit connecting two poles, the zinc will enter into solution and carry with it a certain amount of electricity as this is the characteristic action of all metals going into solution. On the other side the copper plating out from the solution will carry the same amount of electricity out from the solution which enters with the zinc. Such is the reaction taking place, of course, only for the case where there is no exterior source of electricity opposed to the solution tension. The higher tension of the zinc will cause it to enter into solution and the copper to precipitate out. This force which drives the current through the wire and which results from the difference of the solution tensions we call electromotive force. It takes an outside electromotive force larger than that of the cell to drive the current in the opposite

direction, that is to dissolve the copper and to precipitate the zinc.

These combinations are used as primary cells, or have been used at least in former times with great success, but there are difficulties in their application as storage cells. In solution we must have zinc and copper salts. Now it is necessary to separate the copper solution from the zinc, for if this were not done, the zinc electrode would serve as the circuit for a current, and zinc would go in solution and precipitate the copper directly on the zinc. In this case current is produced just the same, but it enters into solution with the zinc and goes out with the copper which latter precipitates on the zinc. The current is therefore not available for any practical purpose, but is used up simply in what is called local action. To prevent such an action, a diaphragm must be used in the Danniel cell, but such a diaphragm is an imperfect thing and cannot prevent completely the diffusion of the electrolytes. For a practical storage cell they seem almost impossible. As a matter of experience we may say: An electric storage battery must contain only one liquid and then of course no diaphragm. We can reject the employment of diaphragms the easier as we have means of producing a much higher voltage by other anodes than that caused by using a metal surrounded by a solution containing the same metal as a salt.

The negative pole, the zinc pole, however, has been retained in a great many storage battery constructions, although none of them has gained any commercial importance. I believe there is a cell on the market, using zinc as negative poles, and in some French constructions of automobile cells the zinc is used instead of lead, as in the ordinary lead cells. The advantages which the introduction of zinc as negative electrode for storage batteries instead of lead would have, are indeed fascinating. In the first place it has a higher solution tension than lead has, and the electromotive force is higher accordingly. In the second place a zinc electrode can be very much

lighter in weight than a lead electrode. Theoretically only 1·29 goes into solution for an ampere hour. Of course the practical consumption of zinc is higher, but nevertheless the weight of a zinc electrode is only a part of the weight of a lead electrode for the same capacity. The trouble is, however, that owing to the same high solution tension the zinc is dangerously near to those metals which decompose water. In acids which are the electrolyte in common storage cells the zinc does the same unless alloyed with very much mercury. In the third place experience has shown that there is no relying on cells which require plating out of a metal from a solution containing it when the cell is charged. Even if the metal precipitate produced in charging a battery is brilliant 99 times, the hundredth time it is sure to be spongy, and will form a bridge for short circuit from one electrode to the other, which means naturally the disabling of the entire cell. Some interesting work has been done in the direction of developing a type of cells with negative zinc poles by Mr. C. J. Reed, of Philadelphia, but I am afraid even his interesting constructions will not mean a commercial success in the manufacture of soluble kathodes. As an axiom derived from practical experience we might make the following statement: Soluble kathodes for electric storage cells are not reliable.

There is a possibility of using soluble anodes for electric storage batteries. It is a well known fact that certain high oxides of some metals can be formed by the electric current passing through a solution of their salts, for example it is a familiar phenomenon in analytical electro-chemistry that lead peroxide can be plated out from lead solutions containing free nitric acid, but the difficulties to be overcome are even greater than in the case of soluble kathodes. It is probably for this reason that this problem has not attracted inventors up to this time.

All constructions of electric storage batteries as far as they are in practical use contain insoluble kathodes and insoluble anodes, to which we will now devote some attention.

If kathodes and anodes would be used in the form of some sheet metal, as we use zinc, for example, in many well known cells, only a slight chemical action would be possible between electrode and electrolyte. Taking the case of lead in sulphuric acid, as an example, it will be readily seen that the surface of the lead will be covered in a short time with the salt formed, in this case lead sulphate, which being rather insoluble and a nonconductor of electricity, will stop the chemical and electrical action. The remedy for this trouble seems evident, it is to increase the surface of the electrodes to such an extent that it will take a long time to coat the whole surface with lead sulphate. It is for this reason that the negative lead electrode is used in spongy form so that it is capable of absorbing a great quantity of lead sulphate without interfering with the action of the electrode. The same thing is true of the anode. The lead peroxide must not be a simple coating of lead which in most cases is the carrier of the lead peroxide, but must be a soft and porous material, able to take up a large quantity of the lead sulphate formed by the current.

Limiting our attention now to the case of insoluble electrodes, which, as we saw, must be porous, the question comes up, what liquids are available as electrolytes? In the first place, the electrolyte must not be decomposed by the electric current into gaseous products. Nitric acid, for example, would be impossible in electric storage batteries because it is reduced to ammonia by the effect of the current. It is furthermore necessary to have an electrolyte of high conductivity. In the third place the electrolyte must be cheap. Among the acid electrolytes sulphuric acid stands alone; there is hardly any other that meets all requirements. Only such metals which form insoluble salts with sulphuric acid, such as barium and lead, can be considered as kathode material. Barium has to be excluded, because it is not reducible by means of the electric current, and we see that the only metal suitable for the construction of accumulators with acid electrolytes is lead. The same is true for positive electrodes. There is noth-

ing but lead peroxide which can be used as depolarizer for the positive pole.

The case of neutral electrolytes is only a medium between acid and alkaline electrolytes. The electric current will always change a neutral solution in such a way that the liquid adjoining the one pole becomes acid, and the liquid adjoining the other pole becomes basic, so that the metals have to be chosen with the same considerations governing the choice of acid and alkaline electrolytes. Among the alkaline electrolytes known as good conductors there is hardly any choice besides the hydrates of sodium and potassium, and, in fact, these are about the only ones which have been applied to storage cells. There are several metals which fulfill the condition to form insoluble hydrates or oxides and will do for kathodes, as iron, nickel, copper, and cadmium. As it is desirable to have a high voltage, only such metals will be used for kathodes which have a high solution tension, that is, either iron or cadmium. Cadmium is better for many reasons, but it seems impossible to produce any quantity which would make the use of cadmium kathodes possible on a commercial scale. A metal which can be used as anode in alkaline solutions must meet the requirement of forming an oxide or hydroxide which has a high depolarizing capacity. These are nickel oxide,* iron oxide, and silver oxide. Nickel plates produce the highest voltage, but for some combinations, silver plates are far superior to nickel plates on account of the higher conductivity of the silver oxides. The oxides which form the depolarizing agent must be supported by a wire frame or other contrivance. In acid solutions lead is the only metal which can be used for this purpose, not being attacked too much, while for alkaline solutions nickel is the only metal which is attacked very little, very much less than lead is attacked in acid. It will be seen from these conditions which we have derived for a construction of electric storage batteries that the only practical possibilities are the lead cell with sulphuric acid as

*Cobalt acts similarly to nickel but probably has to be excluded for practical purposes on account of its rarety.

electrolyte, and alkaline cells with kathodes of iron or cadmium and anodes of silver or nickel. The only cell of really great commercial importance is the lead storage cell, to which we will devote some attention now.

In the first place I might say a word about the process used for manufacturing lead cells. There are two main groups of these processes, first, chemical ones, and, second, mechanical ones. The oldest method of manufacture was the method of Planté, who discovered that if a sheet of lead is immersed in sulphuric acid and a current is passed in one direction, a thin film of lead peroxide is formed on the anode. By reversing the current this film is transformed into a fine film of spongy lead metal. By reversing the current again, the spongy lead affords an opportunity to the current and the acid to attack the underlying solid lead and to form a thicker film of lead peroxide than the first time. By continuing this reversing process for a very long time (more than half a year was necessary), Planté electrodes of high capacity have been produced, but they did not become a commercial success until it was discovered that the time required for making plates according to this process could be shortened considerably by adding certain chemicals to the sulphuric acid solution. Indeed, it is possible nowadays to transform a body of sheet lead into lead peroxide without reversing the direction of the current at all. Making the lead peroxide plate the negative pole will reduce the peroxide formed by such a process to a porous metallic lead as it is desirable for the negative plate.

The mechanical production of the active material in battery plates has been protected by the patents of Faure abroad, and of Brush in this country. Their process simply consists in filling lead grids with a paste made of litharge or chloride of lead with some liquid, and exposing this plate to the action of the electric current in sulphuric acid solution. The lead oxide will then easily be reduced to spongy lead at the kathode, which can be oxidized electrolytically to make positive plates.

An intermediate step between these two processes has been the Tudor process, which consists in pasting Planté plates, the formation of which was not quite finished, with lead oxides in order to reduce the time required for the Planté formation. Tudor plates are not made any more, although the factories bearing the name of Tudor factories are the largest ones in the world at present. Through the disappearance of the Tudor plates from the market, only the other two principal groups of storage battery plates are left. Planté plates are used either as positive plates or as negative plates. One disadvantage of using these Planté plates for the negative, that is, for the spongy lead plates, is that after a while, owing to reactions which have not been studied thoroughly enough, the spongy lead loses its consistency and solidifies into solid lead. Of course there is a decrease in the capacity of these plates according to the change in their structure. A remedy is available in such a case, which is to use the plates which have been negative before as positive plates, the effect of a long series of discharges and charges on the positive Planté plates being just the opposite from its effect on the negative plates. The solid body of the positive plate is slowly but constantly attacked by the combined effect of sulphuric acid and current, and the capacity would increase considerably unless through the action of the gas bubbles developed on the charge of the battery some lead peroxide would be loosened and fall off. But, nevertheless, they are not apt to loose their capacity as quick as the negative plates, and on reversing the polarity and using the negative plates as positives and the positive ones as negative ones, the newly made negative plates start in with quite a high capacity and the positive plates regain their former capacity through the attack to which positive plates are always exposed. The grids in American Planté plates are cut mechanically by machines. The leading Planté plates in Europe are cast plates, which do not seem to gain favor in this country, possibly because casting of such fine things as these battery plates requires a high

development of the art of casting, to which art the younger American factories have not paid attention enough. Positive Faure-Brush plates are not made by any prominent plant in this country, except in small sizes for automobile work; in fact, it is very difficult to make them, but it is possible, for some good plates of this type are manufactured abroad. Negative Faure plates are made in this country by the National Battery Co., Buffalo, N. Y., and by the Electric Storage Battery Co., Philadelphia, Pa. The negative Brush plates formerly had the same disadvantage which the Planté plates still have, of losing their capacity after some time of service through shrinkage, but it has been found that by giving the paste used for manufacturing these plates a certain composition that tendency for shrinking can be overcome, and that it is even possible to manufacture plates which expand and become more and more porous after they have worked for some time. The expansion, and accordingly the porosity of the plates, had to be kept down to prevent falling off of the active material. Recently another type has been brought on the market (Fig. 1), by the Tudor Companies in Europe and by the Electric Storage Battery Co., in this country, which permits the use of material of high expanding power, the falling off of active mass being prevented by a kind of perforated lead wrapper, cast together with the grid. This plate is called box plate, and means a vast improvement over the negative plates made before, and it evidently seems to solve the problem of negative plates, for now the negative plates have a longer life than the positive plates, whereas formerly the life of the battery was always limited by the negative plates.

I may say just a few words about some theoretical problems connected with the action of lead cells; the chemical change taking place while the cell is being discharged, that is, producing current, is

$$1)\ Pb + PbO_2 + 2H_2SO_4 = 2PbSO_4 + 2H_2O.$$

The chemical process taking place at the charge of a cell is represented mainly by the same reaction when read from the right to the left side. The equation indicates in this case that lead and lead peroxide are formed back from lead sulphate. If this equation would represent exactly the reactions at the charge of a cell, the efficiency of the accumulator in Ampere hours would be 100%. In fact, however, some of the charging current is used up to a certain degree by other reactions and is lost for the reprecipitation of lead. Towards the end of the charge a considerable part of the current is taken up by the development of gas, which part is becoming larger when the charge is nearing its end, i. e., when nearly all lead sulphate is decomposed. When the charge is finished and the current is left on nearly all the current is decomposing water, forming hydrogen and oxygen. For economical reasons not every charge of a storage cell is made complete, but some lead sulphate is left in the plates, in order to get an efficiency of from 90 to 95% in ampere hours. In the interest of the preservation of the plates it is necessary to remove from time to time all the lead sulphate as far as possible.

Besides lead and lead peroxide, sulphuric acid enters into the main equation. The question is, which is the most favorable concentration of acid in the use of the lead cell. It is evident from the above mentioned equation that the higher concentration of acid will promote the discharge of a cell, or, in other words, that the electromotive force of the cell using higher specific gravity of acid is higher than for a cell with more dilute acid. Of course it is desirable to have the electromotive force as high as possible, but in fact several other points have to be regarded in deciding what concentration is the most favorable one. For automobile work, where a lightweight cell is desired, a high specific gravity of the acid is desirable, also for the reason that acid of high specific gravity contains more H_2SO_4 than weak acid for the same weight, and therefore reduces the weight of the battery. One more point to be

kept in mind in deciding on the density of the acid is the conductivity of sulphuric acid, which has a maximum near 1·200 specific gravity, about the standard in practical use. A higher specific gravity just as well as a lower specific gravity would mean a higher resistance, and would for this reason somewhat lower the efficiency of the cell, but the most prominent point in deciding the question of concentration is the regard for the life of the plate, a variation in one direction being harmful to the negative plate, a variation in the other direction to the positive plate. The relation between specific gravity and electromotive force can be calculated theoretically from the vapor tension of sulphuric acid solutions, or from the curve of the freezing points. This was done by Dolezalek. He has demonstrated in his work, which is one of the classic researches in electrochemistry, in the case of the lead storage cell the applicability of physical chemical calculations to practical problems.

I have used the word capacity of electric storage batteries several times without giving the definition of it. From the above mentioned equation it follows that if the cell contains only a limited amount of sulphuric acid, the process producing the current would stop, that is, the electromotive power of the cell is exhausted. The same holds when either porous lead or lead peroxide is lacking. In applying Faraday's law to this equation it is possible to calculate the necessary amounts of any of these substances which are indispensable for producing a certain amount of current, but the practical capacity is very much less than the theoretical capacity thus calculated, and is not only dependent upon the amounts of active material present, but also on the amount and intensity of the current taken from the battery. It has been found in researches made by Liebenow that the capacity of storage plates is limited, not by the absolute amount of acid in the cell, but by the quantity of acid in the immediate neighborhood of the working plates. From the fundamental equation of the accumulator, it is evident how much acid is used for producing a certain

amount of current. As this acid is taken up by the plates, the acid being chemically bound by forming lead sulphate, local exhaustion of acid takes place, as soon as the consumption of acid depending on the current taken out from the cell is larger than the supply of new acid, which can be furnished by diffusion and some electrochemical process having the tendency of equalizing the concentration in the different parts of the cell, that is to press acid within the pores of the plates. This theory has been proven by pressing sulphuric acid through working plates, and it has been found indeed that the cell can be raised to nearly its theoretical value. Of course, this is not a practical scheme, the only practical consequence of this theory is that it shows the necessity of making the plates as porous as possible so as to accelerate diffusion as much as it can be done. The construction of the box plate which I mentioned before is practically the result of investigations in this line; it is a pity that the qualities of lead peroxide do not permit these plates to be made as porous as would be desirable for increasing their capacity. As lead peroxide has a tendency to disintegrate in fine particles, it is not possible to make a porous positive plate without endangering its life very much. This is the reason why the construction of an efficient and at the same time durable positive plate presents so many difficulties, in fact, is the main difficulty at present in raising the life of the lead storage cell to the life of other electrical machines, as for example a dynamo or motor.

It seems clear that the lead used, especially that for the positive plate, has to be of very high purity, as otherwise these impurities would be dissolved out of the lead and open the way of attack for the combined efforts of acid and electric current, thus reducing the life of the plate. Not so evident is the detrimental effect of impurities in the acid, of substances like chlorides or organic acids. They act as forming agents in producing Planté's plates, and for this reason their concentration has to be reduced to a minimum in the acid, in order to prevent their forming effect on the positive plates.

The effect of metals like iron, which have two degrees of oxidation, is very interesting. Iron is oxidized to its higher state of oxidation at the positive pole, and reduced to the lower state at the negative pole. In the first place a reduction of the lead peroxide is taking place simultaneously, in the second case oxidation of the spongy lead. Through the action of diffusion an interchange of ferrous and ferric ions takes place between positive and negative plates, which is very much accelerated when the gas developed by the plates on being charged stirs up the electrolyte. Therefore, a reduction of the positive plate and an oxidation of the negative plate takes place continuously, which is equivalent to the discharge of the cell not connected with production of electric current, so that it is evident that the contents of iron in the sulphuric acid mean a self-discharge of the cell and of course at the same time a lower efficiency. Other interesting impurities in sulphuric acid are metals like platinum, etc., which through the action of lead are precipitated on the lead plates. It is a very characteristic action of these metals, even in small traces, that they cause the lead to enter into solution under development of hydrogen.

Judging from thermodynamical calculations, lead ought to develop hydrogen with sulphuric acid without the aid of platinum, but it is a matter of experience that it does not, and fortunately it does not, for otherwise the lead cell would be impossible. But as soon as a trace of platinum or similar metals is mixed with the sulphuric acid, this hydrogen development starts, of course discharging the negative plate at the same time. Although this catalytic action of platinum metals offers some more theoretical problems, I cannot go deeper into the subject, as it would take too much time. I will only add just a few words to my remarks about alkaline cells.

As I mentioned before, for positive plates nickel and silver are available, for negative plates there are iron and cadmium. Both cadmium and silver make very good plates for high capacity, although their solution tension is not far enough

apart to produce a very high voltage, the electromotive force of this combination being only about one volt. For the combination iron and nickel the voltage is somewhat higher, but probably owing to the small conductivity of the oxides, it is not possible to construct plates of any thickness, even when the conductivity of the plates is increased by the addition of some good conductor like graphite or some metallic substance. The only way to make use of this combination is therefore to construct very thin plates. Luckily the metals iron and nickel have mechanical qualities, different from lead, which allow them to be used in very thin sheets. The problem of the alkaline cell this way is reduced to a mere engineering or mechanical problem—that is, to construct plates and batteries of a very fine metal in such a way that they will have enough mechanical strength to resist the wear and tear caused by their use in automobiles.

Although the prospects of success in this field do not appear very great, Edison, the great American inventor, seems to have been at least partly successful. But the problem of a light alkaline cell will enter a new phase, when it will be commercially possible to use cadmium. It does not seem to be doubtful to me that as soon as large enough quantities of cadmium are discovered, the problem of a light accumulator for automobiles will be brought very near its solution, at least for cases where the price does not cut so very large a figure, as to exclude the application of metals like cadmium and silver.

Perhaps it is left to Colorado to make this development possible by supplying sufficient amounts of cadmium.

THE ELECTROSTATIC SEPARATION OF COPPER ORES.

BY W. G. SWART

Read at the Meeting of the Society, March 3, 1906.

The fundamental principles of the Blake-Morscher Electrical Ore Separating Process are probably familiar to the members of this Society, yet a brief preliminary survey of them may serve to make clearer some of the following statements.

In its simplest form the process depends for its action upon the relative conductivity toward static electricity of the several minerals. This conductivity involves the element of time, the static charge passing more rapidly over the surface of some minerals than over others. If any two particles, one a good conductor and the other poor, are allowed to come into contact with an electrically charged surface, the good conductor becomes charged first, when it is quickly repelled. The poor conductor requires a longer time. It is plain that here is a property of matter which may readily be taken advantage of for purposes of separation. It is impossible in a paper of this length and character to discuss the theory lying back of this property or other electrical properties which have been investigated and utilized. This phase of the discussion can be found, together with mathematical formulæ and demonstrations, in a paper presented by Prof. Lucien I. Blake in the Transactions of the American Electro Chemical Institute, April 27, 1905.

The credit for the discovery and development of this process belongs to two trained scientific workers, Lucien I. Blake and Lawrence N. Morscher. Dr. Blake was graduated from Amherst College in 1877, going thence to the University of Berlin, where his degree of Ph.D. was conferred, after four years of study and research in the laboratory of Von Helmholz. Here he was directly associated in original investigations with Herz, Koenig and others, and returned to America exceedingly well equipped for his life work in physics and electricity. After three years of teaching at the Rose Polytechnic he was called to the University of Kansas to the chair of Physics and Electrical Engineering, which he has since held.

Mr. Morscher is a Kansas University man, who while pursuing scientific studies there, became associated with Dr. Blake in the work of developing this electrostatic separating process.

Like so many others, their original incentive was the recovery of gold from the great dry placer fields of the Southwest, and only after long experimenting did they turn their attention to other metals.

The first commercial application six years ago was to ores of zinc originating in Leadville, and the inability of the Joplin field to supply the ore for the recent increased spelter demand, with the consequent pressure for a larger supply of western ores, has forced almost all of the fifty or more machines now in service into the business of separating zinc ores, to the apparent neglect of some of the other metals which might otherwise have been much more extensively worked.

In the handling of complex zinc ores, the process has several distinct advantages. In the first place, since magnetism is not used, it is not confined to the separation of ores containing iron, but will remove copper and lead and the other sulphides, as well as pyrite and pyrrhotite.

In the second place, the work is done without roasting the ore, thus avoiding the cost of roasting and cooling, and leaving the pyrite product in suitable condition for sulphuric

acid manufacture, if desired. In Wisconsin and Illinois, where the products are barren of precious metal values, this is a very important factor.

In the third place, the power consumption is low, averaging less than one H.P. for each 15-ton separator. This includes the generation of the static charge. In addition to separating zinc blende from other metallic sulphides, it is in many cases possible to separate it from barite, siderite, rhodonite, rhodochrosite, garnet, spinel, quartz, etc. A great many other separations are made—too many to enumerate here. The fact that there is a difference in conductivity between almost any two minerals that might be chosen, and theoretically a separation should always be possible, but in practice there are many difficulties.

Among the easier and more successful separations may be mentioned that of flake graphite, or molybdenite from associated gangue material. Molybdenite is especially easy to make and yields very clean products. The softness of graphite and its tendency to coat the particles of gangue during crushing, drying and screening, thus rendering them conductive, introduces an element of trouble not found in other separations.

Rutile has been cleaned from ilmenite and magnetite to a content of Tio_2. Corundum has been successfully separated from feldspar, limonite and pyrite. Monazite has been cleaned from the iron sands with which it is associated. Tin and tungsten concentrates are fairly well cleaned from pyrite, garnet, spinel, barite, etc.

The separation of lead minerals is indifferent except in the case of galena, which is a fine conductor, and separates readily from most gangue materials. One exceedingly interesting application is the separation of galena from barite in a location where wet concentration is impossible. It has never been the policy of the owners of the process to attempt to compete with wet concentration, but rather to work on materials where wet concentration for one reason or another is

inapplicable. The difficulties involved in any dry process are clearly understood, recognized and admitted, and there is no attempt to belittle their importance. It will have to be admitted, however, that wet concentration cannot solve all problems, and three years of mill experience has shown conclusively that electrical separation can be and is to-day being successfully applied.

In the instance just noted—separating galena from barite—there are several complications. In the first place, the ore contains considerable silver values associated with chalcocite, which cannot be separated wet from the barite. In the second place, the mine, from its location on a stream, which is the chief water supply of a large city, is prohibited from discharging any tailings or chemicals into the stream.

A similar case I have in mind, where the ore, consisting of galena, zinc blende and barite, carries a large part of the silver values associated with the blende. In this instance, the Blake machine removes, first the galena, and later during a second treatment, the blende.

It is necessary to state plainly and emphatically here as I have done heretofore in every paper I have prepared on this subject, that conductivity is a relative, not a positive property, and varies widely in different specimens of the same mineral and even in the same specimen under different conditions. This means that no general law can be formulated. Zinc blende from Broken Hill is highly conductive, from Joplin very weakly so. The conductivity of hot calcite is one thing—of the cold mineral another. Consequently such a general statement as that limonite or malachite are conductive materials, is unwarranted, and will not be borne out in practice.

Turning now to copper minerals, which it is my privilege more particularly to discuss this evening, a great deal of very interesting, instructive and profitable work has been done.

Metallic copper itself being one of the very best conductors of electricity, one would naturally expect to find its compounds exhibiting a similar tendency, and with but few excep-

tions the copper minerals are conductive toward static electricity.

The silicates are probably the least so, and up to the present time practically no satisfactory work has been done with them, although certain laboratory work leads us to believe the case is not altogether hopeless. The carbonates are not much better, although the pure minerals are ordinarily conductive enough to readily separate from a silicious gangue. The difficulty comes from the fact that most carbonate ore bodies are impregnations or of a secondary nature, and do not exhibit at all the same properties as do the pure minerals.

The oxide of copper is a very good conductor and if the silicates or carbonates be oxidized, however superficially, they can in many cases be separated. This can be understood when it is remembered that conductivity toward static electricity is a function of the surface of the particles only. This oxidization is not usually a difficult thing to accomplish, especially in view of the fact that practically all ores must be artifically dried in any event before treatment.

Such ores as those of the La Sal mine in Montrose County, Colo., consisting of sulphides and partially oxidized sulphides, in a silica and barite gangue, are readily separated. Without exception, so far as I am aware, the compounds of copper with sulphur, arsenic and antimony, are fine conductors. It is impossible to say which is the best because no accurate method of measuring conductivity has yet been devised. The rapidity of action on good conductors is so great that for all practical purposes it must be called instantaneous. It is therefore impossible to see that there is any difference in behavior toward the static charge between metallic copper and the copper sulphides.

Non-conductors, because of their retarding effect and slower response, admit of much more satisfactory measurements, but measurements, made for the purpose of comparing one mineral with another are practically worthless, for reasons already given. The Blake machine is itself the best

measuring instrument, and about the only safe rule to follow is to cut and try, running over the machine a trial lot of the ore on which separation is desired.

Turning now to actual results, the accomplishments to date may be summed up as follows:

NATIVE COPPER.

On native copper considerable work has been done on ores from Chaffee, Custer and Montrose Counties, in Colorado, also on ores from Nevada and Mexico, but by far the most interesting work and that most productive of results, was done in Michigan about a year ago, when a Blake separator, was installed at the Lake Linden Mill of the Calumet-Hecla Copper Company for experimental purposes. It was hoped that more copper could be saved from the jig tailings than by the present method of regrinding and tabling wet. This hope was based on the fact that the copper was in flakes or scales as well as being finely divided—a condition against clean saving on a table, and in favor of electrostatic work.

The saving proved to be almost exactly the same as that made wet, and in view of the greater cost, the necessity of working dry, and the money invested in the present installation, the idea was abandoned.

It was found however that there were other classes of ore in that region which did not yield at all satisfactory results wet, but which gave products extraordinarily clean and easy to handle, on the Blake machine. These were the sandstone deposits. The work has constantly been followed up for a year past, and success on a large scale seems an assured fact.

COPPER CARBONATES.

The most promising results on copper carbonates have been obtained on ores with a silicious gangue. Where the carbonates occur in lime, the separation is apt to be poor. This

is due not so much to the fact that the carbonates are of un-
certain conductivity as to the unexplained phenomenon that
limestones from most mineralized districts are apt to be more
or less conductive, coming over therefore to a considerable
extent with the copper. I may perhaps be allowed to say here
parenthetically, that I have had under way for a long time
some investigations into the behavior of certain primary and
secondary vein materials, hoping that this property of con-
ductivity might throw some further light on ore deposition.

When these experiments are concluded it is my purpose
to present the results for the consideration of this Society.

COPPER SULPHIDES.

At Golconda in Northern Central Nevada, a machine was
placed more than two years ago for the purpose of separating
chalcopyrité from a heavy garnet and spinel gangue. This
ore gave the following analysis:

Au	0·01 oz.
Ag	4·50 oz.
Cu	4·10
Fe	8·80
SiO_2	46·35
Al_2O_3	22·09
Zn	2·80
S	4·94
CaO	8·01
Total	97.09

This ore was crushed to ten mesh, dried, and delivered
direct to the Blake Separator, without sizing, removal of dust
or preliminary treatment. This is a procedure that cannot be
recommended, yet in this individual instance the separation
was fully as good as could be obtained after careful sizing.
Unlike most ores, a very pretty separation was obtained on
the dust as well as on the coarser ore. Necessarily, the mill
was a very dusty place, and while the separation could be

made on the dust, it seems essential from the standpoint of the health and comfort of the workmen that dust collecting apparatus be installed. The concentrates made from this material by the Blake machine had the following analysis:

Au .... 0·04 oz.
Ag .... 10·65 oz.
Cu .... 14·32
Fe .... 22·90
SiO$_2$........................... . ... 16·48
Al$_2$O$_3$ .... 7·24 .
S.. 18·30
CaO....................................... 3·65

Total.................... 82·89

and the tailings showed a metal content as follows:

Au .... Trace
Ag.. 1·3 oz.
Cu .... 0·17

These results are selected at random from a great many made. The saving of values has ranged from 60 per cent. to 86 per cent., depending almost entirely on the grade of concentrates made—the higher the ratio of concentration and the cleaner the concentrates, the lower the saving. This of course is the general rule with any concentration process, and is to be expected.

In Eldorado and Amador Counties in California, there is a somewhat similar occurrence of ore, except that the copper is in the form of bornite and the gold value is much higher. Wet concentration has also been abandoned here due to the close specific gravity of gangue and mineral, and here again the electrostatic method yields exceedingly good results. This material is a compact, reddish garnet which is yet granular, and in crushing liberates the mineral particles fairly clean at from 16 to 20 mesh. Here again it is not strictly necessary for separation purposes to remove the dust, yet results are

decidedly better when removed. Several analyses of this material as mined have been made of which the following may be taken as average:

Au .... 0·04 to 0·30 oz.
Ag .... 2·47 to 6·80 oz.

Cu............................... 2·70 to 10·24
Fe .... 6·20 to 10·11
CaO .... 5·14 to 7·22
Ins ....59·80 to 77·20
Zn ....Trace to 2·70
S................................ 1·90 to 7·30
Al₂O₃ .... 1·20 to 3·40

More or less clean white quartz occurs scattered through this garnet, but follows the garnet into the tailings. On one lot of this ore which carried 4·40 per cent. copper, the Blake machine made a concentrate carrying

Cu ....39·10
Fe ....14·72
SiO₂ ....13·00

and a tailing product carrying Cu 0·21 per cent.

After allowing the dust loss of 8·23 per cent. by weight, the saving of copper was 77·22 per cent. and the gold and silver savings were about in the same proportion. I regret that I have not permision to give full details of this and other tests, but the owners of some properties object to publication of their results in full detail. From these two illustrations just given, as well as from extensive work done on ores from other similar deposits, I consider it safe to say that the chances for successfully handling any copper sulphide occurring in a heavy gangue, whether that gangue consists of spinel, garnet or barite, are very good.

It was on the strength of this showing that the Cananea Consolidated Copper Co., took over the rights for Sonora, expecting eventually to better their work on certain of their heavier ores, and to conserve their limited water supply.

There is plainly a field for this electric separation in the arid regions where water for milling purposes is wanting, even though the results are no better than, or even not as good as can be obtained wet. It may be stated as a general rule (to which there are plenty of exceptions) that any sulphide of iron, copper or lead, may be separated from quartz, lime, garnet, barite, porphyritic rocks, schist, etc., and it is to the arid regions that this statement possesses its greatest importance.

In some operating zinc mills the copper obtained as a by-product is by no means a negligible quantity. The most striking illustration from the standpoint of amount produced is perhaps in Butte, where about 20 tons daily is being produced on Blake machines of an iron-copper conductive product assaying fifteen to twenty dollars in gold, silver and lead, and about 5 per cent. copper.

The by-product showing the highest copper assay is made at the Moro Mill in Hinsdale County, Colorado, the copper assay running 11 per cent. to 16 per cent. with less than 8 per cent. zinc. This copper occurs as chalcopyrite, bornite and chalcocite. Almost all the zinc ores in the San Juan region are associated with copper as well as lead, and both at the Silver Ledge and the Sunnyside Mills, the copper thus recovered by the Blake machines helps materially in paying the costs of separation. It is true that the zinc is the more valuable product and the chief incentive for this work, but the value of this copper-lead-iron by-product must not be underestimated.

There are two rather unusual separations to which I wish to call your attention briefly. The first is the separation of a small quantity of enargite (an arsenical copper) from pyrite which is to be used for acid making. Both these minerals are in most cases highly conductive, and one would not be led to expect much of a separation. In practice however, it has been found that the enargite is thrown out of the pyrite, leaving the latter below the arsenic limit. About 75 per cent.

of the pyrite is thus recovered, the remainder going with the enargite. For this latter product carrying some 2 per cent. copper no suitable market has as yet been found.

This separation is undoubtedly due to the differing shapes of the particles. The pyrite particles are cubical or granular, while the enargite particles are flat and scaly. The reason has been clearly stated by Mr. Arthur Howe Carpenter, and is as follows:

"The Blake process utilizes two principal forces—gravity and repulsion due to the static charge. Gravity is a function of the mass, while the static charge is a function of the surface, hence a flat particle should be thrown farther horizontally than a granular one, and it is."

The second application mentioned above is to flue dust from a copper smelter. The furnace charge consisted of copper and iron sulphides and oxides, with the usual silica, lime and other charge constituents, but very low in gold and silver values. It was found that a most desirable concentrate was made by the machines, leaving a tailing product possible to discard altogether. This would relieve the furnace of about 70 per cent. of the flue dust ordinarily returned, at a cost not at all burdensome, since practically no preliminary preparation of the material is necessary.

It is of course unnecessary to say that there are troubles and problems connected with this work. If you were asked to state the greatest source of trouble, probably nine out of ten would name the static charge, yet you would be wrong, for this is to-day not a serious problem at all, and the static generator has become almost as reliable as a dynamo. This is due principally to the use of built up mica plates instead of glass, and to the recognition of the fact that the static charge is dissipated and lost, not through the air, no matter how heavily laden with moisture, but through condensation of this moisture on the insulating surfaces. This condensation is readily prevented by the simple expedient of keeping these surfaces slightly warmer than the surrounding air.

There have been three serious difficulties to meet and

overcome in the working out of this process. The first is the proper insulation. Ordinary insulation breaks down quickly under the pressure of the voltages used, both by direct rupture, and by surface deterioration, the latter being the more important. Air is the most reliable insulator, and is used in the machine in the form of gaps and spaces wherever possible. It has the advantage of requiring no attention and of being self-repairing if broken by a spark or discharge. In the way of materials there are but two which can be utilized at the vital points of insulation, and these are vulcanite or hard rubber, and micanite, consisting of thin mica sheets laid up in shellac and compacted by heat and hydraulic pressure. The portions of the machine subject to lesser electrical strains are made of dry wood, impregnated with asphaltum or similar filler. Metal has to be avoided so far as possible except for the actual separating members.

The second difficulty has been the proper feeding of the ore. Theoretically the feed should consist of a regular and continuous sheet of ore, having a thickness approximately the diameter of the average particle. A perfect feed will insure a nearly perfect separation on most materials. The situation is complicated by the fact that the conditions imposed by the electric field restrict the use of metal, and by the further fact that the feeding device must ordinarily be kept out of contact with the separating pole with an air gap interposed, while at the same time the ore must not be dropped from any considerable distance against the pole on account of the mechanical rebound of the particles. It will not be possible to describe the numberless devices tried, but almost everything has had its trial, and but two or three methods have given satisfactory results. No one of them is satisfactory for all ores, the device adapted depending on the nature and size of the material to be fed. Shaking or tapping feeds are not adapted to unsized products, because by their action they size the material, the fines going to the bottom, the coarse riding on top. Roller feeds do not work well on material coarser than 12

mesh, while material finer than 40 mesh requires a positive feed. A perfect feed would be uniform and steady in motion, free from wearing parts, and would deliver a sheet of ore of any desired mesh from 6 to 60 and of any desired thickness. Its adjustments should be quickly made, all in plain sight, easily understood by the average workman, and made by the hands alone. If tools are necessary—even a wrench or screwdriver—proper adjustments are sure to be neglected, which, if possible with the hands alone, would be made.

This is a point that could advantageously be taken up by manufacturers of much of the concentrating machinery now being put out. Adjustments are often obscure, poorly located, and require tools which the workman does not constantly carry with him.

The third problem is that of the dust. The machines themselves are not great dust makers, and to a certain extent their dust is controlled by the static field, but each elevator, conveyor or other appliance contributes its share and the sum total is the dust problem. It seems impossible, even by the free use of fans, blowers, collectors, etc., to entirely eliminate the dust, but it has been our experience that where the machines have been working on a middling product from tables of the Wilfley type, the dust gives practically no trouble at all. This simply means that the dust problem has been displaced by the slime problem. In either wet or dry crushing a certain amount of material is crushed so fine that it cannot successfully be handled by any mechanical appliance. Particles that will float in air are manifestly beyond the reach of mechanical appliances, no matter whether the particles be suspended in air or water. That being the case, and having data extending over some four years of practice in drying of crushed ore and concentrate, I am prepared in many cases to advocate wet crushing of ores, followed by classification and subsequent drying and separation of everything but the finest slime. This dust will then be lost in the water instead of in the air. Drying is a necessity in any event, for ores must be "bone

dry" to separate at all, and the difference in cost between drying an ore containing 4 per cent. or 5 per cent. moisture, and a classified product containing 10 per cent. moisture, is so small as to be almost negligible, and is far more than met by the increased capacity and labor efficiency in the separation department. It is our experience that with the equivalent of good Ohio coal, costing $6.00 at the fire-box, 20 mesh material containing 10 per cent. moisture can be dried for from 7 cents to 9 cents per ton, depending on labor cost and the specific gravity of the material.

The questions of how fine material should be crushed and how much sizing is necessary cannot be definitely answered. Commercial work has been done in Wisconsin on 6 mesh jig middlings, consisting of marcasite and blende. On crude molybdenite ores from Maine, 10 mesh was found the best. In neither of these two cases was any sizing done, but I am inclined to believe sizing would have improved the Wisconsin results, although probably making no great difference in the molybdenite work. As a general rule, the machines do the best work on suitable material at 16 to 40 mesh. Sizing is usually more important on meshes coarser than 24 than on the finer grades. Very fine material alone gives low capacity. Almost its own weight of coarser material can be put through the machine simultaneously without interfering seriously with the separation if properly fed.

There are a great many interesting features about this work that cannot be taken up in this paper, such as the various types of machines used, the peculiar construction of many of the parts, and the electrical reasons therefor, the different forms of electrical energy used and how produced and regulated, and the application of the process to materials other than ores.

I have considered it better and of more general interest to bring here a small separator, together with samples of products which can be separated before you. It has been my own experience that a metallurgical process must be seen to

be understood and appreciated, and further, that more infor-
mation of real value is to be obtained from the discussion of
a paper than from its reading. Furthermore, anyone so closely
associated with a process or apparatus as I have been with
this, is apt to forget that his auditors are not as familiar with
the details as he is himself, and therefore overlook or pass by
as unimportant some points that may be essential to a full
and complete understanding. With your permission, there-
fore, we will now take up the subject from the standpoint of
the machine in operation, with the discussion open to every-
one.

I will answer all questions that I can, but in fairness I
ought to make two statements:

First, I am not an electrical engineer and can probably
give but lame answers to electrical questions, and, second, I
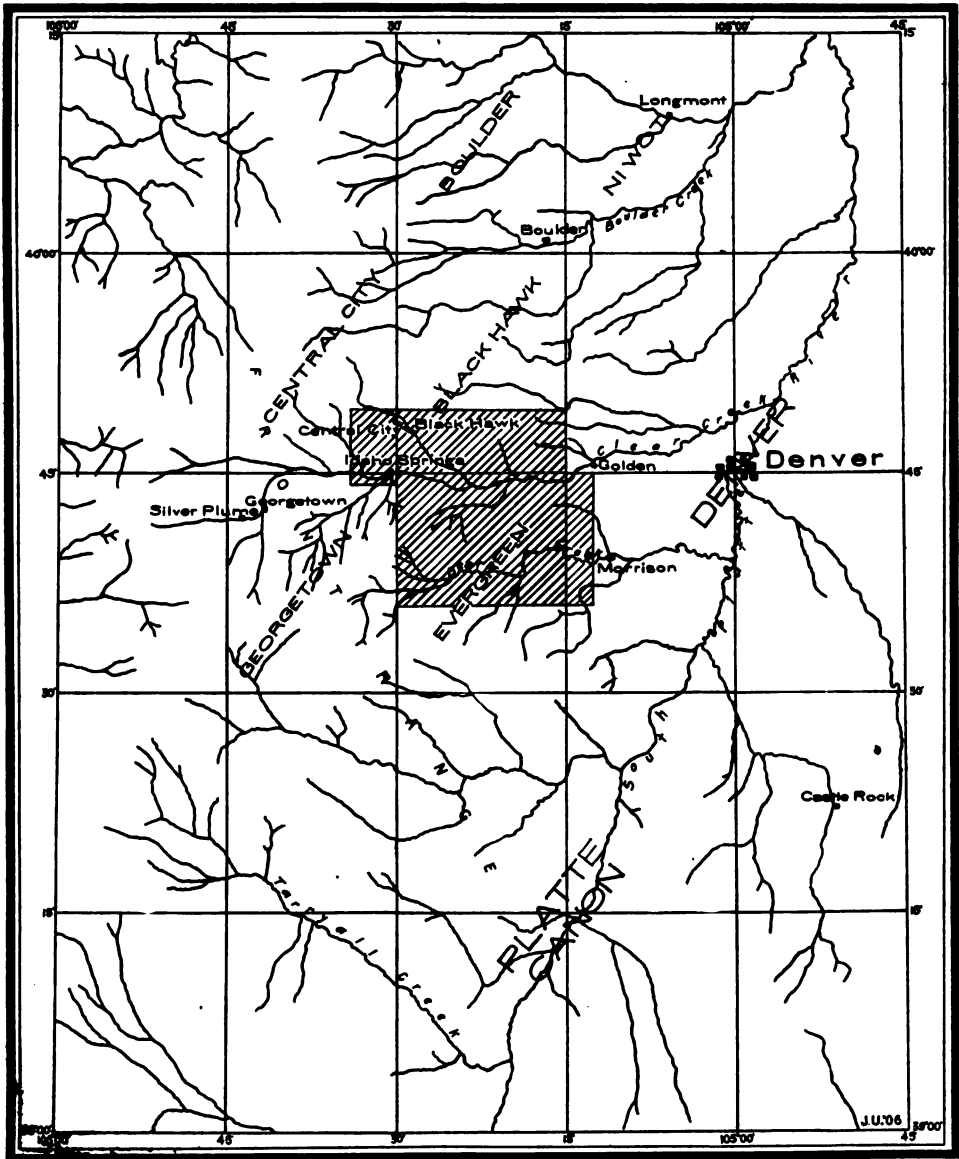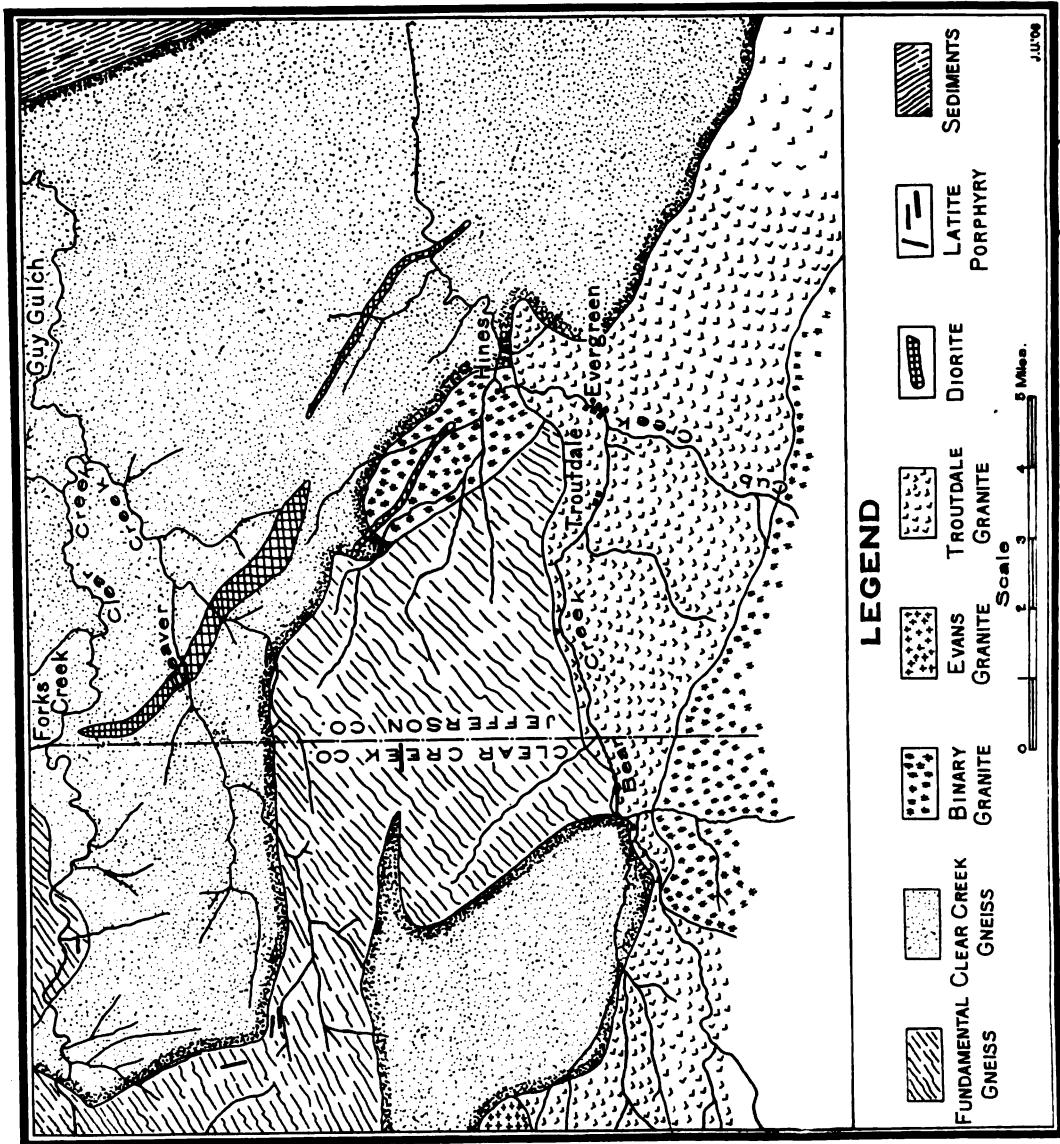do not know what electricity is.

Fig. 1

Fig. 2.

LEGEND

SEDIMENTS

LATITE PORPHYRY

DIORITE

TROUTDALE GRANITE

EVANS GRANITE

BINARY GRANITE

CLEAR CREEK GNEISS

FUNDAMENTAL GNEISS

Scale

0   1   2   3   4   5 Miles.

Fig. 3.

Fig. 4.

North Clear Creek

Central City

QUARTZ HILL

Russell Gulch

GILPIN CO.
CLEAR CREEK CO.

Fall River

SEATON MT.

Virginia Cañon

Idaho Springs

Clear Creek

J.U.'06
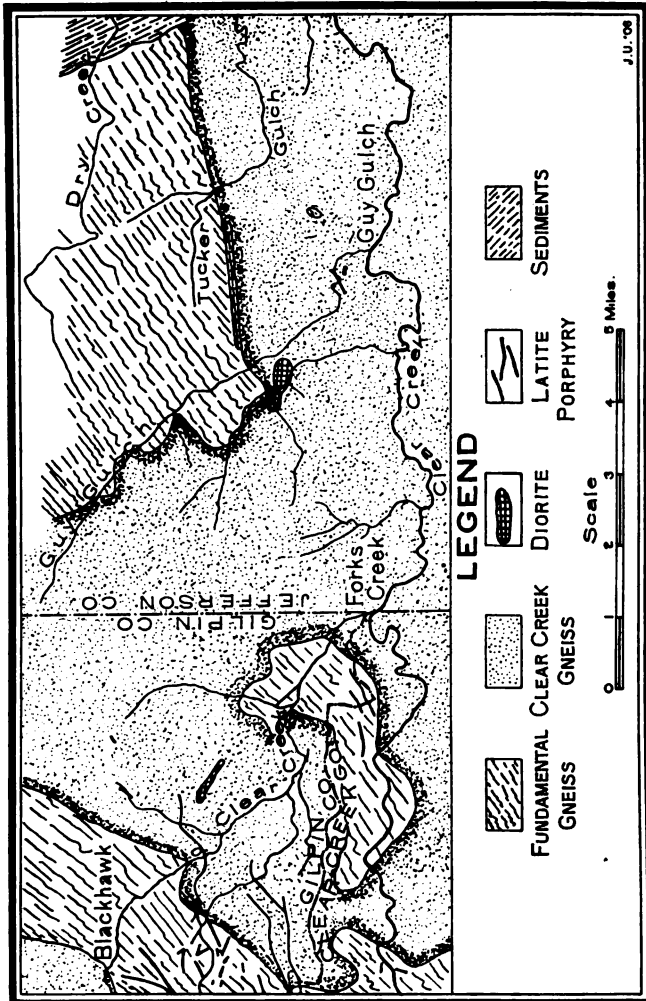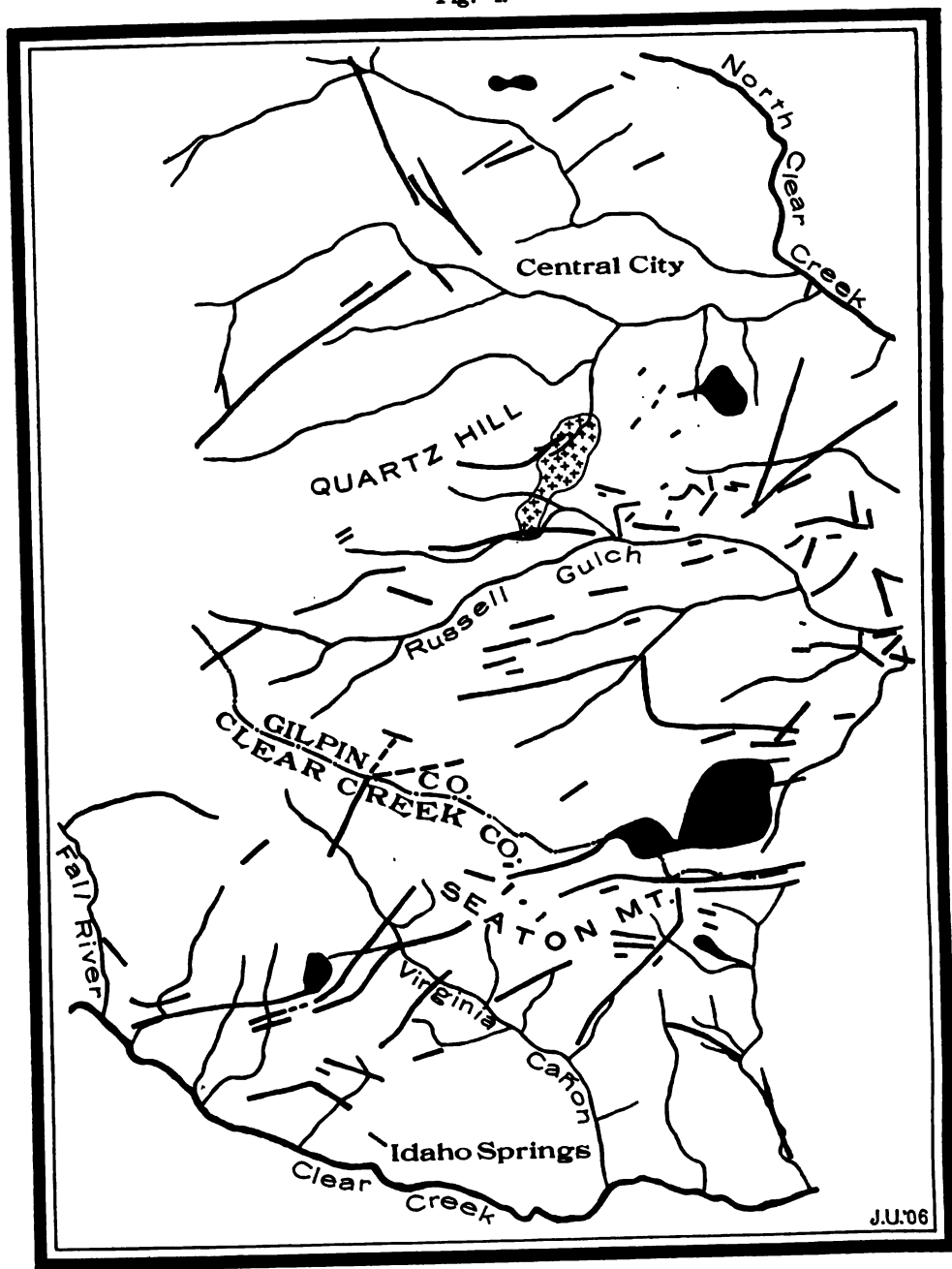
GNEISS

CENTRAL CITY
GRANITE

LATITE
PORPHYRY

SCALE
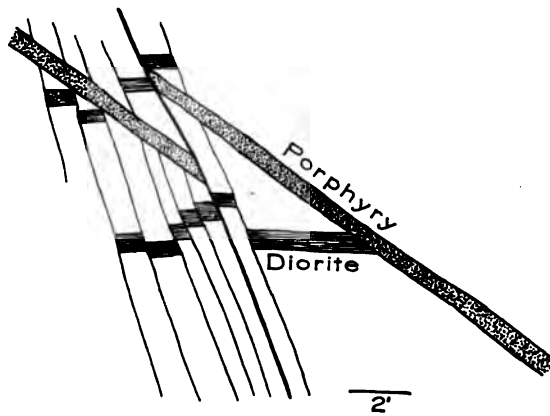
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0   1   2 Miles

Fig. 5.

Porphyry

Diorite

2'

AREAL GEOLOGY OF LOWER CLEAR CREEK.

BY JAMES UNDERHILL

Read at the Meeting of the Society, April 7, 1906.

INTRODUCTION.

The area under consideration shown on the key map Fig 1, embraces the northern portion of what I have called the Evergreen Quadrangle, (Fig. 2), about 180 square miles, and the southern portion of the Blackhawk Quadrangle (Fig. 3), about 60 square miles. I have also covered in great detail, as far as the dikes are concerned, the region embraced in the so-called Idaho Springs and Central City Special maps (Fig. 4), an area of about 18 square miles.

For the Black Hawk I had the excellent topographic map of the United States Geological Survey on a scale of 1-45,000 or about 1 1-2 inches to the mile. For the special area I had the Idaho Springs and Central City Specials on a scale 1-12,000 or about 5 inches to the mile.

There being no topographical map of the Evergreen Quadrangle, one had to be made before geological mapping could be done, and this has been in part constructed as follows: Where the Georgetown and Black Hawk Quadrangles overlapped on the Evergreen Quadrangle, the topography of these maps has been used. On the south and east the topography of the Platte Canon and Denver sheets respectively has been

used. Surrounded as the Evergreen Quadrangle has thus been, it has been admirably checked on all sides. Several triangulation points of the U. S. Geological Survey on the Evergreen Quadrangle, with some other triangulation points on other Quadrangles that may be seen from it, have been platted. Other points have been more or less accurately determined with the pocket sextant. Then the township lines were laid on with checks by the topographic sheets above mentioned, and finally the sections and their topographic "guesses," for they are little better, were sketched in. These topographic features have been found reasonably accurate at the intersections with the township lines, but as a rule absolutely unreliable in other places. These features, which consist usually only of the creeks, have been checked as well as may be by the pocket sextant, and also by pacing and courses taken with the Brunton Compass. The notes of the pipe-line for the City of Golden waterworks kindly furnished by Mr. Carstarphen, the City Engineer, have been of great service as a check on the northern portion of the Evergreen Quadrangle.

TOPOGRAPHY.

The topography of the area in question may be divided into two divisions, the western and eastern sections. The topography of the western section is seen to be rugged, and, while not so much as the Georgetown and Central City Quadrangles to the west, its topography is more accentuated than the topography of the eastern section. The topography of the eastern portion may be defined as subdued topography, except where it is deeply cut by Clear Creek and Bear Creek.

Unlike the Georgetown and Central City Quadrangles, there is little evidence of glaciation. On the flanks of Squaw Mountain, especially at the head of North Beaver Creek, the amphitheatre like topography gives one an impression of a

glacial cirque, and the idea receives confirmation by an accumulation of detrital material just at the beginning of the V-shaped valley of North Beaver Creek. To a less extent South Beaver Creek exhibits the same phenomena and both creeks continue their courses as V valleys. The subdued topography of the eastern portion strongly reminds one of a peneplain, and there is good reason to consider that all the eastern portion was once base levelled, and since has been deeply dissected on the north and south by Clear Creek and Bear Creek, and their respective tributaries.

This peneplain or base level was elevated in common with the remainder of the Rocky Mountains in Tertiary times and Clear Creek and Bear Creek Canons with the canons of their tributaries have been entirely eroded since that period. In many cases the side streams have not yet cut deep canons, and we have at their sources the gentle well rounded slopes of Tertiary time in sharp contrast with the deep canons of the lower portions of the same streams. This is true also of the upper waters of Clear Creek and Bear Creek outside of the area here considered. In fact a very close approximation to Tertiary topography could probably be reached in a topographic map of the eastern portion of the area under consideration by simply neglecting the deep canons and putting in their place mature valleys with gentle slopes to represent the stream system of that time.

GEOLOGY.

In nearly all the accounts of this region and the associated areas of the front range, especially those written some years ago, the rocks have been assumed to be of sedimentary origin, and so described. The banding has nearly always been regarded as the stratification, and thought to represent the dip of the original sedimentary rocks, from which the present complex was derived.

The geology of the Lower Clear Creek Area is a complex of presumably metamorphosed igneous rocks, usually designated as pre-Cambrian, but only certainly pre-Juratrias, and then only for the main masses. That certain portions are of late eruptive origin can be proved, and possibly all of the country will some day be shown, as in the case of the Green Mountain area in Massachusetts, to be as late as Devonian.

That this supposedly pre-Cambrian complex was originally igneous and since metamorphosed by great dynamic forces, regional metamorphism, and thus as a consequence has taken on a well defined schistosity, is borne out by its comparative homogenity over large areas in the field, and by the thin sections studied. It is difficult to believe that alternating strata and formation of sedimentary rocks could have been metamorphosed into such areas of homogeneous material as at present exist, and the appearance of the lithologic units as mapped up to the present strongly give the idea of an arrangement by igneous forces. While the complex of the Lower Clear Creek Area may be divided into a number of lithologic units with more or less certainty, in all probably about eleven or more, only ten can be recognized with certainty in the area in question. These formations beginning with the oldest, the Fundamental Gneiss, have been arranged as follows:

> Fundamental Gneiss
> Clear Creek Gneiss.
> Binary Granite,
> Central City Granite, (Evans Granite),
> Troutdale Granite,
> Diorite,
> Pegmatite and Aplite,
> Latite Porphyry,
> Pleistocene and recent.

The Fundamental Gneiss and Clear Creek Gneiss, while tolerably distinct as areas, grade into each other at their boundaries, and the situation can be best described by a quotation from Monograph XXVIII, U. S. Geological Survey, on the Marquette Region, by W. S. Bayley. On page 151 he says,

"The foliated rocks occupy areas whose boundaries are not so well defined as is the case with the Marquette fragmentals. * * * Nevertheless, an attempt has been made to map these areas. In their interiors, the different phases of schists, granites and syenites are well characterized, but on their peripheries there is always a complex mixture of the various schists with one another or with the granite rocks. The respective colors on the map are believed to cover the areas within which the corresponding rocks predominate largely over other rocks. The boundary lines separating the different areas are drawn at about the places the different varieties are found in approximately equal quantities." And again from the Ashville Folio, Folio 116, p. 4. "* * * In only a few cases do the boundaries shown on the map represent a single contact between two large masses; they usually indicate a narrow zone beyond which one rock or the other predominates. Sometimes an area shown as gneiss may contain many small beds of granite, or it may be substantially all gneiss. On the other hand, many of the areas represented as granite include also small bodies of gneiss. These may be continuous with one another or may be disconnected inclusions. Except where these bodies were the prevalent rock over considerable areas they were disregarded in the mapping." It might be added for the whole Clear Creek district one outcrop may give examples of any or almost all of the lithologic units in question.

It is well known that pre-Cambrian areas have a close resemblance the world over. The lower Clear Creek area closely resembles other areas in the United States that have been most closely studied, as for example, the Lake Superior, Southern Appalachian, Southern Colorado and Grand Encampment regions.

Fundamental Gneiss.—Wherever in the Clear Creek section the rocks have been studied, this biotite gneiss is found to be with the Clear Creek Gneiss, the prevailing lithologic unit recognized and mapped. The Fundamental Gneiss as the prevailing rock is everywhere much plicated and crumpled and shows signs of having been subjected to intense dynamic metamorphism. It is far more metamorphosed than any other rock of the country thus far studied, and is older than any other petrographic unit. Except where it is in contact with the Evans granite its schistosity or banding has a prevailing dip to the north at every possible angle. Its strike is east and west. Where in contact with the Evans granite, it dips away from the granite with a strike parallel to the contact. The intense metamorphism, resulting from pressure, it takes on the most fantastic and varied plications and crumplings possible, and every variety of folding to be found in any mountain region can as a rule be found here within a restricted area. The folding is accompanied by faulting, but wherever possible to be determined the resulting movements are for short distances only.

The history of the rock would seem to be that of an igneous rock exposed to great compression in the zone of flowage, and the recrystallization of its materials along bands or zones. A subsequent folding followed, and afterwards faulting and jointing. The development of garnet and fibrolite, described in the specimens, is not universal, and the fibrolite gneiss does not seem to be developed according to any

particular law. The garnets, on the contrary, have been observed in greatest development on the borders of the granitoid gneiss in the Evergreen Quadrangle on the east, south and west of the mass, though not on the north. This leads to the suggestion that the intrusion of Clear Creek Gneiss has developed the garnets in the Fundamental Gneiss as contact minerals.

Fundamental Gneiss.—The rock in the hand specimen is seen to be a fine grained mixture of quartz, biotite, feldspar, fibrolite and garnet in a general banded arrangement.

Microscopic. Under the microscope the rock is seen to consist of a banded arrangement of biotite, quartz, frequently showing pegmatitic intergrowths with the feldspar, and undulatory extinction, and both microcline and plagioclase feldspar. Apatite is abundant. In many specimens, especially those from the Evergreen Quadrangle, there is an abundant development of fibrolite. This occurs as highly polarizing fibrous masses in parallel bands with the other materials of the section, and even penetrating the biotite, following the cleavage. Usually associated with the fibrolite is developed characteristic iron garnet often in great abundance. In addition we frequently find magnetite, hematite, apparently formed from the magnetite, rubellane mica and occasionally hornblende, closely interwoven with the biotite. The specimens have every indication of an eruptive rock, greatly compressed and recrystallized, hence the banded structure. It nowhere shows any signs of having been a sedimentary rock, and if it ever was, it has been entirely remelted to the complete destruction of all former texture.

Clear Creek Gneiss.—This formation occupies a large portion of the area under consideration, and while at some distance away from the Fundamental Gneiss it differs essentially from that unit, there is rarely any sharp contact between

the two formations.   The two nearest approaches to a sharp
contact are to be seen in the eastern portion of the area
studied.   Here the contact transition zone probably occupies
a space of about five hundred feet.   On North Beaver Creek
there is a space of about half a mile before either rock is pre-
vailingly the unit mapped.

While the Clear Creek Gneiss shows the effects of hav-
ing its banding or gneissic texture developed by great com-
pressive forces, it has nowhere, except perhaps in the transi-
tion zone noted on North Beaver Creek, been so much plicated
as the Fundamental Gneiss, neither has it suffered intrusion
of pegmatite and diorite in so marked a degree as the Funda-
mental Gneiss.   Like the latter, its dip is prevailingly to the
north.   It is predominantly the home of the latite porphyry
dikes.

Macroscopic.   The hand specimen consists of an evenly
banded arrangement of quartz feldspar and mica, but without
the plications usual in the Fundamental Gneiss.

Microscopic.   Under the microscope the rock is seen to
consist of quartz, orthoclase, plagioclase, microcline, biotite,
muscovite, magnetite, apatite, epidote titanite, calcite, zircon,
fibrolite and hematite.   Sericite is occasionally developed.

The quartz is generally in excess and shows in every case
undulatory extinction.   The feldspars appear as in the Fun-
damental Gneiss series, but in most cases show marked un-
dulatory extinction.   The muscovite and biotite occur as inde-
pendent aggregates and also frequently intergrown.   The rock
in question is distinguished from the Fundamental Gneiss
series by its greater resemblance to a normal granite and by
the smaller quantity of biotite.

For the areas covered by the Idaho Springs and Central
City Special maps no attempt has been made to separate the
Fundamental Gneiss from the Clear Creek Gneiss on the map.
There are two reasons for this.

In the first place the two units are very intricately combined in one vast complex which has been subjected to repeated fissuring and faulting. The faulting is not important so far as the distance of movement is concerned, but when one considers the area affected it assumes considerable importance. Then too, this special area has been almost universally injected with pegmatite, and intruded by recent eruptive dikes. In addition to all this, we have the metamorphism of the rock by the subsequent or usually subsequent vein filling solutions. All this causes a complex exceedingly difficult to unravel, and still more difficult to represent on a small scale map such as must be used in a report of this kind. It may be stated, however, that detailed notes have been taken for this area, and material for a reasonably exact map is at hand.

To any one interested in the study of these Gneisses, the Newhouse Tunnel offers an admirable section of some three miles in length. The direction of the tunnel in round numbers is about N. 15° W. At a few hundred feet south of the Gem vein the tunnel leaves the Fundamental Gneiss and cuts the Clear Creek Gneiss. This contact is still further to the south on the surface, in other words the contact dips to the north at an angle of something like 45°. While some porphyry dikes have been cut in the Fundamental Gneiss, a far greater number are to the north in the Clear Creek Gneiss. The Fundamental Gneiss has been greatly plicated and more disturbed, it is true, than the Clear Creek Gneiss to the north, but it is in this latter that we can see most clearly though not on such a large scale, the effects of dynamic action. This is fortunate, for in the narrow section cut by the Newhouse Tunnel every possible example of faulting and folding is in evidence in the course of a few thousand feet. These evidences of movement are rendered clear by the frequent alternating bands of black diorite and white gneiss,

and strongly reminds one of the diagrams illustrating works on geology. In most cases the faults are not composed of one simple fault plane, but are a series of distributive faults or fault zone. Frequently the fault planes are so numerous and close together that we have simply a zone of sheeting. One of the very interesting occurrences is that shown on the west side of the tunnel just beyond the Sun and Moon vein. Fig. 5.

Binary Granite.—This granite occupies a small area just north of Hines, and a much larger area south of the Troutdale granite. No traverse yet made has reached the southern boundary of this mass. As this granite is easily weathered it is almost impossible to find good outcrops, and it can only be traced by its residuals and by an occasional cutting. In this way we find the topography of the area occupied by the Binary Granite subdued, and relatively rolling with well rounded slopes, especially in comparison with the Troutdale Granite area.

Petrography.—In the hand specimen this rock consists essentially of an intimate mixture of quartz and red feldspar. Under the microscope the quartz is seen to have an undulatory extinction. The feldspar is as a rule microline with some acid plagioclase and occasional orthoclase. The accessory minerals are apatite and biotite occurring in small amount.

Central City Granite. This rock so far as known, occurs only on each side and a little to the south of the head of Spring Gulch just south of the Central City railroad station. It is very clearly a mass of granite intruded into the surrounding gneiss with which it forms a sharp contact to the north on the road to Central City. With the exception of a small hill on its most southerly extension this granite is easily disintegrated and forms characteristic well rounded outcrops.

Petrography. In the hand specimen this granite proves to be a hypidiomorphic arrangement of quartz, feldspar, and biotite. There is a suggestion of a banded arrangement, which is more evident in the larger masses.

Under the microscope the quartz shows the results of dynamic action by its undulatory extinction. The feldspar is found to be nearly all an acid plagioclase with some few grains of orthoclase. There is an abundance of bioxite, also a little hornblende. Apatite, titanite, magnetite and zircon occur in the usual form of these minerals.

The rock is classed with the alkali granites or granitites.

Evans Granite.—This granite occupies a small area on the western portion of the Evergreen Quadrangle. It strongly resembles the Central City Granite, and is very likely the same petrographic unit. No petrographic determination was made of this rock.

Troutdale Granite.—As can be seen from the map, this petrographic unit occupies a territory on either side of Bear Creek, from a point just east of the town of Evergreen to the western boundary of the Evergreen Quadrangle. It shows every evidence of being a true granite eruptive, and in many cases along Bear Creek, at best just west of Troutdale, are seen apophyses of granite in the Fundamental Gneiss. This has been called the Troutdale Granite on account of its picturesque development at the resort of that name. It is probably, judging from the comparison of hand specimens, the same granite that occurs at Georgetown, Colo., though so far as known there is no direct connection. While not found cutting the Binary Granite there is good reason for thinking it is younger, especially as it seems to divide the Binary Granite into two masses. The topography of the area occupied by the Troutdale Granite is rough and accentuated forming in many cases deep canons with steep walls and picturesque towers

of rock. This area is in marked contrast with the subdued areas to the north and south.

Petrography, Macroscopic. In the hand specimen this granite appears as a hypidiomorphic mixture of quartz, red or pink feldspar and biotite.

Microscopic. Under the microscope we find that the quartz has a slight undulatory extinction at times, the feldspar is chiefly an acid plagioclase with some orthoclase and microcline. The microcline frequently shows carlsbad twinning in addition to the characteristic cross hatching. Sometimes the feldspar is seen in pegmatitic intergrowths with the quartz. The feldspar is frequently found altered to sericite. In addition to these minerals we have muscovite, apatite, titanite, magnetite and zircon.

This is also an alkali granite. It differs from the Central City granite in the less amount of femic or ferro magnesian minerals, and in the presence of muscovite, wanting in the Central City Granite.

Diorite.—The next lithologic unit of importance is represented by the numerous diorites of which one large mass east of Creswell is particularly interesting. This mass extending nearly to Clear Creek Canon turns towards the southeast to a point north of Bear Creek. Except in several local instances this rock is a massive diorite and shows little or no evidence of dynamic metamorphism, though there is good reason to believe from the study of the specimens collected and examined that chemical metamorphism has been active.

Besides this large mass of diorite there are everywhere present in the Fundamental Gneiss and to some extent in the Clear Creek Gneiss small dikes of diorite, for the most part parallel to the schistosity or banding, and while almost without exception greatly sheared and squeezed by dynamic forces are but rarely plicated. These, while not so extensively

metamorphosed as the enclosing rock, are still greatly affected
by the same or similar forces. The greater metamorphism of
the smaller dikes seems to imply either a greater age for these
intrusions as a rule, than for the larger mass of diorite, or
else a less ability to withstand the forces of metamorphism
than was possessed by the larger mass of diorite. No at-
tempt has been made to map these smaller dikes, only the
most important receiving attention.

Petrography, Macroscopic. The rock consists of an even
grained holocrystalline mixture of hornblende and plagioclase
feldspar. In many specimens and in the larger masses of rock
as a rule, there is no striking evidence of banded texture,
but some specimens have a banded appearance which at times
becomes schistose. In some of the dikes there is a marked
coarse grained texture strongly suggestive of a typical gabbro,
and here the component minerals occur in large crystals with
abundant development of garnet.

Microscopic. Under the microscope the rock is seen to
consist essentially of a holocrystalline mixture of green horn-
blende and plagioclase with some biotite, augite, quartz, apa-
tite, magnetite, titanite, epidote, garnet, and secondary cal-
cite and actinolite. The whole as a rule taking on a banded
arrangement.

The hornblende is of the common green variety, showing
basal sections predominating, with the usual two prismatic
cleavages. It is as a rule distinctly pleochroic, but in some
specimens shows only the faintest pleochroism. In the strong-
ly pleochroic varieties we have $a=$ yellowish green, $b=$ dark
green, $c=$yellowish green. Absorption showing $c=b>a$

The feldspars are all striated, showing polysynthetic
twinning according to both the albite and pericline laws. As
no examples of carlsbad twinning were observed, it was
found impossible to determine the plagioclases according to

the method of Michel-Levy, but as the extinction angles average about 15 degrees and one as high as 40 degrees was observed, the composition is probably about oligoclase-andesine. Nearly all the feldspars show undulatory extinction, showing that they have been exposed to great pressure, but at the same time not so much as would be expected from the appearance of many of the hand specimens. This would seem to imply that considerable recrystallization had taken place.

In the very coarse grained varieties an iron garnet is very abundant. Quartz, plagioclase, and hornblende have been noticed enclosed in the garnet. The other minerals mentioned above present the usual aspects.

Pegmatite and Aplite.—Every rock noticed in this district has been intruded by pegmatite and aplite, usually acid in nature, but more rarely, as in the case of the diorite pegmatite described for Guy Gulch, and also another occurrence near the Gem power plant on Clear Creek, basic in composition. These pegmatites, intruded in every imaginable way into older rocks, have the most fantastic and varied cross section. They frequently carry great quantities of magnetite, which afterwards supplies in great part the black sands and pebbles in the placers. Locally graphic granite is often developed, probably at its best near Roscoe on Clear Creek. The pegmatite rarely shows evidence of having been subjected to great dynamic forces. It has a common development near bodies of sheared diorite.

It has been found impossible to map satisfactorily the pegmatite injections and for this area no attempt has been made in this direction. Some petrographic descriptions of these rocks are, however, added.

Petrography. Pegmatite. (Graphic Granite). Roscoe, by C. & S. tracks.

Macroscopic. The rock consists of bands or pencils of quartz and feldspar showing on cross section the common graphic texture.

Microscopic. Under the microscope the rock is seen to consist of alternating bands of quartz and microcline, the former showing undulatory extinction, giving in one place the appearance of twinning. The microcline has the usual cleavage texture, but with one cleavage developed parallel to the quartz, the other at right angles. This would seem to indicate a continued pressure in one or perhaps two definite directions.

Aplite.—N. W. corner of Evergreen Quadrangle.

Macroscopic. The rock is a pegmatitic rock consisting of quartz, feldspar and some pyrite. The specimen is traversed by a small vein of oxidized material.

Microscopic. The rock under the microscope is seen to consist of a medium fine-grained holocrystalline mixture of quartz, microcline and some orthoclase with small amounts of pyrite, magnetite and muscovite. The quartz shows undulatory extinction and the whole rock shows signs of compression, and effect of dynamic forces as is also suggested by the microcline twining. The specimen is seen to be traversed by a small vein consisting of oxid ized material, and here the feld spars have been impregnated and somewhat altered.

Diorite Pegmatite.—Guy Gulch, by C. & S. tracks.

Macroscopic. The hand specimen is a rather pegmatitic looking mass composed entirely of hornblende, feldspar in most cases striated, and black mica.

Microscopic. Under the microscope the rock is seen to consist of a coarse grained aggregate of green hornblende, biotite, plagioclase, orthoclase; the former predominating, together with a little quartz, apatite, epidote, calcite, titanite and magnetite, all exhibiting the ordinary characteristics of

these minerals. The quartz and feldspar show frequent pegmatitic or granophyric intergrowths. The plagioclase appears to have a low extinction angle and to be near the albite end of the series, probably oligoclase.

Latite Porphyry.—In certain portions of the district in question, notably the areas covered by the special maps and also in the western portion of the Black Hawk Quadrangle, the country is extensively traversed by porphyry dikes. While these dikes run in every direction the majority of them have a course N. E. by S. W. or the same as the prevailing vein system. It is interesting to note that while there are no veins of importance outside of the area traversed by the dikes, the area of the dikes at the same time extends beyond the area traversed by the important veins. These dikes vary in size from a few inches to hundreds of feet in width, and from a few feet to many miles in length. As a rule, however, they die out in a few hundred feet. In the field they all have the same general characteristics, and vary in color from brown and red to gray. They are reasonably straight, but dip at all angles, though like the veins in the majority of cases the dip is rather steep.

At various points all over the area studied, and especially near veins, the dikes have been brecciated and in some cases the fragments in every way resemble water worn pebbles. These occurrences have been explained as true conglomerates of as early as Algonkian time, notwithstanding the fact that there is good reason to consider the porphyry composing the pebbles as Tertiary. The phenomena have also been explained as resulting from the fall of water worn pebbles into open crevices. The true explanation of the phenomena probably is the extensive brecciation and complete shattering of the dike. Subsequent kneading movement, possibly aided by solution, reduced the angularity of the fragments, and in some instances

gave them the appearance of water worn pebbles. The best places to study these phenomena are Banta Hill and the so-called "Queen's Chair."

The dikes as a rule are closely "frozen" to the enclosing walls, and though carefully sought for, in but one case was any sign of contact metamorphism observed. That there has been shrinking in cooling is evident by the lines of fracture when the rock is broken.

It is difficult to obtain fresh specimens on the surface and when near veins they are also greatly decomposed as a rule. The best specimens are to be procured in cross cut tunnels outside of the vein area and in newly made roads. The dikes usually have a fine grained appearance when fresh, and the porphyritic appearance and the display of phenocrysts as a rule are the result of weathering or underground decomposition. In the hand specimen the rock varies through all the stages from what might be called a felsite, which is all ground mass with no phenocrysts, to a granite porphyry which has little ground mass, and which might be said to be all phenocrysts. This latter phase is often taken for a granite and not regarded as a porphyry at all. Those rocks locally known as porphyry have been described by every name from andesite to phonolite in different reports. They do vary from the composition of andesite to that of trachyte, but in the area specially studied they are of intermediate composition and may be called Latite Porphyry.

It is very possible that they are the necks of surface flows which furnished the andesite pebbles for the beds of the Denver Formation.

Microscopic. Under the microscope the porphyries vary from a rock composed of a holocrystalline ground mass of quartz and feldspar with no phenocrysts, to a rock with little ground mass and resembling true granite. As a rule the

ground mass is a fine grained granitic mosaic and might be called a micro-granite. In many specimens, especially those that are highly iron stained and rich in magnetite and hematite, the feldspars are lath shaped and the quartz is allotriomorphic to the feldspar and arranged in the spaces left over after the consolidation of the feldspar. Here in many cases the feldspars are iron stained all through; in other cases the stain has not penetrated to the center. The lath shaped feldspars have here usually taken on a rough flow structure. In the case of vein breccias and the more andesitic varieties the ground mass may resemble a felted paste. The highest powers of the miscroscope fail to resolve this paste into its component minerals.

In the ground mass of whatever character, as a rule are larger crystals or phenocrysts of one or more generation. The larger crystals are generally plagioclase with some orthoclase. These nearly always show evidences of zonal development and are of intratelluric formation. The feldspars frequently show evidence of rebuilding. The crystals of a second growth are the same as those of the first growth but as a rule rather more acid, with quartz, biotite and hornblende. In no case in this area has the quartz been seen in large crystals, though one dike on Mill Creek studied outside of the area shows good quartz phenocrysts, with perfect crystalline outlines. All these larger crystals have suffered more or less from corrosion by the magma before the consolidation of the ground mass. This is especially true of the biotite and hornblende crystals of which in many cases only the skeletons remain for identification. In one case portions of the ground mass were noticed entirely enclosed in a phenocryst of feldspar. Among the earliest consolidations are apatite and titanite frequently in relatively large and well formed crystals. In the ground mass and in addition to the quartz and feldspar previously noticed,

are found pyrite, magnetite, biotite, hornblende, augite, hematite, zircon, and in one case fluorite. Sericite, epidote, zoisite, calcite are present as alteration products, with frequent secondary quartz.

Pleistocene and Recent.—At several places noted previously under glaciation, and also at various points in Clear Creek Canon, gravel deposits have accumulated. On the northwest portion of the Evergreen Quadrangle by the Silver Age Mill on the north side of Clear Creek, and also nearly opposite Sawmill Gulch, on the north side of Clear Creek, the remains of an old stream terrace can be seen about one hundred feet above the present stream bed. These correspond to the old terraces which are more prominently developed on the Georgetown Quadrangle around Idaho Springs. Some of these are more or less completely consolidated into conglomerates.

Sediments.—No attempt has been made to map the sediments which have been described in the Denver Monograph.

Piedra Larga; An anderite mass in tuff.

Outcrop of Rosario Vein, Guadalupe y Calon.

The Patio Process in Parral.

Typical Mountain Stream in the Sierras.

Los Angeles.

NOTES ON MINING CONDITIONS IN AND A SECTION ACROSS THE SIERRA MADRE MOUNTAINS IN MEXICO.

BY A. W. WARWICK

Read at the Meeting of the Society, April 7, 1906.

The object of this paper is to describe the mineral deposits and to give some notes on the methods of mining and the conditions which prevail in the Sierra Madre Mountains in the southwest corner of Chihuahua and eastern border of the State of Sinaloa.

During the last five years the author has spent considerable time in this part of Mexico and has examined a number of mineral deposits in the Sierras from Parral, at the east base of the mountains, to Choix at the west or Pacific base of the Sierra Madres. The country covered by these explorations is an exceedingly interesting one, not merely because of its present state of development, but also because of its potentialities.

To one who makes a first trip across these mountains, keeping to the main travelled trails, the country is a somewhat disappointing one. It appears to be an uncultivated, uninhabited country with very sparsely scattered mineral resources, although even a first visit would force one to recognize that these widely separated deposits are, or have been, exceedingly rich. These impressions gradually get removed and the reasons why these first impressions are obtained become apparent.

We have to remember that Mexico as a country is making a single step from the mediaeval times into the twentieth century. This progress, of course, has taken place more rapidly in the centers of population. In the Sierras there are no wagon roads, and by far the greater number of the inhabitants have never even seen a wheeled vehicle. All transportation is done on pack-animals. The time spent on the trails between points not more than fifty miles apart usually amounts to several days. It is not practicable to pack feed for the animals for such a length of time as this, and still carry any considerable amount of merchandise. The muleteers, therefore, select trails where there is abundance of feed and water for the animals and wood for the camp fires. The animals are turned out to graze and it would be exceedingly inconvenient, nor merely for the traveller, but for the farmers, to have stock grazing near cultivated land, hence the farmers naturally keep away from the main travelled trails, and the muleteers naturally avoid cultivated land. Another reason for the avoidance of the main trails was the fact that until the last fifteen years the inhabitants of the Sierras were turbulent, and robbers abounded. The peaceful traveller did not care, in most cases, to go too near settlements on account of many of these communities forming refuges for outlaws, and the peaceful inhabitants did not care to get too near the main trail so as to invite the predatory traveller to rob and plunder. Hence, we can readily see that a traveller who simply keeps to the main trails might form a very incorrect opinion as to the country he may be passing through.

The author's first visit to this part of Mexico was to Guadalupe y Calvo, leaving Ojito, which was then the terminus of the Parral y Durango railroad. Guadalupe y Calvo is situated about one hundred and eighty miles southwest from Parral. On the whole trip nothing even resembling a mining district was passed through and one could not help reflecting that in this part of Mexico mines were few and far between. Other trips, however, by different trails, showed that the mineral districts were not so widely scattered as my first trip led me to believe, although most of the great mineral deposits are found west of the Sierra divide. The country really con-

tains a large number of very notable mineral deposits, chief
of which are found in the mineral districts of San Julian,
Cueva Colorada, Guadalupe y Calvo, Galena, Dolores, Santa
Cruz de Santa Ana, Los Angeles, Cebollitas, San Jose des
Cruces, La Cumbro de San Manuel, Trigo, La Dura, Morelas,
Calabacillas, San Jose de Gracia, and further to the north
the famous districts of Batopilas and the Lluvia de Oro, be-
sides these there is a great number of districts which have
been abandoned and lost sight of. This country was at one
time very thoroughly exploited by the Jesuits, previous to
their expulsion from the Spanish dominions. The old Jesuit
towns are characterized by a strikingly neat and picturesque
architecture and by old haciendas for the treatment of the
ores. These old haciendas were not confined to the amalgama-
tion of gold and silver ores, but numerous small smelting
establishments were found scattered all over the Sierras.
Some of these old Jesuit mines I have entered, and one cannot
fail to be struck by the intelligence with which the mining
work was directed. It certainly compares favorably with
the old Cornish mining of one hundred and twenty years ago.
Later than the Jesuits and from a period of from about 1820
to 1855, mining operations on a large scale were conducted
by English and Scotch companies. The extraordinary energy
and skill of these companies is mutely demonstrated by the
old mining settlements, haciendas and huge dumps left by
them. One company alone is known to have produced up-
wards of $100,000,000. This particular company operated
three enormous mines, one at Refugio, another at Guadalupe
y Calvo, and concluded their operations in this part of the
country in the famous district of Guana Cevi. From 1855 to
1885 the Sierras were infested by refugees from the numerous
insurrections that made Mexico a by-word among nations.
In 1885 a few enterprising Americans entered this country,
and, after some difficulty, managed to re-open a few of the
mines. Even five years ago, however, the operations by Amer-
icans were few and far between. Today there are many
American and English companies operating in this part of
Mexico. The chief operations are found at San Julian, Cueva
Colorada, Los Angeles, La Cumbre de San Manuel, Calabacil-

las and La Dura. The advent of these companies has done much to improve transportation and to make travel more comfortable and expeditious; whereas a few years ago supplies such as Americans need could only be purchased at a few places, now an engineer is rarely more than a day's ride from some place where he can buy, in reasonable quantities, such staple articles as are purchased in the United States.

STRUCTURE OF THE SIERRA MADRE.

The Sierra Madres rise to an elevation of about ten thousand feet, rising out of an eastern plain, about five thousand feet above sea level, and out of a western plain about one thousand five hundred feet above sea level. The highest part of the Sierras forms a deeply dissected table land. Numberless canyons, running generally in a north and south direction, are to be found, with walls two thousand or more feet high. A magnificent canyon, or barranca, is that of Huarachic, which from the rim rock to the bed of the river which runs through the canyon is about five thousand three hundred feet deep. On the rim of this remarkable canyon grow pines, oaks and an innumerable variety of ferns, whereas in the bed of the barranca grow bananas, oranges, guavas and other tropical fruits. The Sierras on the east side are approached by easy gradients. When the continental divide is reached the plateau is crossed in a westerly direction for a distance of about sixty miles. The western slopes of the Sierras form a remarkable escarpment, which for many miles north and south offers an insuperable barrier to a trans-Sierran railway. At one point where the author crossed the range, aneroid readings showed a drop of from 8500 to 2200 feet on the talus fan plains which lay immediately at the feet of the Sierras. The Sierra Madre range in Mexico and the country to the east and west of it, bear a strong resemblance to the Sierra Madre range in California. On the east side of the range is to be found country very arid in character and covered with a vegetation of mesquite, yucca, sotol, greasewood and cacti. On the west, the coast plains very strongly resemble those of California, even to the existence of a coast range;

however, the Pacific coast plains of Mexico are far better watered and would be far more productive than those of California if the same energy were devoted to their cultivation.

The Sierras are characterized by an almost entire absence of sedimentary rocks, except that on the lower eastern foot hills are to be found shales. On the western side of the Sierras and at their base are to be found beds of limestone of indeterminate age, and very much crumpled schistose rocks. The predominating rock of the Sierras is rhyolite, although where erosion has denuded the rhyolite, the basal andesite is exposed. In the high plateau flows of basalt were encountered, as well as enormous masses of fragmental rocks such as rhyolite tuff, rhyolite and andesite breccias. No granites were encountered on the east side. On the west side of the mountains granites of a monzonite type are common as well as diorites and dolerites. The granites are frequently cut by basalt dikes.

The great western escarpment of the Sierras is due to the great fault plane which was probably formed in post tertiary times. The Sierras probably reached their greatest height during miocene times, although it is possible that the andesites and trachytes, which form the heart of the Sierras, were of late cretaceous age.

The Sierras are regarded mainly as compression folds and to have been forced up during tertiary times. The Sierras, however, are partly built up of enormous masses of volcanic ejectamenta.

There are good reasons to believe that the Sierra Madres of Mexico have been subjected to oscillation similar to those of the Sierra Nevada in California. It is very probable that in late cretaceous times the Sierras formed a low lying peninsula, and were probably formed at that time mainly of andesite and trachyte rocks. The uplift commenced very late in cretaceous times during the period known as the Cordilieran Revolution, which extended into the eocene period.

Two great faulting systems have been recognized in the Sierras, one running generally northeast and southwest and referred to generally as the Cordilleran faulting system, and the line of East and West faulting, known as the Antillean.

It is generally believed that where these faulting planes cross, the great volcanoes of the southern portion of Mexico have been formed. In addition to these main lines of faulting, there is a minor East and West faulting system, which is more or less complementary to the Cordilleran. These minor faulting planes appeared to be rather a favorite habitat of the mineral deposits, not merely in the Sierras, but in the plains of Texas. In Brewster County, Texas, the mercury deposits are associated with these East and West faulting planes.

A few North and South faults of later date occur, but these are not often mineralized. A North and South fissure, however, is strongly mineralized in the Calabacillas District.

A Section Across the Sierras.

On a number of trips across the Sierras, sketch sections were made by means of the aneroid barometer and by estimating the distance ridden in each day's travel. The section made is based merely upon a reconnaissance map, which, however, has been rectified by taking bearings on two high mountains, the distance between which has been accurately, determined by triangulation. It is needless to say that no accurate maps are extant of this portion of the Sierras.

The section is made between Parral, on the eastern foothills, to Choix, on the Pacific coast plains, which are at that point practically a talus of the high Sierras.

The Parral District, as it is more commonly known, really is composed of three independent districts, which are situated close to each other. These districts are Santa Barbara, discovered in 1547; Parral, discovered in 1600; and Minas Nuevas, discovered in 1645. The formation at this point is a highly contorted schist, into which has been intruded porphyry dikes and in places capped by porphyry. These porphyrys are exceedingly difficult of determination, but are probably very much altered dacites. The veins in the district are usually associated with these dikes. The veins have generally a more or less north and south strike. The ores found in these veins are sulphides, containing silver.

The ores contain practically no gold, except in the Palmilla mine, which has produced so enormously in the last five or six years. A number of mines in the Parral district are very deep, some having a depth of over 1100 feet.

West from Parral the range rises rapidly, from 6500 feet at Parral, to about 9000 feet. This steep grade is climbed by a railroad built for the purpose of supplying Parral and the neighboring mines with timber, and known as the Parral and Durango Railroad. The rocks seen from the car windows appeared to be mainly rhyolite, lava flows, tuffs and breccias, which are in places almost snow white. The terminus of the railroad is now at a place known as Sandia.

Leaving Sandia, and riding over rhyolite lava flows, the trail follows a plateau for several miles and then descends steeply to the valley of the Navarro. The eastern slope of this valley is covered by dacite tuffs and breccias. The valley has an altitude of about 5500 feet above sea level. Leaving the bed of the Navarro Arroyo, a slight but very rugged divide is crossed before entering the valley of the Riparro, which has about the same elevation as the Navarro. The Riparro valley is quite fertile and a large number of corn fields are to be found for a number of miles along this valley. One very fine corn field of about 1500 acres in area is to be found on a bench about 750 feet higher than the river of Riparro, or San Juan as it is known a little further down. Riding through corn fields, over the bench alluded to, one comes to the foot of the main Sierras which here rise very abruptly. It is a steady half day's climb on mule back along the hog back to the Rosario Spring, which has an elevation of about 9400 feet. The rocks covered are the characteristic tuffs and breccias of this part of the Sierras.

Leaving the Rosario Spring, one rides through several well timbered arroyo beds to the mesa de las Legunas. On this mesa are to be found a number of very fine lakes which are covered, especially in the fall, with enormous flocks of ducks and geese. This is an exceedingly beautiful country, well timbered, and abounding in game of all kinds. The mesa or plateau of Lagunas is covered by large sheets of basalt. Leaving the Lagunas proper, one rides along a

plateau valley, covered with pine timber. These pines are often four and five feet in diameter, and frequently rise to a height of a hundred feet or more. The great canyon or gorge of the Rio Verde is entered suddenly and almost without warning. This gorge is a magnificent chasm about 2100 feet deep, running more or less in a north and south direction. Through this canyon runs a fine stream of water, which is about to be utilized for the purpose of furnishing electric power to the mines of the Parral district. The flanks of the gorge are covered with rhyolite breccias and tuffs. After reaching the western rim of the Rio Verde gorge, one crosses a mesa covered with an immense number of chalcedony flakes and nodules, which have weathered out from the tuffs in which they were formed. Riding from the Rio Verde west for about fifteen miles, a sudden descent is made into the valley of Cienega Prieta. This valley for many years bore a very evil reputation as being the refuge of a bandit family by the name of Palma. In the center of the valley is a fortified ranch house, which was occupied by the Palmas for many years. It is now, however, in other and better hands. Leaving the valley of Cienega Prieta, the river Turuachic is approached by a somewhat sharp ascent followed by a precipitous descent into the valley of Turuachic. Through this valley flows a broad and rather swift river, both banks of which are well cultivated by numerous Indian settlements, which are scattered up and down the river for many miles. Both flanks of the Turuachic valley are covered with tuffs and breccias. The elevation of the plateau west of the Turuachic is from 9500 to 9700 feet, and following a ridge along this plateau, the mining district of Guadalupe y Calvo is approached.

Guadalupe y Calvo is situated in a gulch or, rather, a pocket. The hills on each side are quite high, and the rocks surrounding the town are rather prettily colored tuffs and breccias. The prevailing colors are a dove tint and a rather rich brown. Here the rocks are mainly dacites and andesites. The town of Guadalupe y Calvo was built as the result of the discovery of the famous Rosario mine, the outcrop of which forms a prominent feature in the landscape.

Going northwest from Guadalupe y Calvo, one covers a beautiful country, characterized by a dense growth of pines and oaks. Innumerable little streams are crossed, along the banks of which are to be found the ruins of old haciendas and numbers of arrastras or tahonas, as they are here generally known. The formations covered are the usual andesite and rhyolite tuffs and breccias. Near the bed of the Arroyo Hondo are to be found beds of volcanic ash, so regularly stratified as to strongly suggest that they had been laid down in water. Beyond the Arroyo Hondo the splendid mesa of Milpillas is crossed. This mesa is well cultivated by Indians who own the soil. In spite of its altitude of 8000 feet, good crops are generally obtained. The Cerro Milpillas, one of the striking features of the landscape, and which shares with Cerro Mohinura the distinction of being one of the highest peaks in the Sierras, rises at an altitude of about 10,000 feet. The trail goes almost over the top of this mountian, which is covered by a heavy growth of timber.

Leaving Milpillas, the trail rapidly descends, following the Arroyo Los Tarros. In this arroyo, which is a tributary of the Sinaloa River, one encounters a granitoid rock for the first time. It is rather close grained and of a monzanite type. Cutting the granite are a number of dikes. In all prabability this dike rock is a dolerite, although it is so aphanitic that it is impossible to determine this with any degree of assurance without the microscope. These dikes are fairly wide, being in places from 50 to 100 feet. The Los Tarros arroyo joins a number of other streams just below the trail, forming a river of considerable size, which flows very rapidly through canyons with very precipitous walls. This river is capable of furnishing considerable horse power.

In the Los Tarros Arroyo is to be found a small stamp mill erected by a Colorado company for the purpose of treating the ore of a mine, the workings of which can be seen from the trail.

Leaving the Los Tarros Arroyo, the trail goes westerly towards the district of Los Angeles. The trail passes over tuffs and breccias for most of the distance. The district of Los Angeles is about a mile south of the main trail across the

Sierras. This district occurs in a basin-like depression, on the floor of which is to be found an exposed area of andesite. The andesite covers about four square miles. The Los Angeles district has in it a mine well developed to a depth of about 400 feet. The development work consists of several thousand feet of drifts, upraises, etc. The ore in this district contains free milling gold. Just east of this district and about three miles distant is the district known as Santa Cruz de Santa Ana. This district was operated on a large scale about fifty years ago by an English company.

Continuing westward from Los Angeles the trail rapidly approaches the descent into the valley of San Juan Nepomuceno. The hill falls very abruptly 2500 feet into the valley. The view from the top of this hill is a magnificent one. The front range to the west of the valley is heavily covered with timber and out of it rises a number of high peaks which may be regarded as the sentinels of the main range. The valley of San Juan Nepomuceno is the first large valley to be passed through after leaving Parral. In this valley are many well-built settlements of the Jesuit padres.

Immediately at the foot of the descent into the valley is to be found the quaint and picturesque settlement of San Jose de Cruces. This settlement was the point from which operations were directed for the numerous old workings to be found scattered all down the mountain side. The Jesuits worked a mine known as the Socabon, from which they obtained large quantities of silver-lead. In San Jose there is to be seen several adobe furnaces with inclined hearths. Passing down the San Jose hill, one crosses several hundred feet of granitic rock, which is so decomposed, however, that it either might be a diorite or a granite. Just below San Jose, to the north of the trail, are to be seen a couple of adobe smelting stacks, the blowers for which had evidently been operated by water power.

In an arroyo approaching the main valley one crosses several hundred feet of a dark-colored, fine-grained, basaltic rock, with a very fine texture. Just south of the trail several good veins are being opened up by an English company which has a prospecting concession or zone over four hundred square

kilometres. The formation in which these veins are being worked is diorite. The ore is silver-lead.

In the arroyo which the trail follows is to be found evidences of considerable placer mining.

Debouching onto the main valley, we soon enter the pretty village of San Juan Nepomuceno. This village is solidly built and the houses are covered with a Venetian red clay tile. Just outside this village are to be found a number of smelting furnaces and in the arroyo one can see placer mining operations going on on a small scale. The valley of San Juan is about fifteen or sixteen miles in length and about two and one-half miles wide. The valley has very little soil. There is practically no agriculture in the valley, owing to the very angular breccia being so close to the surface. The soil is rarely more than a foot or two in thickness.

On the west side of the valley, the front range is approached gently and an altitude of about eight thousand feet is reached. This front range is covered with a heavy growth of timber and numerous streams are crossed by the trail. One passes through numerous corn fields and small ranches. The only formation crossed by the trail are breccias and tuffs. About seven hours' riding west of San Juan brings us to the edge of the great escarpment of the Sierra Madre. This slope is severely precipitous and the trail frequently goes down inclines of from thirty-five to forty degrees. About three thousand feet below the crest, one enters the mining town of Calabacillas, which is supported by the San Geronimo mine. The main vein worked in the San Geronimo is a very large one, which occurs between andesite and rhyolite, although the fissure does not run always with the line of contact, sometimes being entirely in the rhyolite and sometimes entirely in the andesite. This vein is a replacement, sometimes of the rhyolite and sometimes of the andesite. In this settlement some seven hundred people live. The district of Calabacillas is quite a recent one, and was discovered about eight or nine years ago by an Indian who showed it to the present owners, receiving, so I understand, a Winchester carbine for his pay.

Looking over the contour of the country, it would seem as if this slope of Calabacillas led continuously downward until the low lying foothills of the Sierras are reached; however, the trail followed turned off sharply to the northwest to the district of Sarupa. The trail to Sarupa follows a very rugged country, which is well watered and timbered. Only the monotonous breccias and tuffs were passed over. Just off from the main trail there is, I understand, a gold district which is now being exploited by some Americans. I obtained no information, however, in regard to the formations or character and size of the veins. Passing still northwest, I crossed the Riito, one of the main tributaries of the Fuerte River. In the valley of the Riito are to be found cultivated patches of land, producing considerable sugar cane. The trail passes a panocha mill. This panocha mill made the familiar brown sugar, so greatly used by Mexicans. Just below the panocha mill I passed by considerable mine workings. Inasmuch as it was quite dark when I passed, I did not observe the character of the formation.

Leaving the valley of the Riito, another divide was crossed between the river and the foot hills. This divide is about a thousand feet above the river and after reaching the top a steep descent was made down to a well cultivated district in which grew a subtropical vegetation. Passing through this district, which is known as Pichilo, one found evidences of placer operations on a very large scale. There were also evidences of large haciendas, deserted for perhaps two or three centuries. Just before leaving this district, we crossed diorite rocks in which occurred a number of veins of silver and copper. These had been worked evidently before the Mexican revolution and had been abandoned for many years. I saw the ruins of three vasos or small vertical furnaces, the air for which was supplied by hand blowers. Passing still in a general northwest direction, we entered an entirely different formation. The rocks, however, had been so metamorphosed that it was impossible to say exactly what they were. They appeared to be, however, mainly highly contorted schists, cut by numerous dikes of a felsitic rock.

Following the arroyo, we soon came out on to the main coast plains, which resemble very closely those of California. These plains are well cultivated and are dotted over with numerous small settlements. Close to the foothills is the little town of Choix, which is situated close to the Fuerte River. These coast plains are exceedingly fertile. They raise immense crops of corn, and I have been told that where irrigation is practiced three crops of corn can be raised in most years. The fertility of these plains is largely attributable to the fact that they receive, every rainy season, fresh supplies of potash salts, brought down from the very thoroughly decomposed andesite and rhyolite tuffs, which cover the crests and slopes of the Sierras. These tuffs also contain not a little apatite. The torrential rains of the rainy season bring down an immense quantity of disintegrated tuff. This fact has, no doubt, much to do with the wonderful fertility of the coast plains of Sinaloa.

In Choix, itself, there is nothing of interest to a miner. It is merely a trading point for the mining districts to the east of and in the foot hills of the Sierras.

This will conclude the description of the section across the Sierras, although the journey was continued northwest from Choix through the copper districts of Nacimiento and El Gallo. All through this district are to be found numerous small veins of copper containing gold and silver. At Nacimiento I was very much interested in seeing the operations conducted by an old Austrian, who had lived there many years. This gentleman would take his workmen and mine out a considerable tonnage of ore, which would be very carefully sorted and then packed down to a smelter at the foot of the hill. Here he would put his men at work smelting the ore. The smelters were operated by hand blowers, the men working in relays. By this crude process he smelted out black copper, containing considerable gold and silver values. I am told that this Austrian had realized a comfortable competence out of his operations and I saw stacked up ready for shipment a large number of plaques of black copper containing considerable gold and silver values. This was a remarkable example of what can be accomplished by native methods, when directed by experienced and skillful men.

General Mining Conditions in the Sierras.

The mining conditions in the Sierra Madre are not so adverse as might at first be thought when one considers the isolation of the mining districts and the apparent difficulty of transportation. When the drawbacks are balanced by the advantages, there can be little question in the mind of any candid engineer that on the whole the conditions are very favorable.

The main drawback to mining is the necessity of having all machinery made sectional for transportation on mule-back. This renders the erection of machinery very slow and tedious, as well as expensive. The first cost of the machinery is, of course, greatly added to by the necessity of sectionalizing. The cost of erection is also multiplied by the necessity of practically having to build the boilers on the ground. It is impossible in most cases to take in anythng but the boiler sheets, rolled to radius; moreover, the sheets usually receive pretty hard usage on the trail and they have generally to be reshaped to a considerable extent before they can be riveted up.

A great deal of annoyance incident to the erection of a mill in the Sierras can be obviated by care in shipment. It is too often the case that the material is delivered to the mine very irregularly. The arrieros or muleteers, if allowed, pick out the most desirable packages for freighting. Thus, it might be possible to receive the bags of rivets long before the boiler sheets, and so on, thereby rendering it impossible to commence the work of erection until practically all the material has been delivered on the ground. In the case of a large mill to be erected at a long distance from the railroad, the material may come straggling in for a period of six months, and it can readily be seen that serious delays might be caused by not taking care that the material most wanted is delivered in such a way that it can be put into construction practically as soon as it arrives on the ground.

Unless sectional machinery is well erected it is apt to be very inefficient, hence to erect a mill in Mexico mechanics of a high order of skill are necessary.

Care in shipment of material and in handling the material at the rail head, as well as in the selection of good mechanics to do the work, will do much to remove the drawbacks in erecting mining machinery in the Sierras.

The freight rates are not so very excessive when one considers that the machinery is carried on mule-back over rough and exceedingly steep trails. The usual price paid for freighting is fifty cents per carga for each jornada or days-travel for a mule. A mule loaded with three hundred pounds will usually travel about twelve miles a day, hence the freight rate for a mine situated about one hundred and twenty miles from the railroad will be $5.00 per carga of three hundred pounds; however, should the mules have to make a round trip unloaded in one direction, the time taken on that trip will be added to this charge. As the mules usually travel twice as far unloaded as they do loaded, we would have to add to this price $2.50. The cost of freight would be, therefore, about $42.00, Mexican, a ton, or about $1.00 a hundredweight, United States standards.

The taxes paid by the mines are based partly on the acreage and partly on the production. Until recently, the tax levied per pertenencia, 100 metres by 100 metres, was $10.00 per annum. This has been reduced within the past year to $6.00, Mexican. Should, however, the property comprise a large number of pertenencias, the tax is levied at the rate of $6.00 per pertenencia up to twenty-five, and $3.00 per pertenencia thereafter. This reduction of the tax was very welcome, and the taxes are not now a serious burden on the mine. The other tax levied is on bullion, and this amounts to about six per cent. of the gross product. It is levied in the form of State, Federal and Stamp taxes. The Government, however, has recently removed the stamp duty on refined bullion presented to it in shape for coinage and of a certain fineness. The most important reductions made, however, have been on appliances used in mining. The duties on all chemicals used in cyaniding or silver lixiviation have been removed. All scientific apparatus goes into the republic free of duty. This allows the miner to buy his supplies in the

cheapest markets of the world, and greatly reduces the cost of equipping and operating the mines.

Much has been said and written on the efficiency of Mexican mine labor. As a rule, however, the extreme is gone to on either side. The Mexican labor is neither as cheap as some would lead us to believe, nor as expensive and inefficient as others claim. The Mexican miner is, as a rule, a faithful workman whe needs only ordinary closeness of supervision in order to get a good day's work out of him. Under tactful management, his proneness to lay off from work is greatly reduced. I can personally vouch for the fact that at a certain mine a large percentage of the men regularly report for duty, and numbers work for months at a time without losing a day.

The Mexican barratero or hammersman is quite expert. They are usually paid by the foot of hole they drill. They work either single or double handed. At a number of mines where double handed drilling is practiced and where they are paid at the rate of twenty-five cents Mexican, per foot of hole drilled, a pair of barrateros will earn from $5.50 to $6.50 a day. In other words, these men will in moderately hard rock, drill from twenty-two to twenty-six feet of hole a day. This will, on the whole, I think, compare favorably with the average work done by the miners in this country. The "hole contract" system, however, does not tend to improve the skill of the miner in pointing his holes. He is more concerned in drilling holes than in so pointing them as to break ground. As a rule, therefore, the Mexican barratero is not skillful in pointing his holes. The holes are usually so placed that when they are fired, each hole goes off independently of the others. They do not understand the art of firing in volleys so as to break the most ground. This is due, very largely, to the generally poor quality of dynamite supplied to the Mexican mines. Some of this dynamite is very old and has frequently been badly stored. It is not an uncommon experience to obtain an occasional box of powder so deficient in strength that it cannot be detonated even by means of a primer of good powder. The fuse, too, is frequently spoiled by improper storage or careless packing in the rainy season.

For these reasons the Mexican miner prefers to point his holes so that each will break a certain amount of rock regardless as to whether the other holes go off or not.

Under proper direction the Mexican miner rapidly becomes a good timberman. One can frequently see as neat timbering in a Mexican mine as can be found anywhere, although it is of course true that in most cases the Mexican mines are practically untimbered, the ground being supported by pillars of ore left standing. As a rule, it requires a very much more skillful man to direct the miners of the Sierras than in the case of the Rocky Mountain miner. This is explained by the fact that the foremen, in much of the operations, must not only direct the men, but, actually, in many cases, teach them how to do their work. Instead of second rate men being needed to direct operations in Mexico, men of the highest type are required. With thoroughly skillful miners, capable of speaking the language and understanding the Mexican character, most of the difficulties incident to operating a mine in Mexico disappear.

Most mines in the Sierra are compelled to keep a company store. The reason for this is that unless this is done, the men will usually have to leave the mine to lay in the supplies of corn, beans, etc., that they need, or the men would be at the mercy of extortionate storekeepers, who have been known to combine among themselves for the purpose of charging exceedingly high prices for the staple articles consumed by the workers.

Several opportunities have been presented to the author whereby it was possible to obtain data as to the profits made by mine stores. These profits are generally regarded as reducing the cost of the labor. I found, in a certain store, that nearly ninety per cent. of the wages paid to the men was spent in the company's store. The profits on the store were sufficiently great to reduce the labor cost by fifty-three per cent. of the wages paid. Inasmuch as seventy-five per cent. of the expense of operating this particular mine went in labor, it can readily be seen that the reduction in the total cost of operating the mine was immense.

The men, as a rule, only work about eight hours a day when on contract work. Men on day's wages, however, work ten hours. Peons working underground now get in most places in the Sierras from $1.25 to $1.50 a day. Miners working underground get from $2.00 to $2.50 per day. Peons working outside are paid a dollar a day for ten hours work. All these wages are in Mexican money.

In operating a mine in Mexico the law requires certain books to be kept in Spanish and to be stamped with government tax stamps. This usually means that Mexican clerks must be engaged. These men are needed, not only for keeping books but also for handling stores, keeping time and waiting upon the customers of the store. Competent and reliable men for doing this work can be engaged for from $60.00 to $150.00 per month, according to the position they might occupy.

The cost of general mine supplies in the Sierras, delivered at the mine is about as follows:

        40 per cent. dynamite, 22c a pound.
        Caps, 62 1-2c a hundred.
        Fuse, $32.50 a case of 6000 feet.
        Candles, $5.00 a box.
        These prices are in United States currency.

Taking it all in all, therefore, it might be safely said that a mine can be operated nearly as cheaply in the Sierras as it can in most parts of the West.

The Mexican Government has, within the last few months, radically changed many of the laws relating to mining. Most of these changes promulgated to date are really supplementary to the change of the monetary system of Mexico. An important change has been the abolition of the boleta or vale system. This system tended to keep the Mexican laborer in a condition of peonage, making him dependent, practically, for all the necessaries of life on his employer. The men have now to be paid in the money of the country and with the idea, doubtless, that this will tend to make the men more self-reliant and more capable of handling their individual affairs. I understand, however, that the Mexican Government is about

to make a number of radical changes in the laws directly related to mining. Since 1892, when the present laws were passed, conditions have changed immensely in Mexico, and there are, no doubt, a number of changes that could be made which would benefit the condition of the miner and mine owner. It is to be hoped that the Government will change the present system of locating and surveying mineral ground. Under the old conditions it was impossible to obtain skilled surveyors. Today, however, there are a number of men in almost every mining district who can do good surveying, and the laws should be so modified as to compel locators of mining ground to employ competent men.

The regulations governing the location of mining claims in Mexico require the claims to be surveyed within sixty days after the denouncement. When the denouncement is filed by the local mineral agent the locator names a surveyor whom he would like to survey the claim, and this man is practically always appointed, unless there is some grave reason why he should not. The regulations require that where a graduate of the Federal School of Mines in Mexico is available he shall be appointed as surveyor. Where, however, such a graduated engineer is not available, a "practical" surveyor might be appointed. These latter surveyors, so-called, are usually men engaged in other lines of business and men who have the merest rudiments of the art. Many examples could be given of the gross mistakes made by these men. The instruments used by them are, moreover, of the crudest possible description, and, although they are specifically required to work from the true meridian, not one per cent. of the "practical" surveyors have instruments capable of determining this with precision, nor could they make such determination, even if they had such instruments. So grave are the errors in many cases that it is my practice in making examinations of mining properties to always compare the actual location on the ground with the courses and directions given in the titles. I have found every possible kind of error. To quote two specific cases which came within my notice during the last year: A certain vein had a strike of northeast and southwest, and the monuments on the ground called for the same course; the

titles, however, called for a line of pertenencias running northwest and southeast. This was clearly a case where the surveyor used an ordinary traveler's compass and forgot to reverse his east and west points. The other case is quite inexplicable: A group of pertenencias was located to cover an east and west vein, and the vein was so monumented. The title, however, called for north and south lines. Thus, the owners of this property, instead of having six pertenencias on the vein, had only one pertenencia on the vein and five worthless pertenencias covering no mineral ground whatever, so far as is known.

These are but two instances of a number that could be cited within my own practice; however, it is a matter of common knowledge to those who have resurveyed claims originally surveyed by so-called "practical" surveyors that the so-called surveying made for title purposes is generally quite worthless in most cases.

Such a state of affairs as this aims at the very basis of mining titles and steps will, no doubt, be taken by the government to remedy these conditions at the earliest possible moment. It is to be hoped that under the new laws that are to be promulgated, the method of surveying will receive some attention.

It would seem quite possible to weed out the absolutely incompetent surveyors by means of a simple examination, twice a year, for example: Examinations could be held at mineral agencies by means of papers furnished from the City of Mexico and prepared by the professors of the School of Mines, which candidates for the position of mineral surveyor could attend.

The question of erecting mineral monuments in the various districts is one that will, no doubt, receive the attention of such a progressive government as that of Mexico. Today, under the present regulations for surveying, the titles are quite insufficient to locate the claims on the ground; one has no starting point. Further, the regulations requiring the monuments to be solidly constructed and of some shape different to the monuments of adjoining claims are systematically evaded, especially by American locators. I have, time and

time again, gone on claims where no monuments existed, or where, if they ever did exist, they were simply a few rocks loosely thrown together. In such cases it is quite impossible to locate the claims which may be under examination.

Monumenting claims is simply, in most cases, a temporary expedient. As a rule, a well built monument will, of course, stand for many years, unless deliberately knocked down. On the other hand, monuments will not stand very long under some conditions without constant care and attention. I have known a case where the entire monumenting system of a group of pertenencias was entirely obliterated by a large land slide. Against such an accident as this it is impossible to guard by any system of monumenting. It would seem to me very desirable, therefore, to establish mineral monuments in every district, these monuments to be tied by bearings to prominent natural objects, thus establishing their position forever in such a manner as to allow any competent surveyor to re-establish mine monuments, should unfortunately, they be destroyed by earthquakes or other natural forces.

GUADALUPE Y CALVO DISTRICT.

The mining district of Guadalupe y Calvo is a single mine district, practically only one mine ever having been discovered. The Rosario vein has been alluded to as one of the great quartz mines of the world, and certainly the outcrop of the quartz below the town of Guadalupe presents a wonderful sight to a mining man. The property, however, has for all practical purposes been idle now for fifty years, although during a period of active production, covering about ten years, it produced upwards of thirty million dollars. It was operated during this period by an English company. The Rosario vein was alluded to by Murchison in his treatise on the silurian system "as affording a material profit near the surface to become less productive as the mine deepened and finally failed altogether, the gold having thinned out and its place been taken by argentiferous galena."

This mine was discovered in the fall of 1835 by a Tarahumara Indian, who showed it to some officers of the English

company operating the famous Refugio mine, about twenty-five miles from Guadalupe y Calvo. The extraordinary size of the vein and its richness in places caused a typical mining rush, and in a short space of time a population of about ten thousand people was camped in the gulch near the vein. The year following, the well-known family of Ochoa secured title to a large portion of the vein and leased it to an English company, who operated it for about ten years on a royalty of about twenty-five per cent. The production of the vein was enormous; so much so that, owing to its great distance from Government centers, and the necessity for having large quantities of coined money, the Government gave the company the right to erect and operate a mint. The ruins of this mint still form a picturesque part of the town of Guadalupe. The mining skill shown was of a high order; steam machinery having been introduced at considerable cost. A boiler was placed on the ground and an upraise used as a chimney. An underground steam whim was used for a number of years to raise ore from the lower levels. The method of treatment in the old days was by means of the patio process, and from notes given by Percy in his treatise on the metallurgy of silver go to show that a number of improvements on the old patio process were introduced in the hacienda. The production of this mine is given at about forty million dollars under the management of the English company, or about four million dollars per annum, which would be a notable production even today.

The Mexican laws of the 40's did not allow foreign companies to acquire title to mining property, and hence the company was obliged to lease their ground. About the time the lease expired the vein had become poor and considerable water was encountered. The owners of the ground did not realize the immense difficulties with which these properties were operated, and doubtless thought the English company was reaping enormous profits, which, however, were not as large as they should have been for a venture in such a country as this part of Mexico was in those days. Under these circumstances, the company naturally wished a reduction in the royalties, whereas the Ochoas insisted upon a higher royalty. Failing to come to terms, the English company moved its

machinery and appliances to the famous camp of Guanacevi, where they operated for a number of years, and produced a large amount of silver and gold.

The property for many years was worked by gambucinos, who robbed the mine of the pillars of medium grade ore left by the English company and fatally scavenged the mine, so that the main hope of the mine today is the discovery of new ore bodies, which, no doubt, systematic development work would disclose. Until 1892 the Mexican mining laws called for work to be done on a property every year, six men being required to work for half the year. This the Ochoas failed to do, and the property was denounced by Mexicans and Americans. It is said that these new owners realized about one hundred thousand dollars by working over the old dumps and robbing a few pillars in the mine. Some ten years ago the property was acquired by an American company who still owns it.

During the latter years of the ownership of the Ochoas, a Tennessee company acquired an interest in the property and erected a ten-stamp mill and sunk a new shaft to develop the mine. It is said that this company produced as much as one hundred and twenty thousand dollars in one year's operations; however, the company became involved in difficulties and the property was abandoned and redenounced by the Mexicans and Americans alluded to. Today the property is idle, although enormous bodies of low grade ore exist in the mine and in the ore dumps which are scattered over several acres in area.

The vein of the Rosario mine has a northwest and southeast strike with a strong dip to the west, this strike and dip being typical of a large number of veins on the Pacific slope of the Sierras. The vein occurs in a quartz andesite and is evidently a replacement of the country rock. The vein, in all probability, occurs in a crushed fissured zone formed during the numerous oscillations of the Sierras. This is suggested by the brecciated appearance of the vein in many places.

The vein is an exceedingly wide one, the quartz being in places considerably over one hundred feet in width. The great foot wall streak forms a bold cliff, lying on the west

slope of a very steep hill. This cliff contains considerable values in gold and silver although it is naturally of low grade or else it would have been mined. The old time miners evidenty worked the ore up to the limit of pay, since the cliff is ornamented by thousands of drill holes left by old time miners.

Everyone who has seen the Rosario vein seems to have a different theory to explain its formation. Examination of a number of veins to the west of Guadalupe y Calvo would indicate to me, however, that it is not especially exceptional except for its great size. A number of veins are to be found to the west of Guadalupe y Calvo, with a northwest and southeast strike and dipping to the west, corresponding to the well recognized northwest and southeast faulting system of the Sierras and running more or less parallel with the continental divide. All these northwest and southeast veins appear to have somewhat the same characteristics in their mineral filling. Most of them carry considerable values in silver and most that I have seen contain argentiferous galena. Taking these facts into consideration, there would seem to be no difficulty to account for the formation of the Rosario vein by a reference to the faulting system of the Sierras.

The Guadalupe y Calvo district is a somewhat isolated patch of quartz andesite, from which the overlying rhyolite tuffs and breccias have been eroded. The vein can be followed as long as the andesite is exposed, but where the andesite dips under the breccias the vein is masked, although the mine workings vertically below the breccia are still in the andesite showing that the veins probably continue as long as the andesite exists.

Los Angeles District.

The district of Los Angeles is distant about 35 miles in an airline southwest from Guadalupe y Calvo, although the distance by the trail is in the neighborhood of fifty miles. The time taken to ride this distance is usually a day and a half, or about fourteen hours in the saddle. The Los Angeles district has an area of about four square miles and is surrounded by a number of other promising mining districts,

such as Santa Cruz de Santa Ana, Cebolitas, San Jose de Cruces, La Cumbre and Mala Noche. These districts are all very close to each other but each has quite definite boundaries.

The district of Los Angeles forms an amphitheatre, the eastern rim of which is cut through by the Los Angeles Arroyo which drains the basin. The rim of the basin, or amphitheatre, is formed by rhyolite tuffs and andesite breccia. The floor of the amphitheatre is formed of andesite so thoroughly decomposed as in places to be difficult of identification. The feldspars are completely kaolinized and the ferro-magnesian minerals have almost entirely disappeared, although occasionally foliated fragments of a mineral which might possibly be hornblende are found. The andesite mass has been cut by numerous dikes of rhyolitic rocks, generally in an east and west direction. Cutting the andesites are a number of well marked fault planes which, however, only heave the veins very slightly. The fault planes have a strong dip to the east, and these fault planes have probably had much to do with the formation of the ore shoots.

The veins of the Los Angeles district have an east and west strike. The veins are of two orders, one which dips to the north and another which dips to the south. The south dipping veins are almost invariably associated with the dikes. The north dipping veins are almost invariably found entirely in the andesite. One of these south dipping veins is found in the vein system of the Los Angeles mine proper, with a rhyolite hanging wall and andesite foot wall. The north dipping veins occur in crushed zones and the ore bodies have been formed by the replacement of the shattered porphyry. The vein filling is partly quartz, although it is mainly an altered porphyry.

The ores in these veins are free milling, and the greatest depth yet obtained (about 400 feet) fails to disclose heavy sulphide ore, although at this depth sulphides are coming in. The district is somewhat deeply dissected by the Los Angeles Arroyo, and the veins are very thoroughly drained down to the present depth of the mine workings.

When the veins strike the breccias, they are completely masked, the breccias apparently having been laid down long after the veins had been formed and filled.

The breccia is characterized by an almost entire absence of mineralization. Only one vein has thus far been discovered in this formation, and that was a very heavy baryta vein, apparently of no commercial importance. Just outside the Los Angeles amphitheatre, and in the breccia are to be found enormous quantities of petrified trees. Some of these trees were of great size and were mainly oaks. One petrified tree still had its roots imbedded in the volcanic tuff in which it apparently grew, and several feet of trunk stood above the ground. At a number of places in the breccia there are strong indications of intense thermal activity.

The entire district has been covered by denouncements by the company which is operating the Los Angeles mine proper, and plans are now being set on foot for the active exploitation of the numerous parallel veins found in it. The Los Angeles mine is developed to a depth of about 400 feet and numerous levels have cut the ground up into blocks, exposing a large tonnage of ore of good grade on four sides.

The work of the last two years has been entirely devoted to development, the ores extracted being treated in a two-stamp mill and cyanide plant for testing purposes. The little equipment has extracted a great deal of bullion and has practically paid the entire expense of the mine work. Around this property a community of some four hundred inhabitants has grown up, all of whom derive their livelihood from working in and around the mine.

The people employed at the mine are Mexicans and Indians. Los Angeles is just on the outskirts of a large Indian district, populated by the tribe of Tepehuanes, although some Tarahumaras are found nearby. The labor working underground, however, is mainly composed of Mexicans, these Indians not caring, as a rule, to work inside mines. The Indians are mainly employed as wood choppers, peons, around the patios and the mill.

The mine is well laid out and will compare favorably with the average mine in the United States, the workings being well

timbered and the grades in the levels easy and uniform. The
ladders through the mine are not the typical chicken ladder
of the Mexican mines, but are good substantial ladders such
as are used on this side of the border. All this work has
been done entirely by Mexicans, who make first rate timber-
men if patience is taken in their instruction.

The miners engaged in driving levels, etc., are paid by
the "hole contract" system, being paid, as a rule, twenty-five
cents, Mexican, a foot. The hammersmen or barrateros work
in pairs, each man alternately turning the drill and striking.
A pair of men will earn from $5.00 to $6.50 a day, so that
they drill from twenty to twenty-six feet per shift. The bar-
rateros rarely work more than eight hours a day, usually
knocking off when they have earned what they consider a
fair day's wage. This whole contract system is, on the whole,
satisfactory, especially for driving levels, sinking winzes or
making upraises. No stoping has yet been done in the mine,
but it is questionable how the "hole contract" system will work
in stoping. In all probability, the miners for this work will
have to be paid by day's wages.

The winzes, until they reach a depth of fifty feet, are
usually cleaned out by the peons, who pack zurrons, or leather
sacks carried on their back and steadied by a broad strap
which passes around their forehead. A gang of peons, work-
ing about eight hours during the night, will remove about
fifty cubic feet of broken rock, even if very wet. Some of
the loads carried by these peons are almost unbelievable. A
small Indian of magnificent physique has been known to carry
on his back up a notched pole or chicken ladder three hundred
pounds in one load, from a depth of one hundred feet. Although
this method of cleaning out winzes seems very crude, yet my
experience with both windlass and zurron would go to show
that, on the whole, the zurron method in Mexico of course,
offers many advantges over the windlass down to fifty feet.
It is only where water has to be bailed that a windlass is
better. Until recently, the men were paid by boletas, or time
checks. These boletas were good for merchandise at the store,
and once a month any unbartered boletas were cashed by the
company. The new monetary laws of the republic have de-

clared this system illegal, as it tends to keep the workmen in a state of semi-bondage to their employers. The men have now to be paid in cash at regular intervals. On the whole, the boleta system was a good one, but, unfortunately, it was abused by avaricious employers. The abolition of the boleta system is unquestionably another of those steps taken by the Government for the purpose of finally suppressing the peonage system and for the purpose of trying to place the working people of Mexico on a manlier and more self-respecting basis.

The ores of the Los Angeles district are amenable to amalgamation and cyanidation of the residues. The extraction by these two methods runs up to about ninety per cent, and from the ores thus far developed about an equal percentage is obtained by amalgamation or cyanidation.

The Los Angeles mine is ideally situated, having a magnificent climate and an ample supply of wood and water. The miners have been well trained, and do exceedingly good work.

CALABACILLAS.

The mining district of Calabacillas is a one mine district. The San Geronimo mine was discovered about eight or nine years ago, and has been worked continuously by its Mexican owners. No records have been kept of its production, but this must be close to $1,000,000 Mexican. It gives employment to a large number of men and supports a large proportion of the town of Calabacillas and in its immediate vicinity.

The district is situated on the face of the great west escarpment of the Sierra Madre, being about four thousand feet above sea level and about three thousand five hundred feet below the crest of the front range. The climate of this district is nearly ideal as it receives not only the cool breezes from the mountain range, at night, but during the day a cool breeze from the ocean, which is not more than one hundred miles distant, tending to equalize the temperature and mitigate the heat of the subtropical sun. The district is situated in the municipality of San Juan Nepomuceno, in the District of Mina, in the State of Chihuahua, and very close to the boundary line between that state and the State of Sinaloa. Until recently this district was appurtenant to the mining office of

Guadalupe y Calvo, but recently a branch mining office was established in the town to make it more convenient for the registration of mining titles.

In some respects the district of Calabacillas is well situated, as it is easy of access from the Pacific coast and can be reached from Mazatlan to Culiacan and Mocoritio by diligence, and thence by mule-back ride about three days to the mine. The building of the Stillwell Road from Topolobampo to Choix has brought this district very much closer to the markets of the Pacific coast, as it is only a two days ride from Choix to the mine, and a wagon road could, no doubt, easily be constructed.

It is somewhat surprising when one considers the means of transport to such mining districts as this of Calabacillas, to note the comparatively low cost of freight. For example, freight from San Francisco to this district costs no more than $1.50, U. S. C. per one hundred pounds, about the same, in fact, as freight from San Francisco to many points in Southern California or Arizona. The main difficulty, of course, is the slowness of delivery and the roundabout way the freight has to come. For example, machinery is brought from San Francisco in the following manner. From San Francisco to Mazatlan the freight costs $5.00 U. S. C. per ton. From Mazatlan it can go to the little port of Playa Colorado by small sailing vessels, freight being $1.00 per package, not exceeding one hundred and fifty pounds in weight, or equivalent to about $6.50 U. S. C. per ton. From Playa Colorado it is taken by wagon to Cienega, a station on the main stage line which runs along the coast from the north to the south. From Cienega it goes to Calabacillas by mule-back, the freight being $6.00 silver, per carga of three hundred pounds, or about $20.00 U. S. C. per ton. The total from San Francisco to the camp is, therefore, slightly in excess of $31.50 U. S. C. a ton.

The district is covered by a large number of pertenencias, although the actively developed ground is covered by only six pertenencias, or about thirteen acres. The main vein which is worked has a strike nearly due north and south, magnetic, and dips east at an angle of about sixty degrees. The vein occurs in a fracture which roughly follows a line of contact

between andesite and rhyolite. The fracture is not exactly at the contact, but is at all times close to it. Sometimes the fracture is entirely in the andesite and sometimes entirely in the rhyolite. The vein matter is altered breccia of the country rocks and it is sometimes exceedingly difficult to distinguish between the country and the vein matter proper. The values, as a rule, greatly diminish from the center of the mineralized zone toward each wall, and the limits of the vein are determined by constant assaying. The ore bodies are quite large. I took a sample across fourteen metres of the vein which gave about $6.00 a ton in gold. The mine has been worked by characteristic Mexican methods, that is, by a crude system of pillar and stall work. The rich bunches of ore are taken out immediately they are encountered, and the result is that the upper workings consist of an immense number of ramifications, all showing very low grade material and a hasty inspection of the mine might lead one to have an unduly poor opinion of the property. If, however, it were possible to carefully determine the value of the ore standing, and apply to this value the average of the ore extracted, I think there could be no doubt that the value of the vein would show up well over $16.00 or $17.00 U. S. C. per ton. The ore treated about three or four years ago went about $30.00 a ton, U. S. C., and from this an extraction of about eighty-five per cent. was obtained by amalgamation. The tailings from the amalgamation process were treated in a small cyanide plant and the final tailings ran about $2.00 a ton. The main value of the ore is almost entirely in gold.

The mine is quite well equipped for a property operated by Mexicans. There is a neatly built shaft house, with a good double compartment incline shaft, and all reasonable conveniences at the mine for taking care of the supplies and ore piles. The ore is transported from the mine to the mill by means of a car track and an inclined cable way down to the mill. The mill is a Bryan mill, four concentrators, fifteen-ton cyanide plant, assay office, blacksmith and carpenter shop, etc. The mill has a capacity of about twenty tons a day, and steam power is used.

The bullion from the amalgamation plant runs over eight hundred fine in gold. From the cyanide plant the bullion runs six hundred in gold and two hundred in silver.

The expenses of operation are not great when one considers the unsystematic manner of the work. No exact figures could be obtained, but the following may be taken as a close approximation. $10.00, silver, for mining, $9.00, silver, for milling, and $6.00, silver, for cyaniding, or about $12.50 per ton, U. S. C., for all expenses.

LA CUMBRE DISTRICT.

The District of La Cumbre de San Manuel, commonly referred to locally as La Cumbre, is situated at the Southwest end of the San Juan valley in the municipal section of San Juan Nepomuceno. The mines in this district have an interesting history, having been operated by the Jesuit fathers. There is a tradition in the district that when the Jesuits abandoned the mines they sealed up a number of the workings, which have never been entered since. This is not at all improbable, inasmuch as the Jesuits expected to return to the country at some future time. It is stated that the records of the mining operations of the Jesuits are still kept in Alamos, Sonora, and I understand these records are now being searched and those parts of interest are being translated.

The district of La Cumbre is in very rugged country. The bed of the Bazanopa River has an elevation of about 3500 feet above sea level. Although the mines are distant about three or four miles from the river, the elevation reached is about 6700 feet. The la cumbre, or comb, of the mountain has an elevation of from 8000 to 9000 feet. The formation in the district is mainly diorite and andesite, capped in many places by flows of rhyolite breccia. The strike of the veins is about N. 85° E., and has a dip to the south. The ore bodies are replacements of the country on each side of the central fissure. The oxidized zone is very shallow and sulphides soon come in in most of the veins, notably in the Guadalupe and La Fortuna. In other veins, of which I have no data, however, the oxidized zones are much deeper and free milling ore is

found at a considerable depth. The vein of the Guadalupe mine is exceedingly wide, but the ore is very refractory and contains much zinc. The values are mainly in gold.

The mines in this district are being developed by Americans and a very large equipment is now being erected for handling the ores.

AGUA CALIENTE DISTRICT.

The mines of the Agua Caliente district are at present in the prospect stage. The veins of this district are fissures with a northwest and southeast strike, with a dip to the west and all the veins examined are in diorite. A large mass of rhyolite is found immediately to the west of the mineral district, but in this rhyolite, so far as I could learn, no deposits have been found. As in the case of La Cumbre, the oxidized zone of this district is very shallow, most of the veins turning to sulphides at a depth of from twenty to thirty feet. In such cases the ore is galena, carrying good values in gold and silver. These ores will undoubtedly be exceedingly valuable when smelting facilities are provided, inasmuch as they will furnish the lead ore for smelting the ores of the La Cumbre and the peculiar calcareous silver ores of the Trigo.

The veins of the Ague Caliente district have another interest, inasmuch as they show on the surface high grade free gold ores, contrary to the general character of deposits of the Sierras. As a rule, the values in the veins of this part of Mexico have been leached out near surface. For example, out of several hundred assays made at surface on some of the Los Angeles veins, no values were encountered, but a few feet from the surface the values came in abruptly and would frequently be very high.

The surface leaching of gold veins is an interesting subject. It is probably true of most of the producing gold veins examined that the surface showed up quite low grade. The values would generally come in at a depth of from ten to fifty feet. This fact probably accounts for the generally held idea among prospectors that gold veins increase in value with depth and this idea is probably correct in most cases for the limited

depths to which the prospector goes. However, the idea has been more or less discredited by being extended to mining at indefinite depths.

The explanation of the leaching of the veins of the Southwest corner of Chihuahua is understandable if we remember the fact that after the veins had been formed they were covered with rhyolite flows. The effect of these flows is to be seen by the decaying of the andesites and the decomposition of the feldspars. The effect of heat and moisture on the feldspars and pyrite and other sulphides might give rise to the formation of alkaline sulphide solutions dissolving the gold. These solutions would have a run off at the contact between the breccias and the underlying andesites. This idea is one that is purely tentative, but is one whch seems warranted by the conditions.

I am informed that at the Dolores mine where the same general conditions prevail, the veins at surface show up very poorly although it is well known that at comparatively slight depth they are exceedingly rich. In the Los Angeles mine at a number of places where the vein has been upraised on, the values would continue quite steadily until within ten feet of the surface, and then would abruptly cease. A number of instances are known, likewise, where the ore at surface gave assays of less than three dollars a ton, whereas at a depth of less than fifty feet values of from seventy-five to one hundred dollars were encountered.

Sketches
OF
Nannie Baird Reservoir.
Dam.

Water Side.

Plan.

Section on C. Line.

Cross Sections

Sketches
OF
Juniper Tank
Dam
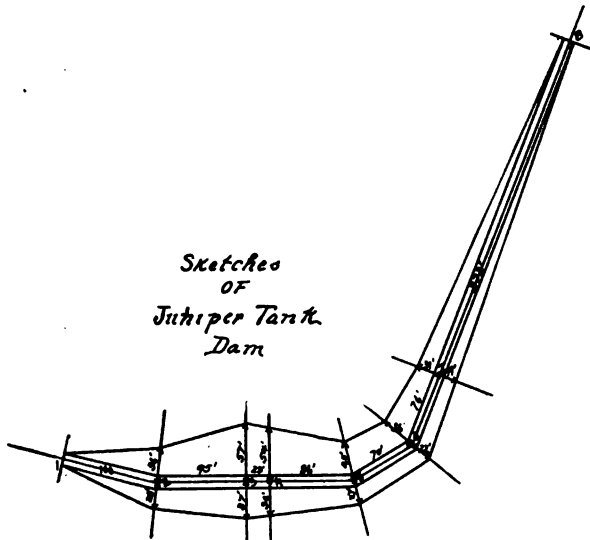
Plan
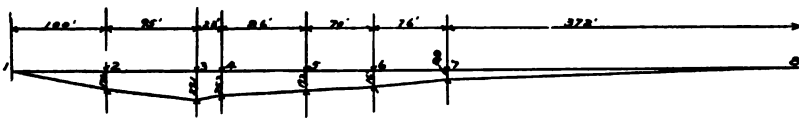
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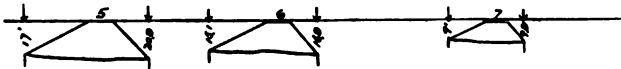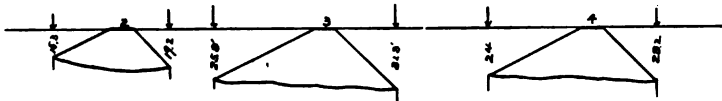
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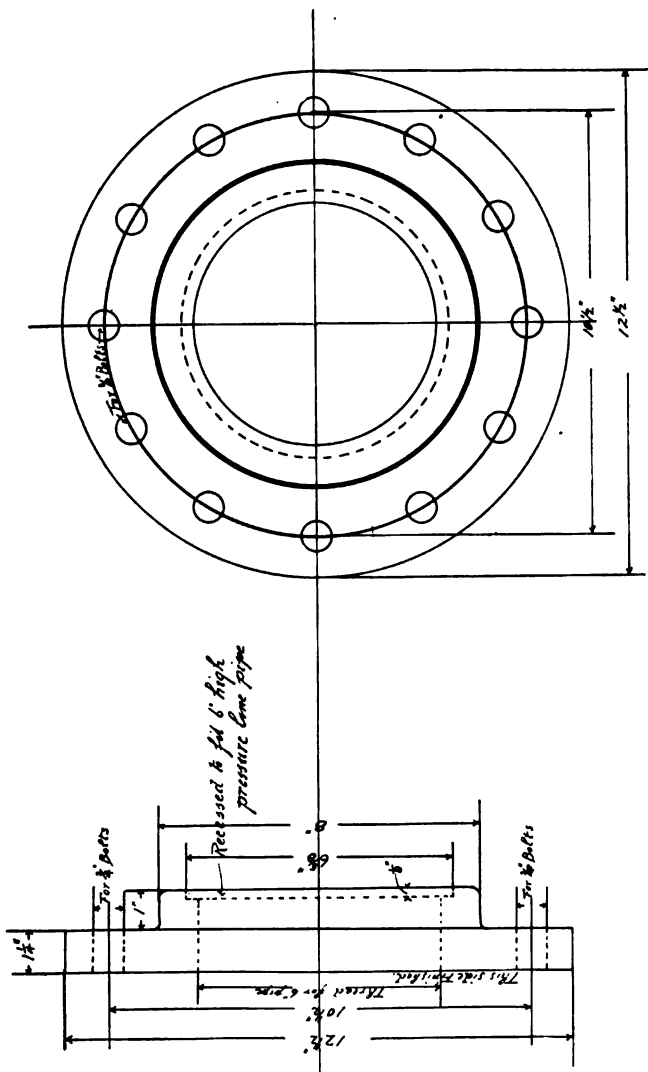
Forged Steel Flanges
For 6" High Pressure Line Pipe

Juniper Tank, looking south toward the Jarilla Mountains
in the distance

A PIPE LINE IN NEW MEXICO.

BY THOMAS L. WILKINSON

Read at the meeting of the Society, May 5, 1906

A well known writer and authority on hydraulics has well said that the science of hydraulics is founded on three following homely and unassailable axioms:

First: "That water always seeks its own lowest level."

Second: "That, therefore, it always tends to run down hill," and

Third: "That, other things being equal, the steeper the hill, the faster it runs."

It may be safely said that in the water supply for commercial or domestic use, or both, that no two are alike in almost any condition.

In the discharge of water through a long line of pipe (or a short one for that matter) the slope down which it flows is the Hydraulic Grade Line. If the slope is such that the pipe line is of a general descending nature, then the hydraulic grade line is a straight line joining the ends of the line—the pipe being of uniform diameter and character, and the pipe line lies wholly below the grade line.

There are other conditions which affect the line—nature of the country, which may make the hydraulic grade line a broken line instead of a straight line—branches in the pipe— varying diameter in the pipe—varying condition of the interior surface of the pipe.

A vertical line drawn from the pipe line at a given point to the hydraulic grade line establishes the Piezometric Height at that point, and so measures the pressure at that point. It may or may not be necessary to ascertain this Piezometric Height in some pipe lines.

With these general observations before us, there followed the existing conditions and the demands to be fulfilled in this particular case.

The place or location of this pipe line is in southern New Mexico not far distant from El Paso.

A smelter to be built was to be supplied with water and in addition to this a reasonable amount for a town, which would grow up with the smelter.

It was estimated that the daily need for the smelter would be about 200,000 to 250,000 gallons. As regards the town, a liberal allowance of 100 gallons per capita per twenty-four hours is in reality a large estimate.

The people of New Mexico are by nature extremely saving in the use of water. During July, 1905, the average daily consumption of water in El Paso was 1,500,000 gallons. The population is estimated at 35,000 and on that basis the amount per person was 40 gallons per 24 hours. So that we may consider 50,000 to 75,000 gallons used by a town estimated at 1,000 population to be within safe limits and at the same time allow for growth. Allowance was also made for a possible growth in the demands of the smelter.

There were two possible ways to obtain water—one by drilling or boring—the other by bringing the water of the Sacramento river to the smelter and town. This was the nearest possible reliable supply.

The results by drilling, as experienced by the El Paso and Northwestern railroad, were very discouraging, both as to the quantity and quality of the water.

The analysis of water from a nearby supply will indicate the character.

	Grains Per U. S. Gallon
Calcium carbonate	9.90
Calcium sulphate	3.13
Magnesium sulphate	6.96
Magnesium chloride	0.38
Sodium chloride	1.29
Iron and alumina	.16
Carbonic acid	6.02
Silica	0.95
Alkalinity	10.49
Suspended matter	.76
Incrusting solids	22.24
Non-incrusting solids	1.29
Pounds of incrusting solids per 1,000 gallons	3.18

At the headwaters of the Sacramento river the water appears to be soft and apparently free from foreign matter. From that point in the river where it is diverted into the ditch it flows some 20 miles, sometimes over clay and gravel and then over limestone formation, so that by the time the water reaches Juniper Tank much foreign matter that is deleterious to steam purposes, may be and probably, is added. The fact that both reservoirs are in reality settling tanks and that at least some of the foreign matter that is gathered by the water in transit from the river to the tanks may settle is a hope that may or may not be realized. If this water proves to be full of scale producing properties naturally the boilers will suffer and the coal bills will gradually become higher, as a small quantity of scale in boiler tubes reduces the efficiency very materially.

At a ranch 4 miles from the location of the smelter and town a well was drilled and the water proved to be salty. This water, as shown by analysis, proved to be very hard on the boilers of the railroad engines. A large sawmill a few miles away having water tube boilers had a stock of old tubes almost filled with scale. I am informed that there were enough

of these scale filled tubes to have made telephone poles for a ten mile line with 35 to the mile.

The quality of the water together with the uncertainty of obtaining a well or wells of sufficient capacity and the consequent expense of pumping, made it imperative that the idea of sinking wells be abandoned and that if the waters of the Sacramento river could be brought in by ditch and pipe line at a reasonable cost it should be done.

Accordingly, an engineer, more or less familiar with that section of the country, was sent to make a survey of the proposed line and to take measurements of the flow of the stream.   It was unfortunate that no measurement of the water during the dry season was made, or, that no measurements over an extended period were made.   At the time of the measurements the river was at full flow and the results showed that 30,000,000 gallons were flowing per 24 hours. The river was measured 60 days later and it was ascertained that about 40,000,000 gallons were flowing.

From this it was concluded that in the dry season a conservative estimate of at least one tenth of the maximum amount would flow.

The Sacramento river has its source in the Sacramento mountains from numerous springs.   This is at an elevation of from 8,600 to 7,300 feet above sea level.   Some of these springs are not permanent and in the dry season give up no water.   The river flows along the Sacramento canon which is heavily wooded and with considerable undergrowth.   Feeders come in here and there, until at a point about 15 miles from the main permanent springs part of the water is diverted by ditch.   A cattleman had some 20 years ago appropriated about 4,000,000 gallons of water for his cattle.   He built a ditch 20 miles long and through it brought the water and filled reservoirs or tanks, as they are called there, for his cattle.   He never used the full amount of water he had appropriated.   From the point of the beginning of the ditch what water flows past in the river is lost in the sands of the desert some seven or eight miles below.

All water rights held by this cattleman, the ditch, right of way and improvements were purchased, excepting that the cattleman was to be furnished with 50,000 gallons per 24 hours for the use of his cattle. This ditch was to be enlarged and improved and water was to be brought in this ditch to a point about 20 miles from the intake and discharged into a reservoir called Juniper Tank. The fall from the intake to Juniper Tank is about 1,400 feet. This tank is now being enlarged to a capacity of 10,000,000 gallons. A new and larger dam is being built to increase the capacity, and is the starting place of the pipe line.

For the first five miles the pipe line runs through very hard, rough country, but after the mouth of the canon is reached, the line runs through an almost level country, which is very sandy. By reference to the profile it will be readily seen what an expanse of country this is.

The pipe line is 25 miles long or 132,000 feet. The amount of water to be taken through the pipe for the smelter and town was settled on at 500,000 gallons per 24 hours. The intake of the pipe at Juniper Tank is at an elevation of 5,900 feet above sea level, the elevation of the discharge is 4,400 feet, so that the head is 1,500 feet.

The following equations to determine the flow through a 6-inch pipe were used:

$$\frac{v^2}{2g} + 4f\frac{l}{d}\frac{v^2}{2g} = 1500$$

$$\left(1 + 4f\frac{l}{d}\right)\frac{v^2}{2g} = 1500$$

where $l = 132,000$
$ d = \frac{1}{2}$
$ f = \cdot007$

$$1 + 4f\frac{l}{d} = 1 + \cdot028 \times 2 \times 132000$$

$$\frac{v^2}{2g} = \frac{1500}{7400}$$

$$v^2 = 2g\ \frac{1500}{7400} = 13\cdot4$$

$$v = 3\cdot65$$

For a 6-inch pipe 1 ft. in length $= \cdot196$ cubic ft.

Therefore $\cdot196 \times 3.65 = \cdot72$ cubic ft. per sec.
$= 324$ gal. per min.
$= 470,000$ gal. per 24 hours.

The coefficient of friction has purposely been taken larger than is usually employed so as to be safe in the delivery of 500,000 gallons per 24 hours.

It was somewhat interesting before the financially interested parties could be brought to a realization of the pressures existing under this head of 1500 feet and of the necessity of strong pipe. However, to meet the conditions, 25 miles of lap welded steel pipe, 6 inches in diameter—known as high pressure line pipe, tested to 1500 lbs. per sq. in. and ·28 inch thick, was purchased. The weight was 18·76 pounds per foot and the total gross weight being about 1300 tons. This was shipped in 40 cars. The pipe was of random lengths,

and was asphalted inside and out. The screw ends were protected and the screw couplings were the patent recessed kind. The pipe and couplings were made and delivered according to specifications. Cast iron pipe although asphalted is often rough on the inside. This pipe was very smooth on the inside, and I have never seen pipe which appeared to better advantage.

Provision was made in order to facilitate repair in case of a break, from water hammer or other cause, by placing forged steel flanged couplings at every 1000 feet of pipe, so in case of a break, 500 feet would be the greatest distance from the couplings, and the pipe easily disjointed. These couplings were especially made from my design of forged steel 12 1-2 inches outside diameter, 1 1-4 inches thickness of flange, the hub was 8 inches in diameter. The entire thickness of the coupling was 2 1-4 inches. The bolt circle was 10½ inches in diameter and drilled for 12 ¾-inch bolts. The gaskets were of sheet lead 3-16 of an inch thick and cut 1-4 inch larger than the diameter of the pipe, so that when bolted up tight the gasket would about come to the inside diameter of the pipe.

At the point where the line passed over a slight ridge from one canon to another an automatic air relief valve of the Crane make was provided. This was the only place in the pipe line which required this precaution.

The pipe was to be laid 24 inches under ground and well laid and covered. No expansion joints were used at all, the velocity of the water and the depth of two feet will serve to keep the temperature of the pipe always about the same, thus avoiding any difficulty with the pipe due to expansion and contraction.

The threads of the screw couplings and pipe where joined together were to be well coated with coal tar. This serves much better than red lead or graphite, the pipe being more readily unscrewed and the threads remaining in good condition, and coal tar forms a tight joint.

At the lowest point of the pipe line which is near the rail-road, provision is made to drain the pipe from either end should occasion arise. Valves are placed at the inlet and discharge ends, as well as suitable arrangements for taking the water out of the tanks directly into the pipe.

At the time the calculations were made for the pipe it was hoped that some water power might be developed. The intake at Juniper Tank was at an altitude of 5,900 feet. It was proposed at an altitude of 4,700 feet to establish a power plant and from this point after the water had passed the wheel to have it enter the pipe and be carried to the delivery point. The loss of head would amount to about 55 feet and the available head about 1,145 feet. With a discharge of 1.84 cubic feet of water per second under this head the horse power developed at the nozzel would be about 200.

The efficiency of the best water wheels is not greater than 85 per cent, this makes 170 horse power delivered at the wheel shaft. After deducting 5 per cent loss in the generator, 10 per cent drop in the line and 5 per cent in the motor and transformer, not more than 135 horsepower can be realized. This amount would not be sufficient for the needs.

It was proposed to convey the water after having passed the wheel in a 12-inch pipe to the point of discharge. The head would have been 500 feet and with 266 feet loss of head due to friction the effective head of 234 feet or a pressure of 101 pounds. This idea would have required about 19 to 20 miles of 12-inch pipe. The results to be obtained were not commensurate with the cost and the scheme was abandoned.

The water delivered by the present pipe line will be 500,000 gallons per 24 hours. This is in excess of present requirements and power may be developed by establishing a wheel at the point of delivery. The flow of water to be cut down somewhat at night and a small alternating electric plant may readily be established which will furnish about 40 horse power. This will be sufficient to furnish the town, about two miles distant, with ample illumination.

DAMS.

The dam for the enlargement of Juniper Tank is located at the beginning of the pipe line, in the Sacramento mountains, and is at an altitude of 5,900 feet. The other dam, known as the Nannie Baird Reservoir dam is at the discharge of the pipe line and holds back the water in Nannie Baird Reservoir to the amount of 25,000,000 gallons.

From this latter reservoir the water flows to the smelter and town, with an effective head of 175 feet. Both these reservoirs are storage tanks and both dams are what are known as earthern dams.

The character of the material for the dam at Juniper Tank is black soily clay mixed with broken rock and calechi. Calechi is a kind of leached limestone and is impervious to water. This combination of material makes an excellent dam as it naturally packs and holds water perfectly.

The material for the Nannie Baird Reservoir Dam is somewhat similar to that at Juniper, the soil being more sandy, due to deposition of the silica and coarse gravel from the hillside.

After the dam sites had been staked out, all vegetable matter was removed and the top soil was so worked up that a good and suitable joint with the material for the dams could be secured. All material entering into the construction of these dams was inspected and no clods of large size were permitted, but the mixture of broken stone or rock, gravel, sandy soil and calechi was well packed by the teams walking and hauling the material onto the site of the dams.

The Nannie Baird dam, being the larger and higher of the two and having to hold back more than two and one-half times as much water as Juniper and to be as impervious as possible was built with the best material at hand, and a facing, on the water side, of one foot in depth of calechi was provided. This calechi is very plentiful and as easily obtained as clay or gravel.

Suitable spillways were provided for each dam.

The general dimensions of Juniper Tank Dam are approximately as follows:

```
Length on top of dam........................625 feet
Width, widest part at bottom................... 95 feet
Width, top ................................. 12 feet
Height, at deepest part....................... 29 feet
Slope, water side ............................ 2 to 1
Slope, outside ............................... 1 to 1
Cubic yards material......................... 15,000
Capacity, approximately ............ 10,000,000 gallons
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NANNIE BAIRD DAM.

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Length an top of dam........................750 feet
Width, widest part at bottom..................175 feet
Width on top ............................... 12 feet
Height at deepest part....................... 40 feet
Slope, water side.............................. 3 to 1
Slope, outside ...............................1½ to 1
Cubic yards material .........................50,000
Capacity approximately.............. 25,000,000 gallons
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Sketches showing the plan, longitudinal and cross sections are shown.

It will naturally be of interest to learn the costs of this pipe line. The whole idea and design was to furnish just about 500,000 gallons in each 24 hours.

It must be remembered that in that county skilled labor is not plentiful, living is high, freights are considerable and conditions generally are of such a nature that costs will be higher than in some more favored locality. So that the cost of this pipe line, including the work on the two dams—the one at the beginning of the line and the one at the discharge—completed, laid and doing work is $100,000.

Drawings of the profile of the line, the plan of the route, the drawing of the forged steel couplings, and the sketches of the dams are given herewith.

MINERALOGICAL NOTES, NO. III.

BY WILLIAM P. HEADDEN

Read at the meeting of the Society, July 7, 1906.

CASSITERITE—MECKLENBERG, N. C.

The sample of cassiterite forming the subject of this note was given to me by Mr. A. B. Frenzel who stated that it came from Mecklenberg, N. C. The cassiterite is very dark, almost black, and in very thin fragments transmits light with a brown color. The gangue rock is a coarse-grained mixture of quartz and a greenish-white muscovite. The sample is interesting because of the presence of tantalic acid, which has also been found in some of the Scandinavian cassiterites; the latter, I believe, are associated with the mineral tantalite and the same is said to be the case with the N. C. cassiterite, but I have not been able to detect any tantalite or columbite in the hand piece given to me; in fact I have not recognized any other minerals than those mentioned. The occurrence of tantalic acid in cassiterite has been known for a long time, but it does not appear often in the published analyses, from which I infer that it is usually absent. I have analyzed a number of tin-stones from many localities in the Black Hills, So. Dak., a district throughout which columbite is of frequent occurrence while tantalite is rare. The columbite, however, is almost always rich in tantalic acid, so there is an abundance of tantalic acid occurring associated with the cassiterite to render probable the presence of this acid in the cassiterite of the

Hills, if this association has any effect upon the composition of the cassiterite, and yet tantalic acid is by no means uniformly present.

I have found several samples of columbite in which there was a small amount of cassiterite, easily recognized by its deportment with potassic hydric sulfate and its insolubility in hydro-fluoric acid; but I have not, on the other hand, found the columbite so intimately associated with the cassiterite. At the Etta mine, Pennington Co., So. Dak., the cassiterite and columbite occur in the same rock, and the cassiterite from this mine, an analysis of which will be given later, shows the presence of tantalic acid. The columbates and tantalates are not more generally distributed in North Carolina than in the Black Hills of South Dakota, and if the presence of tantalic acid in cassiterite is dependent upon its association with the tantalates one would be justified in expecting to find it in cassiterite from such localities as the Etta mine or in the stream tin from Herbert's placer claim where a pure tantalate of iron, tantalite, has been found, and which is, up to the present time, the only locality in the Hills where this mineral has been found. I will subsequently give analyses of cassiterite from both of these localities. The Mecklenberg cassiterite has the following composition:

<div align="center">

CASSITERITE—MECKLENBERG, N. C.

Specific Gravity, 6·7671

</div>

SnO_2	95·18
FeO	1·11
Ta_2O_5	3·82
	100·11

The Ta_2O_5 was determined by being converted into potassic tantalic fluorid, $TaF_5 2KF$, and subsequent precipitation as tantalic acid. I was unable to establish the presence of any columbic acid.

CASSITERITE—ETTA MINE, PENNINGTON CO., S. D.

This locality was discovered in 1883, but tin had been discovered in the northern Hills, the Nigger Hill district, as early as 1877, where it occurred as stream tin, and gave the placer miners trouble in their washings, as it filled the riffles with a heavy black sand.' This sand was sent to Mr. Richard Pearce, who identified it as tin-stone. This was the first identification of stream tin from the Black Hills of South Dakota, but so far as I know lode tin was first discovered at this locality, the Etta, in the year given, 1883. The original find consisted of a small pocket which, according to my informant, furnished several tons of almost pure tin-stone. They have not found any pocket equal to this in size or productiveness since. Though the pocket was discovered in 1883, the ore was not taken out until two years later. During my connection with the School of Mines of South Dakota I was fortunate enough to obtain several very good samples of this original discovery. The cassiterite is unequaled by any subsequently discovered that came to my knowledge. As a rule the cassiterite occurs disseminated in very irregularly sized grains, some quite large ones, but usually as very small ones, throughout the inclosing rock, this occurred in masses weighing several pounds each; one of my samples of this ore weighs six pounds, while others were very much larger and all of it was exceptionally pure. This ore differs from all the other samples of tin ore, as it occurs in the Hills, in that it is marked by green stains caused by the decomposition products of the mineral stannite, a few samples of which were found at the Etta in its early history; I have even detected a few minute grains of this mineral in some of the samples of this cassiterite. Green stains, similar to those occurring on this cassiterite, are also found on some of the granite, where it is sometimes found in quite thick masses. The composition of this material leaves no doubt in regard to its origin, i. e., from the decomposition of the mineral stannite, as I have elsewhere shown. I may

add that the only other locality in the Hills where this mineral or its peculiar decomposition product has been found is at the Peerless, a mine close to the Etta. This latter locality furnished but one small and very poor specimen of stannite, and it was almost wholly decomposed.

The Etta has been worked as a source of spodumene since I was there, and other specimens mày have been found, but so far as my knowledge goes, its occurrence was confined to this association with the first ore found.

I present an analysis of the largest and purest pieces of the cassiterite constituting the first find of this meneral at the Etta mine:

CASSITERITE—ETTA MINE, PENNINGTON CO., S. D.

Specific Gravity, 6·6216

SnO_2	94·36
Ta_2O_5	2·42
Fe_2O_3	1·80
SiO_2	1·00
	99·58

This sample is very dark but shows no sign of decomposition, other portions of the parent piece are not so bright and homogeneous. I do not know whether any columbite was found in this first pocket or not, but it occurred rather abundantly in some portions of the later workings.

STREAM TIN—HERBERT'S PLACER, PENNINGTON CO., S. D.

This sample was chosen for several reasons, i.e., because it is as typical a stream tin as any we have in the Hills, it occurs in the same district in which the Etta is located and is associated with both columbite and tantalite. This placer tin by the way, furnished the first samples of tantalite found in the Hills. The origin of the tantalite and the tin stone occurring with it is, almost beyond a question, the Tin Queen lode which lies a short distance to the north of it and higher.

The analysis of this sample resulted as follows:

STREAM TIN—HERBERT'S PLACER, PENNINGTON CO., S. D.

Specific Gravity, 6·6805

SnO_2	96·08
Fe_2O_3...	1·90
SiO_2...	0·88
Ignition	0·12
	99·68

I could not find any tantalic acid in this sample which appears quite fresh and does not show any signs of alteration.

CASSITERITE—SAMELIAS CLAIM NO. 3, PENNINGTON CO., S. D.

This occurrence is worthy of special mention as it is unusual, and for the district unique. The usual occurrence of cassiterite in the Hills is in the granite veins or dikes, being found in bunches, usually on one of the walls, but seldom disseminated throughout the mass. The only examples of large masses of granite with the tin stone disseminated through them, that I can recall, were found on the Darwin claim, but the source from which these boulders were derived has never been satisfactorily established; the vein from which they are supposed to have come does not differ from other masses of granite in this respect, so while the individual boulders of Darwin ore were large and might have been taken to indicate that there were some granite veins in which the tin stone is distributed throughout the whole mass, they seem, in fact, to be exceptional only in the size of the bunches of ore, just as the original Etta pocket was a wholly exceptional occurrence. The rule is that the tin stone occurs in bunches, sometimes on one wall of the granite vein and sometimes on the other. Occasionally a series of lenses occur with the tin stone occurring on the same wall, I recall such a case in the southeastern portion of the Harney Peak district. In the Samelias the cassiterite occurs in a white, pellucid quartz, frequently associated with arsenopyrite. The arsenopyrite is not

especially abundant and the cassiterite is as a rule entirely free from it. The tin stone is very irregularly distributed through the quartz and the individual particles vary in size from mere specks to groups of crystals of three or more pounds in weight. While the cassiterite usually occurred in bunches distributed through the vein, it also occurred in continuous bands near the walls. These bands were thin, about an eighth of an inch in thickness, and varied in their distance apart. I have stated that the tin stone occurs near the walls of the granite veins and lenses, but it is exceptional to find it distinctly banded as in this case.

The Samelias cassiterite is of a light brown color, but that which occurs in bands is quite dark and is intimately associated with mica. This is, I believe, the purest cassiterite to be found in any part of this district.

CASSITERITE—SAMELIAS CLAIM, No. 3, PENNINGTON CO., S. D.

Specific Gravity, 7·0187

SnO_2	98·22	98·13
Fe_2O_3	0·72	0·43
Insoluble	0·64	1·40
Ignition	0·34 CaO trace	
	99·92	99·96

The first of the preceding analyses was made recently, while the second was made a number of years ago.

I may state what most of you already know, i.e., that there are two theories in regard to the manner in which these granites came into existence, each of which has its advocates: one that they are of igneous, the other that they are of aqueous origin. There are serious difficulties presenting themselves to the acceptance of either theory, and it is probable that neither should be accepted to the exclusion of the other. In the case of the Samelias, it seems certain that it is a segregated vein. The mixture of quartz and mica, forming the portion next to the walls, passes into a pure quartz in the inner portion of the vein. The banding of the quartz, mica

and cassiterite parallel to the walls of the vein shows quite conclusively that they have been deposited from solution, but I would certainly hesitate to accept this explanation for the formation of the granites of this section in general.

The analyses of the Etta and N. C. samples show a fair amount of tantalic acid while the other samples show none; this is interesting, for the sample from Herbert's placer was found in association with both tantalite and columbite. The fact that those tin stones, in which tantalic acid is usually found, occur in association with tantalite might be taken to indicate that they had a common origin; the sample from the Herbert placer occurs with both these minerals, columbite and tantalite, but it contains no tantalic acid, and while not conclusive casts serious doubt on the value of this suggestion.

JAMESONITE—SHERIDAN, PENNINGTON CO., S. D.

This mineral occurs in irregular masses in quartz veins traversing the schists of the district. It has been taken for galena and so reported in the literature of the district. The bunches are of considerable size and are composed of short, stout crystals. I have found but one on which definite surfaces can be recognized. These are prism surfaces, but so curved and striated that I cannot tell whether a pinacoid is present or not. There are no acicular or capillary forms in the samples from this locality. The small spaces between the crystals are coated with a thin layer of an ochreous material and there are, here and there, little cavities lined with a yellowish white mineral with a hardness of 3·5 to 4 and with a vitreous to resinous lustre, both it and the preceding material are to be considered as decomposition products of the mineral proper. Selected material is so nearly free from these that their influence upon the result of the analysis is nil. The outer portions of the larger pieces and almost the whole of the smaller ones have been changed into a brown mass related to bindheimite, but this material is too impure for analytical purposes. The material in my possession came from near the surface and is altered to a great degree.

JAMESONITE—SHERIDAN, PENNINGTON CO., S. D.

Specific Gravity, 5·81304

Insoluble .... 1·13				
S .... 18·90	5·9	5·9	2·6	5·2
Sb .... 26·99	2·24	2·24	1·0	2·0
Pb .... 51·15	2·47 ⎫			
Fe .... 1·30	0·21 ⎪			
Cu .... 0·24	0·04 ⎬ 2·73		1·1	2·2
Zn .... 0·05	0·01 ⎭			
Co .... trace				
99·76				

The atomic equivalents are not perfect, but they are as nearly so as one could expect, and sufficiently close to indicate clearly that the ratio for this mineral is 2 : 2 : 5, or 2PbS, Sb_3S_2, which is the accepted formula of Jamesonite, requiring Pb, 50·80; S, 19·69; Sb, 29·51.

MENEGHINITE—ROCHFORD, PENNINGTON CO., S. D.

This mineral occurs in the Gorman claim near Rochford, S. D., in the schists. There was only a small amount of it found, but no extensive development work had been done as the amount of mineral found did not justify it. The ore is argentiferous and consists for the most part of a fibrous mineral, spoken of as antimonial lead, galena, zincblende and pyrite. This ore differs considerable in color and lustre from the Jamesonite occurring at Sheridan, and also in the aggregation of its crystals.

MENEGHINITE—ROCHFORD, PENNINGTON CO., S. D.

Specific Gravity, 6·21

Insoluble .... 0·49		
S .... 17·51	5·5	7·2
Sb .... 18·20	1·5	2·0
As .... trace		
Pb .... 62·85	3·0	
Fe .... trace		4·0
Bi, Cd .... trace		
Cu .... 0·86	0·1	
99·91		

The ratio is only approximate but it shows that the probable formula for the mineral is $4PbS,Sb_2S_3$ which is that of the mineral meneghinite.

HUEBNERITE—COMSTOCK MINE, LAWRENCE CO., S. D.

This locality was known in the early '80s as a source of beautiful specimens of this mineral, but unfortunately the supply was soon exhausted and I have not learned of any new discoveries in recent years. The mineral occurred in groups of radiating crystals six or more inches long. At the time of my visit to this locality the property was not being worked and only inferior specimens were obtainable; in these the cavities were filled with rough and intergrown crystals, some of which showed clean, though dull terminations. Such crystals showed, as I read them, the following forms, 100, 110, 101, 011, 120?, and one, probably two, pyramidal surfaces. The crystals are so flattened by the extension of the macropinacoid that they appear as thick plates packed together. The color of the mineral is black.

HUEBNERITE—COMSTOCK MINE, LAWRENCE CO., S. D.

WO_3 .... 75·12
MnO .... 20·54
FeO.. 3·01
CaO.. .... 1·04
                                            ———
                                            99·71

WOLFRAMITE—SUNDAY GULCH, PENNINGTON CO., S. D.

This locality lies south and east of Hill city, and was known as a source of specimens of this mineral several years before it was discovered in the northern hills. It occurred in bunches of varying size, was massive, granular and almost entirely free from admixed gangue.

WOLFRAMITE—SUNDAY GULCH, PENNINGTON CO., S. D.

WO_3 ....74·46
MnO ....19·90
FeO .... 3·29
CaO... 1·05
Insoluble..................................... 0·42
Ignition .... 0·75
                                             ————
                                             99·87

PHOSPHORESCENT ZINCBLENDES.

The statement is made in Dana's System of Mineralogy, page 61, that some specimens of zincblende phosphoresce when struck with a steel or by friction. It is probably too rare a property of zincblendes and of too little significance to deserve further mention than this, for after all, we can tell nothing further than the simple fact that it does phosphoresce under these conditions.

Dr. Bradbury, of Grand Junction, gave me a small specimen of a mineral from the southeastern part of Utah which phosphoresces when rubbed with the flat side of a knife blade or even with the finger nail. The phosphorescence shown by this sample is strong enough to be easily observed in diffused daylight, especially if a light shadow be cast by turning one's back to the source of light, the window for instance. The phosphorescence produced by rubbing it with the finger nail is also intense enough to be seen under the same conditions, but shows much more pronouncedly in partial darkness. On close inspection the sample is seen to be a mixture of zincblende, a large portion of which is of a pure white color, galena and gangue. As this phosphorescence is easily excited and is so strong as to readily attract attention I thought that an analysis of it might show something unusual, but it did not.

ZINCBLENDE—SOUTHEASTERN UTAH

Insoluble.....................................15·84
S ....24·96
Zn ....46·07
Pb ....10·54
Fe_2O_3, Al_2O_3................................. 1·64
Ignition in H................................. 0·31
                                             ————
                                             99·36

The analysis corroborates the macroscopic examination, *i. e.*, that the mass is a mixture of zincblende, galena and gangue. The loss is probably due to the fact that I did not heat it to a sufficiently high temperature.

I have, since making the preceding analysis, received a sample of a soft, white, micaceous material, somewhat resembling sericite schist, from Mr. W. C. Wynkoop, who gives the locality as Mariposa Co., California. Mr. Wynkoop writes concerning it as follows: It is said to have radio-active properties. In the dark or under water it glows when rubbed with metal or the thumb nail. According to all accounts it discounts christian science as a healer.

This sample in no way resembles a zincblende, but rather a sericite schist, which I at first took it to be. Partial investigation, however, shows that aqua regia dissolves out 35·32 per cent. of the mass; this represents the amount of zincblende, chalcopyrite and water present. The ignited residue was fused with sodic carbonate and a barium determination made which indicated the presence of 23·90 per cent of the mineral barite; the remaining 40·78 per cent. is essentially a silicate of alumina; a partial analysis of it gave SiO_2 53·55 per cent.; Al_2O_3 41·76 per cent., titanic acid, lime, magnesia and alkalies were not determined. The mass is evidently a mixture of zincblende, barite, chalcopyrite and kaolinite. The phosphorescence is in all probability due to the presence of the zincblende.

TAPIOLITE—CUSTER CITY, CUSTER CO., S. D.

The specimen described in this note was collected by the writer about 15 years ago at a prospect hole near the side of the road leading from Custer City to Hill City and about three miles from the former place. The specimen occurred in a light colored granite, supposed by the prospectors to carry tin stone in commercial quantities. In regard to the latter point I do not recall, at this remote time, whether the granite carried more tin stone than usual or not, but my impression is that it

was below the average in this respect. The dark colored minerals, tourmaline, etc., taken by the prospectors to be tin stone, occurred in rather larger grains than usual and appeared to a great advantage in their setting of light granite. Had there been any crystals of cassiterite, columbite or tantalite, I would, without doubt, have saved some specimens of the ore, but as I have not done so, I think that this was an isolated group of crystals which I had the good fortune to find.

The group consists of several crystals, so distorted and intergrown that I was uncertain as to their form, which, in this case, was necessary to determine, as upon it depended the identification of the mineral as tantalite or tapiolite. I therefore sent the group to Prof. S. L. Penfield, who was kind enough to examine the crystals and who describes them as follows: The habit is pyramidal and idealized would be, as in figure 1, a combination of pyramids of the first and second orders p(111) and s(201). Tapiolite crystals seem to be often much distorted, and the one under discussion is no exception. The faces of pyramid p are grooved and striated, and so intergrown that practically the only measurements which it is possible to make is from p' to p''' over the top of the crystal; this is 84½° to 85°, calculated for tapiolite 84°52'. The faces of the pyramids are curved and uneven. The sketch, figure 2, of one end of the crystal, gives an idea of the irregular development of the faces, and studied in connection with figure 1 the forms may be readily interpreted. The other end of the crystal is still more complicated by what is apparently irregular intergrowth and there is also an indication of twinning.
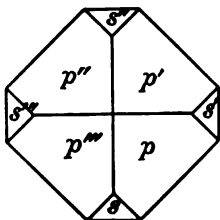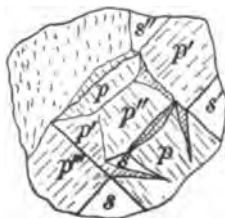

Fig. 1

Fig. 2

An analysis of a portion of these crystals gave me the following results:

TAPIOLITE—CUSTER CITY, CUSTER CO., S. D.

Specific Gravity, 7·2185

Cassiterite....................	0·31			
SnO_2....................	0·07	0·05		
WO_3....................	0·11	0·05		
TiO_2....................	trace		19·54	1·0
Cb_2O_5....................	4·29	1·82		
Ta_2O_5....................	78·61	17·62		
FeO	16·85	23·68	23·68	1·2

100·24

The formula for this mineral is evidently FeO, Ta_2O_5 or $FeTa_2O_6$ in which a small portion of the tantalic acid has been replaced by columbic acid. The formula is very close to that of a normal tantalite and the minerals, tapiolite and tantalite, probably differ only in their form.

In the analysis of tapiolite given in Dana's System of Mineralogy, sixth edition, we find the ratio of the tantalic acid to the columbic acid given as 4 to 1, in this analysis it is as 10 to 1 and we infer that the columbic acid is accidental, just as we find it in the tantalites. The specific gravity of this sample is very low; a tantalite containing no manganese and so little columbic acid as this, 4·29, should have a specific gravity of 8 or more. We have, for example, tontalite from Grizzly Bear Gulch, S. D., with 3·57 per cent. columbic acid and a specific gravity of 8·2, and in another form the same locality with 6·23 per cent. columbic acid, a specific gravity of 7·773. It should be stated, however, that these fragments are not definitely known to have been portions of orthorhombic crystals, still I have found orthorhombic tantalate of iron at this locality.

After the last preceding sentences were written my attention was kindly called to certain inconsistencies in the analysis, the particular points were the low specific gravity, the high percentage of tantalic acid and the imperfect ratio afford-

ed by the analysis. I have repeated the specific gravity deter-
mination and obtain the same result. The specific gravity
given, 7·2185, was obtained by weighing the whole sample in
air and then in water with the usual precautions; this figure
is probably a trifle low, as there is a little quartz attached to
the mineral, but this error is so small that it is negligible.
The analysis was also repeated with the following results:

Insoluble	1·29			
SnO₂WO₃	0·59			
Cb₂O₅	3·90	1·45	19·1	1·0
Ta₂O₅	78·58	17·60		
FeO	15·60	21·66	21·7	1·1

99·96

The percentages obtained for the respective acids in this
analysis are almost the same as those obtained in the first
analysis and do not change the ratio. As remarked in a
preceding paragraph. The low specific gravity of the mineral
indicates a higher percentage of columbic acid than is shown
by the analysis. Adopting the indirect determination of these
acids given by Penfield and Ford in the current number of the
American Journal of Science it would appear, that the ratio
of columbic to tantalic acid ought to be 1 : 3 or columbic acid
20 per cent. and tantalic acid 62 per cent. The agreement in
the determinations of the columbic and tantalic acids in the
two analyses is better than I dared hope for and is within
closer limits than can usually be obtained. I do not know
how close others can make these determinations, but I am
satisfied if I can get them within two or even three per cent.;
in this analysis, however, it is not a question of two or three
per cent. but of twenty per cent. and about the same in the
first one. The analytical work on these two analyses was
done with considerable care, but I find that I weighed my
ferric oxid in the first analysis in two portions and failed to
reduce a part of it to ferrous oxid, for this reason the FeO is
too high in the first instance and the summation of the analysis

should be so much below one hundred that I would reject it if I felt that it would be altogether right to do so.

The method followed in this work is essentially an old one, I convert the acids into their double compounds with potassium and fluorin by dissolving the acids as obtained by fusion with potassic acid sulfate in hydrofluoric acid, adding potassic fluorid in sufficient quantity and evaporating to dryness, or nearly so, taking up in the least possible quantity of hot water and allowing the tantalic salt to crystallize out. I have tried fusion with potassic fluorid, but I did not succeed nearly so well in this way. The separation is difficult and at best incomplete; the question concerning it is, not how good but how bad is it? I have tried to answer this question for the method in my hands by making mixtures of the two acids containing 20, 40 and 75 per cent. of tantalic acid and then trying to determine the tantalic acid. The difficult point in this separation is to tell when the columbic salt has all gone into solution. I do not believe that there is any point where the whole of the columbic and none of the tantalic salt has gone into solution, and if there is I know of no way of recognizing it. The two salts are very different in their crystal forms, and the best way of judging when it is proper to stop washing is to examine a portion of the mass of crystals with the microscope and to stop washing when the plates of the columbic salt have disappeared. That this method is tedious and lacking in sharpness is evident. My time has not permitted of my making more than five experiments for the purposes of this paper, two each with 20 and 75 per cent. of tantalic acid, and one with 40 per cent. In the four experiments, two each with 20 and 75 per cent. tantalic acid, I tried to overwash in one pair and underwash in the other; in underwashing I obtained 24, in overwashing 18.2 per cent., instead of 20 per cent., in the other pair I obtained 78.8 and 72.85 per cent. respectively; this, I believe, represents the extremes which one would be likely to meet with due to the weakness of the method. The result in the fifth case was 40.45 instead of 40 per cent. These

results are not flattering to one's skill or chemical judgment but I think that they show that the method is reliable to within two per cent at least, when very carefully carried out.

The low specific gravity and the result of the indirect determination both indicate a higher percentage of columbic acid and yet my judgment is that the analyses give it too high rather than too low, and I am unable to reconcile the facts.

REV. H. MARTYN HART

ANTON EILERS

W. F. HILLEBRAND

J. B. GRANT

A. von SCHULZ

S. F. EMMONS

P. H. van DIEST

HERMANN BEEGER

A. H. LOW

WHITMAN CROSS

N. P. HILL

RICHARD PEARCE

Charter Members Colorado Scientific Society
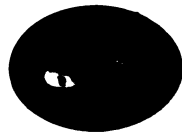
Mr. President:

Under the head of *unfinished business* I wish to say a few words on a subject, which, when I tell you more about it, you will readily see and I think you will agree with me, that it properly comes under this head. The subject I wish to bring up and close has been unfinished business for a long time, and I am happy to say that this particular business is now successfully brought to an end.

A little more than three years ago, Mr. Comstock and I conceived an *idea*—we do that semi-occasionally. We spoke to several of the members about it and it was considered a good thing. It was not for ourselves at all, but it was in the interests of the Society. We started out on this work, but our efforts were not immediately crowned with success. It required considerable correspondence from time to time, and results were rather discouraging. However, this special work, begun more than three years ago, I can report at an end tonight.

Many of the older members of the Society, I believe, will agree with me that our action was well taken and will endorse what we have done, and upon the younger and more recent members, the result should have its influence, and should be an inspiration.

It is for this reason that I say these few words, for I believe the occasion well worthy of it, not by way of eulogy, only a statement of facts. I know and feel that I am not the one who should really do this part, but some older member, who is a contemporary, who, by reason of long acquaintance and friendship and long and active connection with this Society, would be more justly entitled to this honor. But the work has been so long drawn out and I think none of you

know just what has been done, so I will go on and finish the whole as well.

"On Friday evening, the eighth of December, 1882, a number of gentlemen met in the rooms of the U. S. Geological Survey in the Tabor Block, Denver, at the invitation of Mr. S. F. Emmons, to consider the project of organizing a Scientific Society in Colorado."

This is the first sentence written in the minute book of the Society nearly twenty-four years ago. Eleven gentlemen responded to the invitation of Mr. Emmons and these twelve men became the founders and charter members of the Colorado Scientific Society. As is well known, Mr. Emmons became the first president, Mr. Richard Pearce, vice president, and Mr. Whitman Cross, secretary.

Mr. Emmons was the organizer of the Society and gave his time and attention to it during the first years. The proceedings of the Society give ample evidence of his devotion to the Society, and his works on the geology of Colorado stand as masterpieces. However, for length of active service, from the inception of the Society almost until his death we must yield first place to Prof. P. H. van Diest. He was the nestor of the Society. He was a great and untiring worker, and there is no single member who has done the work for the Society that he did. He held every office in the gift of the Society and he discharged his trust beautifully.

He was one of the most interesting and lovable men the Society ever had. It was my pleasure to have known Prof. van Diest well.

When that part of the U. S. Geological Survey in Denver was moved to Washington, Mr. Emmons was stationed there also, and Mr. Whitman Cross and Mr. Hillebrand soon followed him. So the Society lost the active work and pleasant personality of three men it could ill afford to lose. They have risen to places of distinction and the Society is honored in that it has these three gentlemen as Honorary Fellows.

There are not many now in the Society who, knew or re-member, Mr. Hermann Beeger. He was a character. I met him once, I think it was in 1891 and had a pleasant chat with him. From his picture it may readily be imagined that he had an individuality of his own.

Most of us know Mr. Richard Pearce, J. B. Grant, A. von Schulz, Anton Eilers, Rev. H. Martyn Hart, and A. H. Low, for they are men of affairs and identified with the activity and welfare of Denver and Colorado.

Hermann Beeger, N. P. Hill, and Prof. P. H. van Diest are no longer living. Anton Eilers, Rev. H. Martyn Hart, and A. H. Low, have retired from active membership. The others are still with us and let us hope their years may be many.

From the association of these twelve gentlemen, aided by those who followed, the Colorado Scientific Society has grown and prospered, with varying success, until now, its most suc-cessful period, to over two hundred members. When these men organized the Society they were young men, of the age of many of us here tonight. At that time I do not think any of them had made a name for himself, but as we turn and look back, we know that some already have done so, and that the others will.

I think this is a fine group of men, men that it was, and is, an honor and a pleasure to have known. They are an honor to us. Many of the members of the Society know them by name only, and to this end that their faces may not fade from our memory the idea, that presented itself over three years ago, that we gather their pictures together in one group to adorn the walls of the Society's rooms, has at last been ac-complished.

It is a distinct pleasure for me to report this work ended, and I take pleasure on behalf of the Society of unveiling this group picture tonight. Whether or not our idea was a good one I will leave the members to judge for themselves.

THOMAS L. WILKINSON.

NOTES ON FRANKLIN BI-CENTENARY.

RECENTLY HELD IN PHILADELPHIA UNDER THE AUSPICES OF THE AMERICAN PHILOSOPHICAL SOCIETY.

By Edwin N. Hawkins

Representing the Colorado Scientific Society.

Read at the Meeting of the Society, October 6, 1906.

The American Philosophical Society conceived by Benjamin Franklin observed the double centennial celebration of the birth of its founder by appropriate and interesting, as well as imposing, exercises in Philadelphia lasting nearly an entire week beginning April 17th, 1906.

By order of the Mayor of the City of Philadelphia the entire exterior of the City Hall was festooned in outline by many blazing cables of electric lights and the kite and the key shown in incandescents upon each of the four sides of the great building. Flags fluttered in the breeze from all the public buildings and from thousands of houses, and the entire city welcomed the assembly of eminent savants who were there to do honor to the memory of Franklin.

About 200 delegates representing that many learned societies and institutions in Europe and America were present at the invitation of the Philosophical Society, and the brilliant assemblage in academic robes filled Witherspoon Hall at the first meeting held for introductions and the presentation of addresses. The President of the Society called the roll of delegates after which the institutions sending formal greetings were heard from. Sir George Darwin responded for

Cambridge, Professor Simon Newcomb for the Academy of Sciences of the Institute of France, President Hadley for Yale, Dr. Furness for Harvard, Mr. Andrew Carnegie for the University of St. Andrews—the full list is too numerous to mention.

The President of the Philosophical Society, Dr. Edgar F. Smith, in the address historical of the occasion told of the letter written by Franklin on May 14th, 1743, to his friend Cadwalader Colden, Esq., of New York, proposing this foundation under the title of "A Proposal for Promoting Useful Knowledge Among the British Plantations in America" and how Franklin named the charter members, among whom he himself was the first Secretary. How later the Society was successfully launched and how it had held three meetings in the first year of its existence, gradually enrolling among its members the most prominent men in America until in 1768 its membership numbered more than 200.

Following the President's address Mr. Andrew Carnegie in his capacity as Lord Rector of the second oldest institution of learning in Europe, the University of St. Andrews, conferred upon Franklin's great-granddaughter, Miss Agnes Irwin, the Honorary Degree of Doctor of Laws. Mr. Carnegie's choice of language was felicitous. He said: "The Senatus of St. Andrews having given to Franklin his degree of Doctor of Laws in 1759 resolved unanimously 147 years afterward, on April 3rd last, to give his great-granddaughter a like degree. I need not tell you that an honor which is still the price of personal achievement was not granted to the graduate except for her own services to knowledge and her own merit."

On the next day of the celebration the Philosophical Society held its general meeting at which the delegates were welcomed and a number of papers read by some of the distinguished gentlemen representing at the Centenary, Societies and Institutions of Learning of Europe.

Probably the most impressive of the Bi-Centennial services were the ceremonies at the grave of Franklin on Thurs-

day, April 19th, at 3 p. m.   The entire body of the Philosophi-
cal Society and delegates marched from the quaint and an-
cient building of the Society on South Fifth street to Christ
Church Burying Ground.   They were followed in parade by the
marines of the battleship Pennsylvania, the United States
Marine band, the First regiment of the State National Guard,
Representatives of Institutions and Great Projects fostered
and established by Franklin and the Grand Lodge of Masons
of Pennsylvania.   Appropriate addresses were made in the
placing of the commemorative wreaths on Franklin's grave
and the solemn services came to an end.

On the last day of the Bi-Centenary the Philosophical
Society terminated the celebration in a most successful man-
ner.   At the American Academy of Music three addresses
were delivered by the following gentlemen and upon the sub-
jects named:

"Benjamin Franklin as a Citizen and Philanthropist."—
Dr. Horace Howard Furness.

"Benjamin Franklin as Printer and Philosopher."—Dr.
Charles Eliot Norton.

"Benjamin Franklin as Statesman and Diplomatist."—
Hon. Joseph Hodges Choate.

All three addresses were immensely scholarly and in-
spiring and every auditor was deeply impressed with the
enormous value to this country and to the world of this great
man and foremost American.

Under the direction of the President of the United States,
Hon. Elihu Root presented to the Republic of France through
her Ambassador His Excellency Jules Jusserand, the Franklin
Commemorative Medal struck for that purpose by order of the
Congress of the United States.   The speech of presentation
was able and that of reception was whole souled as well, and
the entire audience was justly aroused to such an enthusiastic
pitch that it rose *en masse* while the orchestra rendered the
Marsellaise.

In addition to the features of the celebration already re-
ferred to the President and Council of the American Philoso-

phical Society entertained the delegates at a reception and dinner given in their honor on two successive evenings at the Bellevue-Stratford. Both occasions were most pleasant.

Perhaps the mention of the additional Franklin celebration by the University of Pennsylvania in honor of its founder should be included in these notes, as it was arranged in conjunction with the ceremonies held by the American Philosophical Society. It was opened by an imposing academic procession, in which the delegates took part, robed in gowns and hoods significant of their respective universities and degrees. Hon. Hampton L. Carson, Attorney General of the Commonwealth of Pennsylvania, delivered the oration upon the many sided Franklin. The Wilson portrait of the great American, painted in 1759, which was removed from Philadelphia by Major Andre on the evacuation of the city by the British, was presented to the University by Earl Grey, the present Governor General of Canada, and Dr. S. Weir Mitchell acted for the Viceroy.

The conferring of honorary degrees by the Provost of the University of Pennsylvania followed. In the person of his Ambassador, Sir Henry Mortimer Durand, the King of England, Edward VII, received the degree of Doctor of Laws, and by that act did honor to the memory of that plain American, who perhaps did more than any other man not wearing the uniform of a soldier to effect the victory of the Colonies in the Revolutionary War. Following, various honorary degrees were conferred upon nineteen eminent delegates to the Franklin celebration, including among them Sir George Howard Darwin and Andrew Carnegie. The graduating class of the University presented the College with a bronze tablet inscribed with Franklin's epitaph, written by himself:

The Body

of

BENJAMIN FRANKLIN, PRINTER,

Like the cover of an old book,

Its contents torn out,

And stripped of its lettering and its gilding,

Lies here, food for worms.

Yet the work itself shall not be lost,

For it will (as he believes) appear once more

In a new

And more beautiful edition,

Revised and corrected

by

The Author.

The Bi-Centenary was beautifully planned and successfully carried out, and the delegate of the Colorado Scientific Society to this celebration feels grateful to have had the privilege of being present.

Some of the achievements of Benjamin Franklin spoken of in the exercises constituting the Bi-Centennial of his birth may be of interest in this connection:

As a Printer—Founded the Pennsylvania Gazette, which revolutionized colonial journalism.

Published the "Poor Richard" almanac—a teacher of thrift and wisdom.

As a Citizen—Founder of the Philadelphia Library—the first of subscription libraries in America.

Founder of the Pennsylvania Hospital—the first general hospital in America.

Founder of the University of Pennsylvania.

Founder of the American Philosophical Society—the first association of its kind on this continent.

As a Statesman and Diplomatist—Framed the first scheme for uniting the Colonies, which contained many ideas embodied subsequently in the Constitution.

Represented the Province of Pennsylvania at the English Court in the contest with the Proprietary Government.

Carried on the campaign which ended with the Repeal of the Stamp Act.

Served on the Committee which framed the Declaration of Independence.

Procured the Treaty of Alliance with France, which assured the success of the American Revolution.

Member of Commission which made Treaty of Ghent.

Organized the Postal System of the country.

As Inventor and Scientist.—Demonstrated that electricity was the element of Lightning.

Introduced Lightning Rod as protection to buildings.

Discovered the nature of cyclones and the cause of water spouts.

Devised a stove that made possible the heating of houses at vast economy in fuel.

Revealed cause and devised cure for smoky chimneys.

George L. Cannon gave a brief account of his services as a delegate of the Society at the Pike Centennial Celebration held in Colorado Springs on September 23-29, 1906; including the "christening" of the summit of the peak in a snow storm.

Mr. Cannon also gave a description of a recent tour through the museums of the eastern states made with reference to studying some recent methods of installing scientific collections. He noted that Denver is an exception among cities of equal size, wealth and culture in lacking the usual museums of art, natural history and commercial products and called attention to the extraordinary fact that although the separate collections of the various scientific organizations contained enough valuable and properly mounted material to equip a first-class museum and that, although Denver had for years been spending large sums for the erection and maintenance of such institutions, we are yet without a museum which we do not feel ashamed to show eastern friends because of its incompleteness or, in some cases, improper methods of installing specimens. He attributed this deficiency largely to the unfortunate lack of cooperation which in past times has existed between the science workers of this vicinity and public spirited citizens who although contributing liberally to the promotion of such enterprises have entrusted the work to persons who for lack of professional training and experience were wofully unfit to conduct such work and who by their misguided zeal and ignorance have wasted enough funds to equip and maintain a museum that would command respect rather than ridicule.

He was glad to note a marked change in the general attitude of the public to the science workers of Colorado with reference to consulting trained and experienced naturalists before inaugurating public enterprises which require for their

success a large knowledge of local scientific conditions, and expressed the hope that the time was not far distant when Denver might have a municipal scientific league comparable to our excellent municipal art league to which all questions of a public nature pertaining to scientific nature should be referred.

# NOTES ON SOME FOSSILS RECENTLY DISCOVERED NEAR DENVER, COLORADO.

By GEORGE L. CANNON

Read at the Meeting of the Society, October 6, 1906.

George L. Cannon exhibited a number of enormous bones recently found by Mr. George Coon in excavating for brick clay on the north bank of Green Mountain Creek (Dry Creek) near the intersection of Boulevard F and the Denver and Intermountain railway in North Denver, among which were a femur which had diameters of ten inches at both distal and proximal ends, a nasal horncore and a fine tooth of some theropodous dinosaur. With the exception of the tooth, these bones were portions of one of the species of huge horned dinosaurs for which this neighborhood is noted. The semi-popular account of these animals given by Mr. Cannon being familiar to readers of the standard works on vertebrate paleontology, only the unrecorded notes will be given in the following article:

Our knowledge of the vertebrate life of the Denver formation is principally based on Prof. O. C. Marsh's description of the material in the collections gathered in this vicinity by the late George H. Eldridge and the writer.

In common with all material so far obtained from the Denver beds, these collections consisted largely of fragmentary material which in most cases permitted only generic or ordinal determination. The conditions which in Wyoming and other portions of the west have secured the preservation
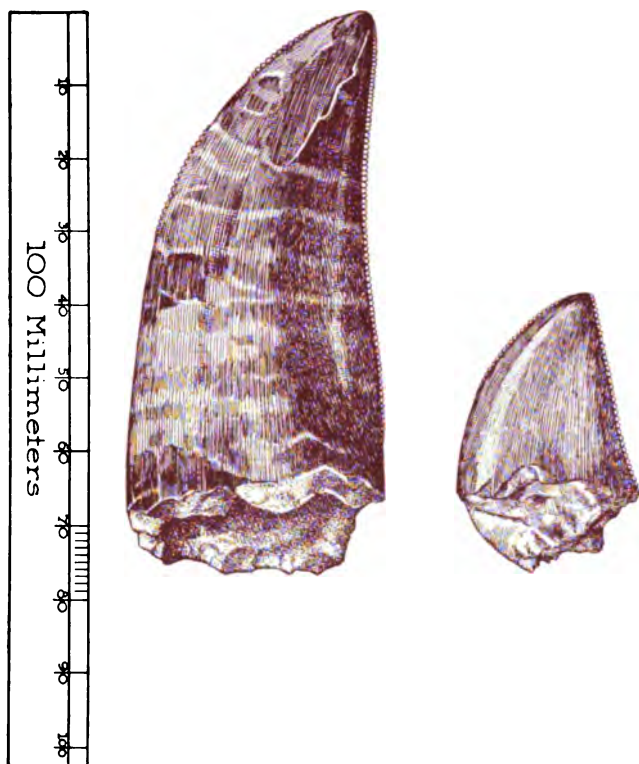
Teeth of a Carnivorous Dinosaur, discovered in the Denver
formation by Ruben W. Bowland.

of the greater portion of the skeletons of so many extinct animals were notably absent near Denver—fluviatile rather than lacustrine conditions prevailing during the deposition of the Denver beds. So instead of the entire skeletons of mired animals, as a rule, but isolated bones, widely dispersed by river currents, can be found and these with difficulty discoverable because of the massive mantle of Pleistocene material which obscures so large a portion of the surface. At the time when Prof. Marsh examined these collections, he was receiving from his field parties in the western states enormous quantities of the most interesting material and had, therefore, but little time or patience to examine the inferior collections from this locality. The writer believes that if these collections could receive a more thorough examination a greater number of species could be credited to the Denver formation than is given in the list at the end of the chapter on vertebrate paleontology in the Monograph on the Denver Coal Basin. In addition to a probable increase in the number of chelonian and crocodilian species Prof. Marsh, in private letters to the writer, spoke of the collection containing the bones of some large carnivorous dinosaur and also, after the publication of this monograph, identified a tooth found at Berkeley Bluffs as belonging to the species not uncommon in the Ceratops beds of Wyoming *Palaeoscinus latus* Marsh.

The accompanying plate shows two teeth of flesh-eating dinosaurs found in North Denver on the banks of Green Mountain Creek (Dry Creek) which although much larger, bear a marked resemblance to the figures of the teeth of *Megalosaurus Bucklandi.* A similar tooth was found many years ago by Prof. A. Lakes near the southwest end of South Table Mountain at Golden and another was recently found in the ravine on the north side of Berkeley Bluffs. These teeth probably belonged to a large species of theropodous dinosaur like the *Laelaps aquilunguis* Cope which is estimated to have been twenty-four feet long—animals which were probably largely responsible for the extermination of the gigantic but excessively stupid, herbivorous, horned dinosaurs.

Since the publication of the Monograph, the exposures of the Denver beds have received repeated examination by hundreds of students of the State School of Mines and from the Denver High Schools who were familiar with the appearance and location of fossil bones but beyond fragmentary specimens of horned dinosaurs such as the fine horn core presented to the East Denver High School by Horace Danforth, Esq., occasional teeth of crocodiles, and isolated scales, but little of value is known to have been secured. Miss Marian Yerkes, a pupil of the East Denver High School recently obtained at Berkeley Bluffs a specimen of considerable interest —the incisor of a Multituberculate animal resembling the specimen in the National Museum labeled *Priacodon ferox.*

This tooth and a Multituberculate molar, lost before specific determination could be secured are the only mammalian remains known to have been found in the Denver beds of this vicinity.

The Pleistocene deposits, mainly the river drift deposits of the ancient Platte River and its tributaries, have yielded additional bones of the three species of elephants that once roamed in this vicinity, discoveries having been recently made at Golden, Morrison, Brighton and Littleton. A fine tusk and some vertebrae were found in the ravine made by the run-off from Cooper's Lake in North Denver. Isolated molars have also been found near the corners of 14th and Lawrence streets and at 17th and California streets. Some Mastodon teeth are reported to have been secured near Cripple Creek and at Boulder.

In connection with the recent controversy in Science relative to the alleged pebble-swallowing habits of reptiles, for digestive purposes, it may be of interest to recall the fact that similar highly polished, siliceous pebbles, foreign to the formation in which they were found, were found in intimate connection with the bones of the type specimen of *Atlantosourus immanis* Marsh and perhaps with the type specimen of what was formerly known as *Apatosaurus ajax* Marsh.

Some fine specimens of the leaves of fan palms, originally eight to ten feet in diameter have just been discovered by the East Denver High School students and presented to the State Museum in the Capitol.

The obligation of vertebrate paleontology to the neighborhood of Denver seems to be in some danger of being obscured by the remarkable discoveries made in recent years near Como and Converse County, Wyoming, and writers, more familiar with the recent than the earlier discoveries, have made statements which should receive correction, e. g., in recent works of F. A. Lucas occur such statements as "Nearly all the examples of these animals (Stegosours) come from Como, Wyo., the exceptions being two closely related species from England." "From the Cretaceous rocks of Converse County, Wyoming, have been obtained all the specimens of the great Triceratops so far found." "With one exception specimens of these animals (Triceratops) have come from Converse County, Wyoming." Labels bearing similar misstatements appear on the notable specimens in the National Museum which have been exhibited at several international fairs.

Reference to the files of the *American Journal of Science* and to various writings of Marsh, Cope, and Hatcher will show that the Stegosauria are by no means limited to Como, Wyoming, nor the Ceratopsidae to Converse County of that state, and that, without entering into the vexed controversy as to who were the first discoverers of these interesting forms, it is certain that Colorado shared with Wyoming the honor of having been the home of these extraordinary creatures and that members of this Society obtained from the immediate vicinity of Denver and its suburb Morrison some of the first specimens of both of these families. In the fourth edition of J. D. Dana's Manual of Geology and elsewhere the locality of *Ornithomimus velox* Marsh is given as Wyoming although Prof. Marsh expressly states that it was obtained by the writer in the Denver beds near Green Mountain. The writer was also surprised to find in the National Museum collection,

a specimen which he presented to the Peabody Museum at
Yale with the distince understanding that it bear the names
of the discoverers and the locality from which it was ob-
tained without any such label.   The notoriety of this famous
bone of contention variously known as *Bison alticornis, Certa-
tops alticornis* and finally *Triceratops alticornis* makes it de-
sirable that it should be properly labeled.   It is to be hoped
that in the present revision of the fossil vertebrate material
of the National Museum, these glaring errors may be corrected
and that Denver and the members of this society may receive
proper credit for their discoveries and that the chronological
and distributional value of our local discoveries may not be
obscured by the more perfect specimens which have been
found in other portions of the west.

ORE DEPOSITS OF THE JOPLIN DISTRICT.

By F. L. CLERC

Read at the Meeting of the Society, December 1, 1906.

The decision of the American Mining Congress, whose sessions at Denver have recently closed, to hold its next annual meeting at Joplin, Missouri, suggests to me the thought that an outline sketch of the Joplin District might be acceptable to the Colorado Scientific Society, and that I might write a paper which would be of interest to some of its members. In presenting this subject even to a scientific society, I think it is proper to first call your attention to the present production of the district, as this is a measure of its industrial and commercial importance.

The following figures of the tonnage and values of the lead and zinc ores of the Joplin District during the years 1905 and 1904, and the amounts of pig lead and metallic zinc (Spelter) obtained from them, and the fluctuations in price during 1905 of both lead and zinc ores, are all taken from the special reports of Mr. Ingalls and Mr. Zook on this district, contained in Vol. XIV of Mineral Industry.*

For 1905 the production of zinc ore was 252,435 tons, its value at the mines was $11,335,280, from it was produced 124,000 tons of spelter. With this should be compared the value of the total amount of zinc ore produced in the United States which was used for the manufacture of Spelter, which was $15,596,457, and the total amount of Spelter produced, which was 201,748 tons. Some of this metal, however, was

*Published by E. & M. Journal, N. Y., 1906.

made from ores imported from Mexico and British Columbia, which is reduced to the equivalent of 40,725 tons of zinc ore. This was largely offset by exports of spelter ore principally from New Jersey.

The production of lead ore from the Joplin District in 1905 was 31,679 tons, its value at the mines was $1,968,480, from it was produced rather more than 22,175 tons of pig lead.

During this year the highest price paid for zinc ore at the mine was for first grade ore $60 a ton, for the same grade the lowest price was $43.50, and the average of all grades, Sulphides and Silicates during the year was $44.88.

For lead concentrates the highest price of this year was $80 per ton, the lowest was $57 and the average during the year for all grades was $62.12. For the year 1904 the output of zinc ore was 267,240 tons, its value was $9,572,160, from it was produced 128,000 tons of spelter. For this year the value of the zinc ore produced in the United States and used for the manufacture of spelter was $12,071,456, and the amount of spelter produced was 181,800 tons. Imports of zinc ores were unimportant. The production of lead ore for this district in 1904 was 34,362 tons.

Mr. Jesse Zook says, "The falling off of the production of zinc ore in 1905 was directly attributable to the extraordinary rainfall, amounting to 50 inches." The total value of lead and zinc ore at the mines produced in the Joplin district in 1905 was $13,302,000.00. Zinc ores used for the production of paint are not included in these figures.

The system of mining under which this amount of ores and metals has been produced requires a passing notice and partial explanation. In general the ore is discovered, mined and prepared for the market by unincorporated partnerships of working miners whose holdings under mining rights are usually small, often less than an acre in area and who pay royalty and pump rent either to the owner of the land or the company which has a lease upon it. Altogether the conditions appear at first sight quite anarchic and opposed to all

principles of successful mining. They are somewhat analagous to the method of working the Kimberly Diamond Mines before that field was controlled by a single company, and it is just as necessary to understand this system in order to follow the development of the Joplin district, as it would be to know the earlier history of the Kimberly mines in order to know just how the diamond industry in Africa has reached its present state of development. However, there are two sides to nearly every question, and like most human institutions this system is a natural outgrowth of temporary and local conditions. I have described this system elsewhere, and to this article would refer you. To show that something may be said in its favor I quote from this article as follows:

"Looked at altogether, as the main dependence of the zinc industries of this country, such a condition of affairs is far from being satisfactory, and yet it is not easy to suggest a practicable remedy......Nor is the present arrangement without obvious advantages in a new country, and it is seriously questioned whether any other could be as effective or as economical. When mineral is once discovered, it requires but little capital to open mines, and consequently individual risks are small. The miners working on their own account, with hopes of large gains, have every inducement to work hard and cheaply, and to follow every clew that may lead to the discovery of ore. There is a large body of keen, hard-working prospectors, who during season wander from place to place, live in wagons, under tents, or in the open air, and carefully observe and follow every real or supposed indication of ore. How else, it may be asked, could prospecting be so well or so cheaply done? And there is a class of enterprising, skillful, well-to-do miners, naturally associated as partners, who have made one or more good strikes, and are always ready to take hold of any new venture which promises well, either in working a lot or forming a land company to open new mines. Where else could be found capitalists so willing to risk their money in a speculative venture? Men of this sort are always ready and able to work themselves, or to direct the work above or below ground. How else could be obtained as willing and as watchful superintendents, foreman and clerks."*

This system with some inevitable modifications due to the development of the region and the higher price received for ores, continues in force to-day. I can only hope to touch

*Mineral Resources of U. S. Albert Williams, Wash. 1883, page 37.

upon the principal reports upon this region in the most general way. The first adequate geological report was written by Dr. Adolf Schmidt and was published in 1874. This was about the time I first visited Joplin. The town was then only a few years old, but the mines at Granby had been known and worked for about twenty years.

Considering the condition of the mines at that time and the means at his disposal, this report reflects very great credit on Dr. Schmidt, he covered the ground well, observed accurately and in many ways anticipated the theories which have since been advanced to explain the form and origin of the ore deposits.

He noted that the principal known deposits were not on the larger creeks but were on the smaller branches. That the coal measure shales and sandstones were not conformable with the Lower Carboniferous strata, that Dolomization was local, and was generally associated with deposits of ore. He says ores were deposited from aqueous solutions which found their way into existing cavities, joints, and solution cavities, and gives instances of deposits formed between a bar of rock and a talus of clay and broken material. He describes the ore bodies as occurring in openings, runs, and beds, and explains satisfactorily the formation of caves, sinks, and circles, and the effect of the circulation of underground water on the topography of the country. He also mentions secondary quartzite as a cementing material.

In the spring of 1887 after several years residence at Joplin, I wrote a short quasi geological essay* as an introduction to, so far as I know, the first complete and authentic statistics of the production of this district, by camps and companies, based on the sworn statements of company officials. Strange as it may appear, prior to this, land owners were very reluctant to make known figures, and ore buyers were instructed to keep secret the amount of their purchase. These

*Lead and Zinc Ore of Southwest Mo. Mines. Authenticated Statistics. The output of lead and zinc ores from this mining district for the year ending March 25, 1887, by Jno. N. Wilson, Carthage, Mo., with contributions by F. L. Clerc and Thos. N. Davey.

statistics were collected and published by John N. Wilson then Editor of the Carthage Democrat. It is a pleasure to be able to state that since that time, the weekly production of the region, by camps, that is towns or districts, has been regularly published by the local papers with very considerable accuracy, and for many years has been published in the Engineering and Mining Journal. As I continue to hold in the main the views I expressed at that time, I shall quote from this essay as follows:

"If we somewhat extend the term 'lateral secretion' so as to include secretion from any side, that is from above or below, as well as from the walls of a vein or opening, and do not insist that the minerals shall be deposited against the outside of the formation from which they are leached out, but admit that they may have been conveyed some distance before deposition, then we may say the deposits have been formed by lateral secretion."........

"The question still remains, what are they (the minerals) secreted from? From the limestone beds? From the flint beds? From the slates or clays which in places overlie the rocks? Or from some bed above or below that we may have never seen and perhaps may never see? This question if capable of being answered, can only be answered by minute and careful chemical analyses."

After noting the occurrence of local basins of black shale in all the principal camps of the district, I say:

"The conclusions I draw from these slate basins are as follows, first: Before the slate was deposited here, it had formed part of a coal bed in place, 2nd, before it was brought here, the limestones and flints of the lower carboniferous period had been deeply eroded by both surface and underground streams to the depth at least to which these slates are found, 3rd, that the filling up of these old water courses leveled up the country and the present system of rivers, creeks and branches, dates from that period and is wholly or in part a new one, 4th, that (some of) these materials must have been brought to where they are, in the form of very fine mud or silt, as though they were dropped from a slow moving river, or a broad lake."*

"They seem never to have covered the highest lands, for here the top clays rest on solid beds of either limestone or flint, these top clays seem to have resulted in part from the disintegration in situ of lime-

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*After the lapse of twenty years I cannot recall what particular occurrence I had in mind, this appears to be the case with some thin beds of shale which feather out on the top of rock in place, but does not apply to the deeper deposits lying under sub-carboniferous rocks.

stone and chert beds, and in part resemble the so-called gumbo clays which cover the Kansas coal beds. Above both of these kinds of clays, there are often found on high ground beds of rounded river pebbles, which are flint and contain fossils common to the region.

"The carving out of the later valleys has been a very interesting operation, starting from the general level of the high prairies, the action of the rain water flowing over the water sheds has for a large part of its course to spring river been mainly chemical, dissolving carbonate of lime, and thus enlarging the minutest cracks in the rock to which it can find entrance. In this way only can be explained the facts that for a large part of their course there is little washing out of the surface clays by the small streams, and the strata of rock are often continuous across the bed even some distance from (the) head, pitching toward the bed on one side, and rising on the other. Farther down stream, where the volume of water is greater, and the fall more steep, the roof over the underground stream breaks down and the current washes away the broken up material, and there is only left, at the side of the stream, broken strata pitching towards the center. Evidence of these underground streams, can be found throughout the region, in many cases they are sufficiently large to carry all the ordinary flow of the stream, so that only the flood waters are carried by the surface bed, which there becomes a dry fork. Underground branches, particularly of Turkey Creek can be traced coming out of the caves quite a distance away from the surface branches. The width of the valleys of the present streams, and the amount of erosion they have effected proves them to have been once much larger streams. All this appears to have taken place since the black slate was placed where it is now found. If the date of this be fixed as the close of the Ice Age and the melting of the glaciers which has plowed deep north and south grooves through the coal fields of the north, it brings the origin of the present ore deposits down well into the Quarternary age. If now lead and zinc were contained in even the minutest traces in the black slate, it is easy to see how laternal secretions would effect their concentration. The small portion of the rainfall which worked its way through the slate would slowly leach out its mineral salts. This water could only circulate very slowly, drop by drop, but it would surely find its way into every crack and crevice open to receive it, and in some of them the minerals would be crystallized out. Thus every slate basin would become a separate source of ore deposits. The few that remain may be only a small part of those which once existed but have been entirely washed away. Going on simultaneously would be the action of the surface water carving out the valleys and the low lands. As this cutting reached the mineral beds already formed, it would cut through them, break them down and mix them together

with other debris at the sides of the valleys. In some of the ore de-
posits it looks as though the mineral bearing waters had taken possession
of drainage channels and filled them with ore, and forced the surface
water to carve out new ones. It is certain, on the other hand, that if
the surface waters were turned into ore channels they would soon cut
out, oxidize and carry away the ore which they contain. In all the
mining camps there are, apparently more recent water courses crossing
the ore fields, and sometimes only a few feet distant from large ore
bodies, in which it would be useless to attempt to find ore. Practical
miners recognize them, and call them mud openings."

About this time or shortly afterwards, an appeal was
made to Hon. J. W. Powell, who was then director of the
United States Geological Survey and also to the secretary of
the interior, Gen. John Noble, who was a Missouri man, to
have the general government make a geological survey of the
region. The grounds on which we principally based our peti-
tion were that it embraced portions of three states, Missouri,
Kansas and Arkansas, and extended into the lands of the
Indians in the territory, who were wards of the nation. In
answer to our request, Dr. Walter P. Jenney was detailed, and
Mr. J. D. Robertson of the State Survey was assigned as his
assistant. Mr. Jenney went over the country very thoroughly
and the result of his examination is given in a paper he read
before the A. I. M. E. in Chicago, 1893.

As his views are set forth somewhat at length in connec-
tion with Mr. Buckley's report, I think I can fairly summarize
them here in the words of Mr. Jenney himself who closed the
discussion which followed the presentation of his paper. The
italics are in the published report.

"Faulting and the disturbances of the strata are the controlling
factors influencing the localization of the lead and zinc ores throughout
the Mississippi Valley. This is true as well for all metalliferous forma-
tions in all the mining regions of the globe, so that the law may be
stated as universal that *all workable deposits of ore occur in direct asso-
ciation with faulting fissures traversing the strata, and with zones or beds
of crushed or brecciated rock, produced by movements of disturbance. The
undisturbed rocks are everywhere barren of ore.**

*Jenney Vol XXII Trans. A. I. M. E. page 642.

Mr. Arthur Winslow, who was at that time State Geologist of Missouri, did not concur with the views of Mr. Jenney, his own conclusions were presented in two papers (English and A. I. M. E.)

His formal report was issued as Vol. VI and VII of the Missouri Geological Survey by his successor, Charles R. Keyes, Jefferson City, 1894. I quote from this report.

"The principal hypotheses advanced are as follows: 1. Original or simultaneous deposition with the rocks, in a concentrated condition, from oceanic waters. 2. Derivation from great depths in solutions ascending through profound fissures, from which the minerals were deposited in cavities, or impregnated the rocks.

"3. Original diffusion through the country rocks, and subsequent concentration by percolating waters, by the process known as lateral secretion. 4. Original diffusion through the country rocks and subsequent concentration through surface decomposition of the latter, supplemented by percolating waters."

After considering the first three hypotheses, and dismissing them as untenable, Mr. Winslow says:

"4. Concentration through surface decomposition. This hypothesis which we now formally advance, starts with the proposition that the metalliferous minerals originally existed in the Archean rocks, either in a disseminated condition or in veins. With the decay of these early rocks, the minerals became diffused through later formed sediments, this diffusion being quite uniform over contiguous areas. Successive decaying of successively formed rocks simply resulted in the transfer of these minerals.*

"The silicification which gave rise to the secondary cherts of these bodies must have taken place at the same time or shortly after. To the post-Lower Carboniferous, or early Coal-Measure epoch we therefore assign the formation of the principal deposits of S. W. Missouri."

(Robertson's analyses are found in above p. 479 et seq.) They are condensed by Winslow as follows:

	Lead.	Zinc.
Archean Rocks. Range of 8 Analyses of 4 Samples	0·00197–0·00680	0·00139–0·01760
Silurian Limestone. Range of 12 Analyses of 6 Samples	Trace–0·00156	Trace–0·01538
Lower Carboniferous Limestones Range of 15 Analyes of 7 Samples†	Trace–0·00346	Trace–0·00256

*Mo. G. S. Vol. VII pt. 2 Winslow. C. R. Keyes 1894, page 477.

†Averages of J. D. Robertson's Analyses quoted by Winslow, Vol. XXIV Trans. A. I. M. E., page 684.

In XXII Annual Report U. S. Geol. Sur. 1901 there is a preliminary report on the Lead and Zinc deposits of the Ozark Region, by Messrs. Van Hise, Bain and Adams. I quote from the introduction of Prof. C. H. Van Hise.

"Considering now the Mississippi Valley lead and zinc region as a whole........In all of the districts, the Cambro-Silurian limestone is regarded as the immediate source of the ores. Through these limestones are widely dispersed minute quantities of lead and zinc compounds which served as the supply."........"While the wide-spread occurrences of lead and zinc in the Cambro-Silurian limestones of the Mississippi Valley, bounded by relatively impervious shales, leaves no doubt in my mind that the limestone itself is the main source of the ores, I express no opinion as to the manner in which the exceedingly small fraction of 1 per cent lead and zinc was originally deposited in the limestone." He then outlines T. C. Chamberlin's theory of the precipitation from sea water, and adds "If the theory given above be correct, the occurrences of lead and zinc in all the districts of the Mississippi Valley furnish excellent illustrations of that class of ores produced as a result of a first concentration by ascending waters and a second concentration by descending waters."*

In a paper† presented at the Mexican meeting of the A. I. M. E.

Mr. Chas. R. Keyes, formerly State Geologist of Missouri, says:

"During the past decade the genesis of the lead and zinc deposits of the Mississippi Valley has received special attention from many distinguished observers. But their united efforts, instead of settling all disputed questions, have, in many respects, involved the question in greater obscurity than would have been thought possible under the circumstances........ there is unexpected disagreement, largely due to the fact that, instead of giving attention to a possible multiplicity of ore producing conditions among the different deposits, the attempt has been made to bring all deposits under a single genetic head........The problem involved (diverse origins, etc.), has not been generally recognized as yet by students of ore deposition; but, among investigators of rock-metamorphism, it has been repeatedly solved in many different phases."........ "The revelations of the microscope along this line in connection with the crystalline rocks also bear directly upon the phenomena of ore-deposition."

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*An. Report U. S. G. S., Pt. II., pages 59–60, Wash. 1901.
†Diverse Origins and Diverse Times of Formation of the Lead and Zinc Deposits of the Mississippi Valley, Nov. 1901.

He instances Allanite and Epidote as representative of a large number of metalliferous and non-metalliferous substances which enter into the constitution of igneous rocks. He mentions four methods of genesis of epidote in igneous rocks, not including "the common process by which *ores* are most widely formed, that is directly through the agency of circulating waters" and says "In certain Maryland granites, epidotes of at least three different origins are believed to occur in the same rock-mass." He further says:

"Of late years, a number of writers have attempted to account for the presence of lead- and zinc-ores on the hypothesis that the metallic materials arose in heated solutions from the non-sedimentary zone of the earth's crust, through openings formed by profound faults. Posepny and Jenney especially have emphasized this view. On the other hand, students of the same region do not consider as possible, for any of these ore-bodies, a deep-seated source."........"The lead-and-zinc deposits of the Ozark region present at least four distinct types of genesis. They have been formed through: (1) fumarole-impregnation, or pneumatolysis; (2) fissure-occupation, in which heated waters rise from the depths; (3) precipitative action, or reduction in contact with organic matter; or (4) crevice-accretion, in joint spaces and porous layers, and derived from ordinary ground waters."

He cites as an illustration of class (1) the

'Silver Mines 20 miles east of Ironton, Missouri,' in 'Algonkin Granites.' ....lately investigated by Haworth."*
........"Picked samples of the ore are said on good authority to have yielded as high as 300 oz. of silver to the ton."........"The time of formation of this........is pre-Cambrian, since the filled fissures are all truncated by pre-Cambrian erosion, leaving the Cambrian strata unbroken over all."

As illustration of (2) he cites:

"the argentiferous lead- and zinc-ores of central Arkansas on the southern border of the Ozark highland."........Comstock† seems to associate these silver-bearing ores with a peculiar system of faults which traverse the folded region diagonally."

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*Mo. G. S. Vol. VIII, page 83.
†Arkansas G. S. Annual Report 1888, page 219.

"The evidence which he produces indicates almost conclusively that the ore-bodies were formed by thermal waters rising along dislocation planes........Some of the ore bodies appear to occur in the vicinity of old hot springs, similar to those which are still in operation in this region."

As illustration of class (3) :

"of small practical import," "The blende reported by Wheeler‡ in lignite from middle carboniferous sandstones near St. Louis"........"the blende-deposits.......in the coal beds of Morgan Co.,* and the pyrite tubules in the loess-deposits."§

As instances of class (4) Crevice-Accretion, he says:

"The gash-veins and crevices of S. W. Missouri, and of the Dubuque District, and the desseminated ore-bodies of S. E. Missouri, all appear to have the same origin. The most recently acquired information in all these districts precludes the supposition that the ores were formed from thermal waters rising from the deep-seated zones. All evidence points to their deposition from circulating underground waters at ordinary temperatures under well-known hydrostatic conditions........The only essential difference between the disseminated ores and the crevice ores is, that in the case of the former, deposition took place chiefly in horizontal porous layers, and in the latter chiefly in the vertical spaces opened out along joint-planes or small faults in rocks having no porous layers."........"In S. W. Missouri district, the conditions are peculiar ....much of the water that falls upon the surface is carried off in deep underground channels. In the case of larger streams, the roofs are continually caving in, and the disentombed waters flow in deep, narrow canyons."........"The subterranean water courses are subject to the same laws of aggradation as the rivers open to the sky........Many of the frequent faults of small throw have been manifestly produced since the ore-bodies were formed. Moreover, the few known great faults are not usually associated with ore-bodies........The geological date of the formation of the ore-deposits has been a theme of more or less discussion."........"To the fourth group, which contains practically all of the productive deposits at present worked extensively, a very recent geological date is assigned. In the Ozarks, deposition began to proceed vigorously with the last period of up-lifting of the region, which occurred since Tertiary times. The up-rising is even now evidently going on rapidly, and with it, ore formation also. The formation of blende crystals, a quarter of an inch in size, on old nails immersed in mine-waters

‡St. L. A. Sci. Vol. VIII, page 123.
*Trans. A. I. M. E. Vol. XXX, page 346.
§A. J. Sci. (4) Vol. VI, page 299.

for fifteen years, gives an idea of the rapidity with which the process may actually go on. It is not at all unlikely that most, if not all, of the Ozark deposits of this class were really formed within the memory of man."

In justice to Mr. Keyes, I ought to say that all of my quotations are taken from an advance copy of his paper which is issued subject to revision. I do not find his paper in the published Transactions A. I. M. E.

Mr. C. E. Siebenthal of the U. S. Geol. Sur. in a paper published by permission of the Director of the Survey,* says:

"From the beginning of geologic investigation in the Joplin District there has been much difference of opinion in regard to the structural features. All are agreed that the region, in common with the remainder of the Mississippi Valley, was subject to extensive erosion before the deposition of the Coal-Measures. All are agreed that while minor faulting is common, horizontal juxtaposition of Coal-Measures and Mississippian rocks can only be accepted as evidence of profound faulting with much hesitation.".........The question of the magnitude of the faulting is one of much scientific interest and economic importance.".........
"The writer visited the blanket-vein or 'sheet ground' workings on the Cornfield tract of the American Zinc, Lead and Smelting Co., and neighboring tracts south of Carterville. Through this territory runs a line of disturbance that throws much light on the structural features of the district. In this vicinity there are irregular pitches of Coal-Measure shales and sandstones lying unconformably in depressions in the Boone formation which constitutes the country rock of the region. The sheet ground is reached about 170 feet from the surface, and the working face averages about 10 feet in height. The ore occurs near the top of a heavy development of flint in the Boone, and the super-jacent rocks consisting of the limestones and cherts of the Boone, together with patches of Coal-Measure shale and sandstone as noted. Here and there the undisturbed stratigraphic arrangement or 'regular formation' is replaced by 'confused' or 'broken ground,' an intimate mixture of limestone and chert boulders in a cement of spar (dolomite), selvage or shale, or all three.".........On the Cornfield and adjoining properties the sheet ground has been mined out over an area of 2,000 feet long by 400 to 800 feet wide, thus offering excellent opportunity to detect any deformation of the bedding. Through this area runs a 'barren bar' of deformed, confused and broken ground, in width varying from 50 to 300 feet, and in length, with its extension beyond the Cornfield, nearly three-quarters of

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*Structural features of the Joplin District, Economic Geology Vol. 1, No. 2, page 119, et seq., 1905.

a mile.".......".The bar is usually barren or poor in ore, but the richest of the sheet ground lies within 30 or 40 feet of it."

Four sections across the bar are given and discussed in detail, all the sections are included in a length of about 800 ft.

"After noticing the surface distribution of the shale, a study of Sec. 1 would very logically lead one to conclude that the shale was thrown down here 185 feet from the surface as the result of a fault, or perhaps more probably of a double fault letting down a long, narrow block of shale........The evidence is as decisive for deep faulting as has been seen in the district.........however, a study of the next section to the west 150 feet shows that the total displacement by faulting and folding is only ten feet. On the Richland, on the continuation of the bar to the S. E. there is no deformation whatever........If the shale was not faulted down, how came it there? First and most important is the non-conformity of shale and limestone........The second important factor has been solution........In other places in the district the shale fills extensive cave galleries in such a way that it could only have been deposited by underground drainage."

"Lastly, faulting and deformation are plainly shown in the section ....It does not exceed 25 or 30 feet at the utmost, and is incompetent except in combination with unconformity to bring the shale to such depths."

Discussing this paper Mr. Bain says:*

"Mr. Siebenthal has shown........that many at least of the apparently heavy faults have only a slight throw........the burden of proof is evidently upon us, if any there be remaining, who would still maintain a belief in faults of larger throw........In the matter of the bearing of these discoveries on the theory of the genesis of the ores I shall not at this time say much. While it is true that single faults of four to six feet are not likely to persist in depth two thousand feet or more, it is none the less probable, as it seems to me, that such zones of faulting as are present do break up and disturb the rocks sufficiently to establish a connection between the artesian waters of the Cambro-Ordovician and those of the Boone formation. Such a connection seems furthermore to be established by many independent facts of ore occurrences and association, and such a connection is all that is necessary so far as is concerned the theory of genesis put forward by myself and associates in the work of 1900."

*Idem.

Last May I prepared a paper which I have presented to
The American Institute of Mining Engineers. Before speak-
ing of this paper, I shall ask your attention to the last report
of Mr. E. R. Buckley. I do not know when this report was
printed. The letter of transmittal is dated Nov. 1st, 1905. I
did not see the report until last July. From this report I shall
quote freely.

"We believe (with Winslow) that the lead and zinc was originally
deposited in the marginal sediments of the Pennsylvania sea, and that
the localization of the ore bodies is due to the character and dis-
tribution of the drainage from the land area which existed during
Lower Coal Measure time. We do not believe that the lead and zinc
minerals were concentrated in the breccias at the time the shales were
being deposited, but that the deposition of the lead and zinc was in
minute quantities through portions of the coal measure shales. We
believe that the present position of the ores is the result of a concen-
tration by circulating ground water.*

Referring to the views of Van Hise and Bain he quotes
from a paper presented at a meeting on the Institute of Min-
ing Engineers in London in 1902:

"On page 20 they say 'In every case the ore bodies are found where
there is the clearest evidence of the movement and mingling of consider-
able bodies of solutions......No ore bodies have been found except in
areas where there was opportunity for a mingling of the ground waters
of the Carboniferous and the Cambro-Silurian limestones........Only
when opportunity was afforded, by deep fault planes cutting the inter-
vening shale, for the waters of the Cambro-Silurian to rise and mingle
with the waters above, was there any considerable ore-deposition, and it
is an interesting confirmation of the correctness of this view, that dolo-
mite is a constant accompaniment of the ore. Wells penetrating the
carboniferous rocks away from the ore bodies, yield water practically
free from magnesia. Those penetrating the Combro-Silurian show that
the water is notably charged with magnesia. This indicates that both
the magnesia and the metals now found in the ore bodies were brought
into the carboniferous rocks from or through the Cambro-Silurian
below......The Eureka-Kinderhook shale prevented the actual upward
flow, until the faulted area near Joplin is reached, where the water
passed upward along fault places.' "

*Geology of the Granby Area, E. R. Buckley and H. A. Buchler, 1905.

Buckley also quoted Bain.*

"The best reason for believing that the ground water is fed mainly from distant sources, lies in the fact that the amount of water pumped from the mines is independent of seasonal changes. Except in the case of unprotected openings or very open ground, severe storms and rainy weather do not increase the amount of water that must be handled."

Also,†

"The presence of deep fractures‡ in the Joplin regions is shown by faults of 100 to 150 feet or more........In this district the faulting is made clear by the relations of the overlying Coal-Measures, shales and sandstones to the limestones and cherts of the Boone formation. These relations are, however, obscured by unconformity between these beds, and by the influence of downward settling as a result of solution."

"Brecciation and faulting are closely associated throughout the district; they occur together along zones of fracturing. The same stress has been relieved at one point by brecciation and at another by definite fracturing or faulting. Brecciation is far the more common, and this seems an expression of the general law that stresses are relieved more frequently by many small fractures than by a few large ones."

Upon these and other quotations he comments §

"It is evident from the above extracts from Van Hise and Bain, that they consider the southwestern lead and zinc district, of which the Granby area is a part, the clearest exposition of the theory of a first concentration by an upward circulation, and a second concentration by a descending circulation, of any of the districts of the Mississippi Valley. This being the case, it is of the utmost importance that the attention of the reader should be directed to certain structural features of the district which we believe have been misinterpreted. A short time after the publication of the report on 'The Lead and Zinc Deposits of the Ozark Region,' a week or so was spent in an examination of the Aurora area. Later this area was visited a second time. We were unable to identify the faults indicated on Bain's map, and from their position concluded that the unconformity between the coal measures and the Mississippi limestone had been mistaken for faulting. Since that time most of the localities in the district where faulting has been mapped have been examined and we are unable, in any instance, to find any major faulting........Upon the belief in deep seated and extensive faulting, is based the theory that the lead and zinc had their source in the

*XXII An. Report U. S. G. S. page 168.
†Idem.
‡Idem, page 174.
§Granby Area, page 19.

Cambro-Ordovician formation. To bring them near the surface, an artesian circulation is necessary, and in order to supply an artesian we must have deep seated faulting or brecciation. Without these the theory is apparently untenable. Another proof which Bain cites for believing that the ground water is derived mainly from the Cambro-Ordovician is given in his statement that the amount of water pumped is independent of seasonal changes. We do not know from what source this information was obtained, but it is contrary to all that we have been able to learn in the district. Another reason given by Bain for the ores having a deep seated origin, is the occurrence of large quantities of dolomite. He states that there is no other adequate source from which the magnesia could have been derived. W. P. Jenney believed that the Mississippian limestone was the source of the magnesia. We believe that the Pennsylvania strata, which have been practically removed from this area, contained an abundance of magnesia to provide all the dolomite associated with the ore bodies in the district. If one will read carefully Bain's characterization of the ores of the first and second concentration he will find the description to be somewhat confusing. ....To make ourselves clear, let me say that from our investigation we are unable to distinguish any well defined first and second concentrations. The concentration has been practically continuous, subject to interruptions occasioned by physical changes accompanying periods of elevation and subsidence."

Mr. Buckley quotes Mr. Jenney*

"The result of this investigation of the deposits of lead and zinc in the Mississippi Valley has made it possible to announce the general law that all workable deposits of ore occur in direct association with faulting fissures traversing the strata, and with zones or beds of crushed and brecciated rock, produced by movements of disturbance. The undisturbed rocks are everywhere barren of ore.".......... "For the occurrences of ore deposits it is requisite not only that the strata should be disturbed and faulted, but that the fissures should penetrate to, and form open channels connecting with the zone of supply of the ore-forming solutions, which may be located at a considerable depth in the earth; also that the pressure should be sufficient to force the mineralizing solutions to the surface; that the solutions should contain metallic substances in adequate quantity, and that the physical and chemical conditions should be such as to permit ore deposition. Through the absence of any of these conditions, districts otherwise favorable for ore may remain unmineralized.".......... "In conclusion, it may be said of the fissures, which occur in direct association with the deposits of lead and zinc ores in

*A. I. M. E., Vol. XXII, page 171, et seq.

the Ozark and Wisconsin uplifts, that they are not the result of local causes, and are not confined to a narrow vertical range, or to rocks of a similar lithological character, but on the contrary that these fissures are the result of forces connected with widespread dynamic disturbances, affecting the North American continent, and that the fissures are faulting-planes of indefinite vertical extent, traversing all the geological formations from the crystalline rocks to the Coal-Measures."........"All the deposits of lead and zinc ores in the Ozark uplift belong to the great class of fissure fed impregnations and may be designated as runs, a term by which this form of deposits is known to the miners."

Upon these and other extracts his comments are:*

"Mr. Jenney was evidently very firmly imbued with the idea that the southwestern lead and zinc district is traversed by numerous faults extending to great depths, and even penetrating the pre-Cambrian formations.........A careful study of this district has not yet revealed the presence of extensive faults........Analyses of the water from deep wells show the presence of practically no lead or zinc. Mr. Jenney's theory of the deposition of the ores is based upon the same facts as is the Van Hise-Bain theory, and therefore is open to the same objections."†

In elaborating his own theory Mr. Buckley says:

"The Pennsylvania strata covered this area to an unknown depth, probably hundreds of feet, having been almost completely removed by subsequent erosions."......."At the close of the Mississippian, there was an erosian period of considerable duration. During this period the upper beds were removed and the land deeply trenched by running water. The underground waters flowing along joints took the limestone into solution, producing caves, caverns and sink holes."........"It may be well to repeat that there is no evidence that either lead or zinc or dolomite in any form was deposited during the Mississippian period or the post-Mississippian erosion interval; that there is evidence of deposition and solution of silica, and that the limestone was very generally re-crystallized and removed in solution where it came within the belt of weathering."

After giving a very interesting account of the several varieties of chert, he sums up with this resume:‡

"As stated elsewhere, there was established in pre-Pennsylvanian times a system of drainage which, in many places, practically coincides with

*Granby Area, page 25.
†Page 29, et seq., idem.
‡Idem, page 41.

the present. Prior to the Pennsylvanian time, the beds of Mississippian limestone were decomposed and disintegrated, and the hillsides were strewn with chert fragments in a manner very similar to that in which they are today. Not only were the systems of drainage well established, but there were produced sink holes of large and small dimensions, forming circular and often irregular depressions at the surface. There are very few within the area included in this report, but elsewhere in the South-western Lead- and Zinc-District they are abundant. The encroachment of the Pennsylvania sea resulted in covering the uneven land surface with an unknown thickness of sandstone and shale. The old stream channels and the circular depressions resulting from sink holes were filled with these sediments. The residual flint, which covered, in places, the flanks of the hills and tops of the ridges, was deeply buried. The open porous zones, formed by this mantle of chert along the hillsides, became channels through which the ground water circulated freely and abundantly.........In many cases the present streams are flowing through valleys which were developed in pre-Pennsylvanian time. There still remain, however, small areas of sandstone and shale, nestled back in the hills and sunk into depressions on the prairie land, where they have been protected by the surrounding more elevated beds from the active agents of erosion."

"The manner in which the lead and zinc minerals occur within the openings varies widely in different parts of the area, depending chiefly upon the nature of the opening. Where the opening consists of broken flint or boulders of flint forming a brecciated mass, the lead and zinc minerals occur in the interstices among the so-called cod-rock, black flint, dolomite and other associated minerals. Where the rock within the opening is more or less stratified, and where the flint nodules are still found intact within the opening, the ore is usually in sheets approxi-mately parallel to the roof."*........The openings in which the ore occurs were to some extent at least formed by solution during pre-Pennsylvanian times. After the deposition of the Pennslvanian rocks, these openings constituted channels through which the ground waters circulated with the greatest freedom."

"Everywhere it is clearly evident that the geologists who have formerly mapped extensive faults in these districts have mistaken un-conformity for faulting. The faults mapped in the Aurora and Granby areas are lines of discordant bedding, due to the unconformity between the Mississippian and Pennsylvanian series."........"All of the above observations go to show that associated with the ore bodies in the Gran-by area, or even in the Southwestern or Central districts, faults, of sufficient magnitude to have any but a very minor relation to the forma-tion or distribution of the ore bodies have not been recognized.".......
"It follows as a corollary that there are no fault breccias in this area.

The so-called breccias are, in part, basal conglomerates belonging to the Pennsylvanian era, and in part solution breccias. The latter, however, are often so intimately associated with the conglomerate as to make the separation a matter of some difficulty and greater uncertainty."......
"The absence of faults and fault breccias argues that very little, if any, of the deep-seated ground water reaches the superficial zone in which the ores occur. It has been shown by analyses, made in the laboratory of this Bureau and elsewhere, that the water from the deep wells"— "those penetrating the Cambro-Ordovician series"—"contain no appreciable quantity of zinc.".......·"The absence of brecciated or fault zones argue against the lead and zinc having been derived from the magnesian limestones of the Cambro-Ordovician series by an artesian circulation, as held by Van Hise, Bain and others. We therefore hold that the ore bodies from the first to the nth concentration are the result of converging, downward circulating waters, the oxidizing portions of which carried the metallic salts, and the reducing portions the organic matter, which was an important factor in furnishing the conditions necessary for precipitation."†

"That there was undoubtedly considerable difference in the Pennsylvanian throughout the ore producing area of Southwest Missouri, is shown in the abundant sandstones found at Aurora and Granby, while in the Joplin and Webb City areas the remnants of the Pennsylvanian consist chiefly of shale."‡

Mr. Buckley goes very fully into the chemical reactions involved in the formation of observed minerals, and he finds in the order of their occurrence a strong additional argument, against the theory that they were first deposited from an ascending solution and then concentrated by descending waters, a large part of his report deals with the formation of silicate and carbonate of zinc and carbonate of lead, which are an important part of the Granby output, but are of rare occurrence elsewhere, except at Aurora.

In connection with Mr. Keyes surmise that some of the deposits now worked may have been formed at a very recent period, it may be of interest to put on record the somewhat meagre details I am able to recall of the finding of Elephant bones in a quagmire of black muck, the washing from the

*Page 61.
†Page 78, et seq.
‡Page 104, idem.

adjacent shales, among the zinc mines in Center Creek bottoms. It was stated at the time in the local papers, that more or less perfect skeletons of seven individuals were uncovered. There was one or more very large tusks 8 or 9 feet long. And one baby elephant. The find was made about 1891, and it was at once proposed to exhibit these bones at the Chicago Exhibition. The finders put such an extravagant value on their find, and the skill and expense required to preserve them in their softened condition was so great, that I regret to say they were not preserved. I made careful inquiries at the time and I believe the substantial accuracy of this statement can be relied upon. Some additional particulars, might still be gathered from newspaper files and from old residents.

A paper which I have presented to the American Institute of Mining Engineers, has been accepted. It was completed and out of my hands last May, more than a month before I knew of Dr. Buckley's report. It is somewhat uncertain how long it will be before this paper can be printed, for this reason I will attempt to present to you some of my conclusions, and carry them out a little farther. For the purpose of study, I have divided the country around Joplin, topographically into three classes, namely, the upland prairies, the bottom lands of the main creeks, and the broken land between these two. Selecting the first class, the upland prairies as presenting the simplest problem, I have worked out in detail a system of shallow drainage on the surface and underground, and I think have established a definite relation between these two, both genetically and topographically, that is, they are both due to the same cause, the annual rainfall, and the operation of natural forces tends to develop them pari passu. The knowledge gained on the prairies can be used to interpret the formation and structure of the broken ground. The forces at work are precisely the same, but the effect of the topography, which is itself an effect of this shallow drainage and in turn a controling force, is to favor the intersection of both surface and underground channels, so that the tendency of both surface

and underground streams is to change their channels frequently.

This broken country has yielded and is yielding very large amounts of ore, but the deposits are quite irregular and are not easy to follow. They to some extent justify the term "pockets" so often used in connection with the mines of this region. But it is in the development of the bottoms of the main creeks that most is to be hoped for in the application of the theory. It is well established that in some cases at least the bottom of the shale filled "cave galleries" are below the beds of these main creeks. The creek bottoms are in many places saturated with water, prospecting in them is very expensive. It is therefore of the utmost importance to determine if possible, and to select for prospecting those places where these ancient water channels pass under or debouch into these bottom lands. My conclusions as to the deposits themselves are as follows: I believe that the "Locus" of the principal ore deposits of the Joplin district is a system of surface and underground water channels, which was once much more closely connected with the surface drainage, than it is now. That the agency which diverted the surface waters from those old courses, was a geological and not a chemical one. That this diversion has been effected within comparatively recent times long after the close of the Carboniferous age. That the ores where we now find them, were deposited by mineral bearing waters which found access to these old channels, and a retarded passage through them after the surface waters were largely excluded. That this old system of surface and underground drainage is strictly analagous in form and origin to the present drainage system, but is entirely distinct from it. That, where the later system intersects the ancient system, the surface waters rapidly cut out and dissolve the ores. That the ore bodies of the region form a true system of connected and ramifying ore veins, which presents just as definite a problem to be worked out as do the surface and underground streams of the present day. I direct particular attention to the large bodies of shales and clays which are found in this district and

the effect they have in controlling and directing the under-
ground circulation of water; they seem to have in some places
closed the channels of the ancient underground streams and
largely excluded surface waters from them.   These shales and
clays wherever I have seen them in connection with workable
ore deposits have shown conclusively by their physical condi-
tion, their position and the order of their arrangement, that
they have been transported and rearranged, long after they
have formed part of the Pennsylvania Series in place, and after
they have been impressed by time and pressure with the physi-
cal properties of the same materials where we now find them
in place.   If this be the case, that they have been eroded, trans-
ported and redeposited, however many of their original char-
acteristics they have retained, I maintain that their geological
age dates from their arrival at their present location.   Even
if they have been transported vertically downward, if such
a transfer were possible.

The study of the stratigraphy of the district is difficult
partly owing to the numerous local dips of the strata, the
large amount of erosion and dissolution they have undergone
and partly to change in rocks produced by leaching and cemen-
tation.   The study of its ancient physiography is still more
difficult but the importance of the subject is sufficient to en-
courage the effort to decypher at least its main features.

REPORT OF MR. GEO. E. COLLINS
AS DELEGATE OF THE COLORADO SCIENTIFIC SOCIETY TO THE MEETING OF THE AMERICAN MINING CONGRESS, HELD IN DENVER, OCT. 16, 1906.

Having been appointed by the president as a delegate from our Society to the American Mining Congress, I attended the sessions of that body from October 16th to Oct. 19th.

As one who had never previously attended a meeting of the Congress, either as member or delegate, it may not be out of place to state frankly the impression left on my mind after listening to the papers and the discussions. Several of the former were excellent; but read before a large body of people, many of whom were not particularly interested in the subjects dealt with, it seemed to me that they did not always get the careful attention they deserved. The fact, moreover, that they were not delivered in any particular order, and that it was not possible to find out precisely when any particular subject would come up for discussion, had the unfortunate result for the writer, who was compelled to run off to his office from time to time, that he missed the opening of several of the most important, and patiently listened to a few which were unworthy of the Congress. As a general rule, I am inclined to think technical papers entirely out of place, read before such an audience. Moreover, the directors might wisely insist that a draft of all papers to be read should be submitted to the secretary beforehand; and as the growing standing of the Congress entitles it to take a more independent stand, some of them should be politely but firmly weeded out.

It is perhaps inevitable, as yet, that the proceedings of a body chosen in such a haphazard way should be characterized by the over-prominence of a few bores whose loquacity is in inverse proportion to their knowledge of the subject. With these the Congress was perhaps too patient; but so far as the executive officers who occupied the chair were able to exert their influence, I am frank to say that while showing remarkable discretion, they succeeded admirably in keeping the meeting to the point. As a whole, my belief is that the Congress has arrived at the stage where it can do valuable work, and is entitled to the support of all who have the welfare of the industry at heart. It should, however, bear in mind that it is the greatest of mistakes to make itself cheap, and should refrain from passing resolutions without sufficient consideration, in order that a resolution once passed may be regarded as the deliberate judgment of the mining community. My own idea would be that all resolutions offered, if approved by the Committee on Resolutions, should be held over until the next meeting, at which papers should be arranged to be read, expressing both sides of the question. All measures proposed may be looked at from two sides; but few among the more thoughtful of the audience care to make themselves conspicuous by getting up on the spur of the moment and pointing out the fallacies involved in some proposal which does not particularly concern them. In some cases it was obvious that resolutions were passed with a light heart, without the least idea on the part of those voting that they dealt with questions of a highly controversial nature, the best solution of which demands the closest study and the most deliberate reflection.

Apart from the reading of papers, the principal matters discussed were the question of mining frauds, that of the establishment of mine drainage districts, and that of the grievances of the ore producers against the smelter trust. Of these, the two former were introduced by the presentation of measures drawn up by committees which had evidently given much consideration to the matter in hand, and the resulting

discussions had, therefore, a greater tendency to take a practical form.

The mine drainage bill was introduced by Mr. D. W. Brunton, chairman of the committee which had drafted it, obviously with a special eye to the immediate problems of the Cripple Creek district. The concensus of opinion seemed to be that the proposed measure was entirely workable. A few amendments were made in the original draft, and the bill was then adopted by the Congress, and recommended for passage by the Legislatures of the various mining states. The only serious objection raised to it was on behalf of a few who seemed to think its provisions would bear too hardly on dissenting property owners, and might in some cases amount to confiscation. The meeting as a whole was however so persuaded of the danger to the mining industry, arising from the present ability of an individual mine owner, by declining to contribute to any plan for joint drainage, to hold back the development of an entire district, that this objection was overruled. It was considered that the principle was nothing more than that involved in the assessment of property directly benefited for the cost of local improvements in cities.

The measure aiming at the prevention of frauds in mining promotions, drafted by a committee presided over by Gov. Pardee of California, proved to be merely one to make the knowing dissemination of false statements a misdemeanor. Gov. Pardee, in a moderate and convincing speech, proved to the satisfaction of a majority of his audience that whilst this might not effect very much, it was all that is immediately practicable. The only doubt remaining in the minds of some was as to whether many states may not have already on their statute books enactments which cover practically the same ground. Undoubtedly, however, the passage at approximately the same time of the same measure by a large number of states, if carried out, would have some moral effect, and might result in the enforcement of laws which are a dead letter on the statute books today. Many delegates made an effort to have the Congress recommend that the States should appoint

officials to examine into and pass upon mining enterprises
originating within their borders.   The common sense of the
Congress, however, decided that this was entirely impossible,
and might not be at all wise, even if within the bounds of prac-
ticability.   At the end of the proceedings a resolution was
adopted, recommending that each State should appoint some
official to investigate charges of violation of the Pardee meas-
ure, a fee for the necessary investigation being paid by the
party desiring it.

Senator De La Vergne's paper dealing with the griev-
ances of the ore producers against the so-called smelting trust
had special reference to the dissatisfaction of the Cripple
Creek shippers with the methods of sampling and settlement
adopted by the American Smelting & Refining Company.   It
was somewhat general in character, a public meeting being
obviously unsuited to the discussion of specific questions.   It
elicited a very forcible statement from Mr. Guiterman, in
which he pointed out the undoubted fact that, as a whole,
smelting rates throughout Colorado had not been raised since
the consolidation of the smelters.   As was perhaps inevitable,
neither the paper nor the rejoinder dealt with the concrete
points in the minds of the audience.   A few questions, asked
after Mr. Guiterman had concluded his remarks, showed per-
haps too much animus for serious discussion, and were left
unanswered.   The general impression seemed to be that Mr.
Guiterman had adroitly turned the flank of his critics by a
masterly and convincing statement of something which Sena-
tor De La Vergne had not called into question, and which is
not disputed by those who understand the subject.   The dis-
cussion was, therefore, inconclusive, as it was bound to be.
The only real gain was that some of the delegates discovered,
apparently to their surprise, that even a trust manager does
not necessarily possess either horns or tail.   A resolution was
carried, appointing a committee to consider the relations be-
tween the ore producers and the smelters, and to see wherein
their conflicting interests may be harmonized.   Such a com-
mittee, if it enter upon its duties in a practical manner, avoid-

ing a spirit of mere carping criticism, may do some good, and certainly can do no harm. Another resolution called for the passage of a measure to prevent smelters and ore buyers from bedding or otherwise disposing of shipments of ores consigned to them, until final settlement should have been made. This falls into the category of proposals which sound reasonable at first blush to those who are unfamiliar with the procedure necessary when handling a great tonnage of varying ores, but which are insufficiently thought out.

Resolutions were passed recommending the drafting by a committee of a uniform mining law for adoption by the mining States; and the abolition of the extralateral rights of mining claims. To the former no valid objection can be offered. The latter, whilst approved by probably a great majority of technical men of all classes, is almost certainly in advance of the general sentiment among miners.

As a whole, the meeting was an undoubted success. Even if no actual business of importance were transacted, which is no longer the case, if it ever was, the bringing together of mining men from all parts of the Union for mutual consultation is in itself a great step in advance. Whilst to most people the high ideals voiced by the president, Mr. J. H. Richards, may seem unattainable, there is no room for doubt that the American Mining Congress has come to stay, and is destined to be the means of securing many benefits for the industry.

REPORT OF SECRETARY OF THE COLORADO SCIENTIFIC SOCIETY FOR YEAR ENDING DECEMBER, 1906.

As Secretary of your Society I have the honor to submit the following report for the year 1906:

The regular meetings held were nine, and the average attendance 13. Eleven papers were presented and read, viz:

"Electrical Separation of Copper Ores," by W. G. Swart.

"Notes on the Ore Deposits in the Magdalena District," by Philip Argall.

"Notes on the Geological and Mining Condition of a Section Across the Sierra Madre Mountains in Old Mexico," by ·A. W. Warwick.

"A Pipe Line in New Mexico," by T. L. Wilkinson.

"Mineralogical Notes No. 3," by Prof. Wm. P. Headden.

"The Bicentenary of Benjamin Franklin," by E. N. Hawkins.

"A Visit to Eastern Museums and Recent Additions to the Fauna of the Denver Formation," by Prof. Geo. L. Cannon.

"Report on the American Mining Congress," by Geo. E. Collins.

"Ore Deposits of the Joplin District," by F. L. Clerc.

"Fossil Footprints in the Flagstones of Denver," by Prof. Geo. L. Cannon.

No meeting was held in January on account of the annual dinner being very close to the date of the regular meeting and in a measure taking the place of such meeting. It was deemed advisable to discontinue the regular meetings during the heated term, and none were held in August and September.

The small average attendance is attributed to the ususual prosperity of the state, members being too actively engaged in business affairs to spare the time to attend meetings.

Of the eleven papers presented, two were reports of delegates, leaving nine on technical subjects, being an average of one for each meeting. During such prosperous times it is difficult to get members to prepare and read papers. The small attendance and the paucity of papers is not due to any lack of interest manifested in the welfare of the Society. From all other points of view it has been very encouraging.

Our membership has grown to 207, and we have a number of applications for new members under consideration. Of the 207 members, 111 reside in Denver, 48 outside of Denver, 45 outside of Colorado, and 3 outside of the United States. During the year we have lost two members by resignations.

The Executive Committee has worked harmoniously and faithfully for the interests of the society. While there were only four meetings of the committee on record, a number of informal meetings were held and the business of the society has been well looked after.

The library now consists of 2,369 volumes, besides numerous unbound pamphlets, and the following accessions have been made during the year by donations:

"Professional Papers of U. S. G. S.," two numbers. Geo. E. Collins.

"Presidential Address to the Australasian Institute of Mining Engineers." Robt. Sticht.

"Elements of Geology." Le Conte. T. G. Smith.

"A Manual of Mining." Ihlseng. T. G. Smith.

"Flora of Colorado." P. A. Rydberg. Colorado Agricultural College.

Two boxes of books, containing a complete set of the "Proceedings of the American Society of Mechanical Engineers," and many other valuable volumes. Francis T. Freeland.

Our library casing was insufficient for holding all of these volumes, and the Executive Committee authorized the purchase of two dozen Gunn Sectional Cases, which are now in place. Most of the present shelving is old and antiquated, and it is hoped that it will not be long before we can reshelve the entire library.

On our reading table may be found the following publications:

Engineering News, Electrical Review, Engineering and Mining Journal, Chemical News, American Naturalist, Dingler's Polytechnisches Journal, Mining Reporter, Ores and Metals, American Chemical Journal, Science, Frontier Monthly, Electro-Chemical and Metallurgical Industry, Annales de Chimie et de Physique, American Inventor, Journal of Geography, Quarterly Journal Microscopical Science, American Geologist, American Journal of Science, Mines and Minerals, School Science.

Our exchange list embraces the publications of over 120 societies and learned institutions from all parts of the world, and the list is too long to embrace in this report, but is made a part of it. These publications contain some of the best thoughts of modern times, and are welcome and useful additions to our library.

Our mineral collection consists of one small case and thirty-four larger cases. These specimens have all been catalogued and grouped with much care by our librarian. This catalogue is made out in triplicate; one is in the hands of the treasurer, one with the secretary, and the other in possession of the librarian.

There are also three cases of very attractive and valuable specimens loaned to the society by Mrs. B. F. House.

The matter of the Hill collection is still in abeyance. The subscriptions for the purchase of this collection amounts to $654, and it is expected the balance to complete the purchase will be raised during the coming year.

There are many specimens that require mounting and labeling. These would add very materially to the collection, and it seems impossible for any of our members to find time to attend to this work. It may not be out of order to suggest that an appropriation be made sufficient to employ some capable student to perform the task.

The collection has served a very useful purpose in aiding students in their geological studies and the number of student

and other visitors to the museum and library have increased from month to month during the year. The total number of such visitors registering were 1,054, an increase over last year of 237.

It gives me pleasure to record here that Miss Bacon, our librarian, has done well for the interests of the society in the very judicious and capable manner she has looked after the affairs of the library and museum.

W. A. JOHNSTON, Secretary.

REPORT OF THE TREASURER OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR ENDING DECEMBER 15, 1906.

RECEIPTS.

Received from dues	$1,640.00
Balance remaining from the A. B. Frenzel Prize Fund	150.00
Fees of the last annual dinner	135.00
Total	$1,925.00

EXPENDITURES.

Printing	$ 566.30
Services custodian and janitor	418.00
Furniture, pictures and books	116.45
Subscription to periodicals	112.35
Lights	130.00
Dinner and lunch expense	171.65
Postage	85.00
Typewriter	65.00
Insurance	47.70
Library expense	5.00
Painting floor	10.35
Final payment of the A. B. Frenzel Prize Fund	150.00
Expressage	8.23
Total	$1,886.03

Total receipts	$1,925.00
Total expenditures	1,886.03
Balance	$ 38.97

GEO. L. CANNON, Treasurer.

LIST OF EXCHANGES OF THE COLORADO SCIENTIFIC SOCIETY.

Academia Mexicana, Mexico.
Academy of Natural Sciences of Philadelphia.
Academy of Science, St. Louis.
Agricultural Experiment Station, Ft. Collins, Colo.
Akademie der Wissenchaften, Wein, Austria.
American Academy of Arts and Sciences.
American Geographical Society.
American Institute of Mining Engineers.
American Mining Congress.
American Museum of Natural History.
American Philosophical Society.
Australasian Institute of Mining Engineers.
Augustana Library Publications.
Akademie der Wissenchaften, Munchen, Germany.
Boston Society of Natural History.
Brooklyn Institute of Arts and Sciences.
Buffalo Society of Natural Sciences.
Cambridge Philosophical Society.
Canadian Year Book.
California Academy of Sciences.
Carnegie Museum.
Chemical and Metallurgical Society of South Africa.
Chemical Society Journal, London.
Cincinnati Society of Natural History.
Colorado College Studies.
Cincinnati Museum Association.
Connecticut Geological and Natural History Survey.
Cuerpo Ingenieros de Minas del Peru.
Canadian Institute.

Chronik der Ukrainischen Gesellschaft der Wissen-
    schaften.
Davenport Academy of Sciences.
Department of Agriculture, Forestry Bureau.
Department of the Interior.
Department of Mines and Agriculture of New South
    Wales.
Department of the Interior of Canada.
Entomologisk Tidskrift fran Entomologiska Foreningen.
Earthquake Investigation Committee, Tokyo, Japan.
Elisha Mitchell Scientific Association.
Engineers' Society of Western Pennsylvania.
Field Columbian Museum.
Franklin · Institute.
Geological Survey of Ohio.
Geological Society, Quarterly Journal.
Geological Society of America.
Geological Society of London.
Geological Survey of Canada.
Geological Survey of New South Wales.
Gesellschaft der Wissenschaften.
Geological Survey of New Jersey.
Geographical Society of Philadelphia.
Hamilton Scientific Association.
Historical and Philosophical Society of Ohio.
Historical and Scientific Society of Manitoba.
Imperial University of Tokyo.
Iowa Academy of Sciences.
Institute Geologico de Mexico.
John Crerar Library.
Kansas University.
K. K. Naturhistorischen Hofmuseums.
Kansas Academy of Science.
Liverpool Geological Society.
L'Observatoire Royale de Belgique.
L'Academie Imperiale des Sciences de St. Petersburg.
McGill University.

Museum of Natural History.
Massachusetts Institute of Technology.
Minnesota Academy of Natural Sciences.
Montana Agricultural College.
Museo Nacional de Montevideo.
Museo Nacional de Buenos Aires.
Museum of Comparative Zoology.
Mycological Writings of C. G. Lloyd.
Manchester Geological and Mining Society.
National Academy of Sciences.
Natural Science Association of Staten Island.
Naturforschenden Gesellschaft Frieburg im Baden.
New York Academy of Sciences. ·
Natural History Society of New Brunswick.
Naturwissenschaftlichen Gesellschaft.
Nova Scotian Institute of Science.
Naturwissenschaftlichen Vereins für Steiermark.
Ohio Archaeological and Historical Society.
Philosophical Library, Cambridge, England.
Philosophical Society of Washington.
Queensland Geographical Journal.
Rochester Academy of Science.
Royal Geographical Society of Australia.
Royal Geological Society of England.
Royal Philosophical Society of Glasgow.·
Royal Society of New South Wales.
Royal Institution of Cornwall.
Royal Society of Edinburgh.
Staten Island Association of Arts and Sciences.
School of Mines Quarterly, Columbia University.
Sociedad Cientifica "Antonio Alzate."
Societe Geologique de France.
Societe Imperiale de Naturalistes de Moscow.
Societe Royale Zoologique et Malacologique de Belgique.
Societe Vaudoise des Sciences.
Society of Arts.
Societe Geologique de Belgique.

Syracuse Public Library.
Tufts' College Studies.
Texas Academy of Science.
University of California.
University de Toulouse.
University of Colorado.
University of Missouri.
University of Montana.
University of Nebraska.
University of Upsala.
United States National Museum.
United States Geological Survey.
University of Michigan.
Western Society of Engineers.
Wilson Bulletin.
Wisconsin Academy of Sciences.
Zeehan School of Mines.
Mining Reporter.
Ores and Metals.
Mining and Scientific Press.
Engineering and Mining Journal.
Engineering News.

THE HISTORY OF THE AIR HAMMER DRILL.

By H. L. SINCLAIR

Read at the Meeting of the Society, Feb. 2, 1907.

No doubt those of the members of this Society who are interested in mining or the improvements in mining machinery, are aware that during the past three years many changes are noticeable in the methods used in breaking ground. Since the introduction of the first piston drills, many years ago, improvements have, of course been made from time to time, but the general construction has been the same. While admitting that the cost per foot broken was, in many cases, higher than with hand drilling, operators have continued using the larger 3-inch to 3¼-inch machines in their cross-cuts and shafts, and 2½-inch to 2¾-inch machines in their drifts, raises and stopes. At the same time, there have been many complaints made against the operating and maintenance expenses. Fuel costs in most mining camps were high and there was very little ground in a cross-cut or shaft which could be broken and mucked for less than $10.00 per foot. It was necessary to have a drill runner and helper for each machine, or, where two drills were worked in the same heading, two drill runners and a helper. The runners were supposed to be experienced men, both in the art of breaking ground and in keeping their drills in good running order, and were entitled to at least $4.00 for an 8-hour shift. In drift and cross-cut work it was necessary to either work but one drill shift or handle part of the muck twice in order to give the runners a "set up." For these reasons, it was no wonder that the costs of breaking ground

ran into money and the operators were at their wits' ends to find means of cutting down the expense.

In the stopes, raises and drifts, the lighter 2¼-inch drills would give fairly satisfactory results, as they could, in a pinch, be handled by one man with a little assistance now and then from a mucker or timberman. Still, each drill, even when new, consumed 80 to 90 cubic feet of free air compressed to 90 or 100 pounds receiver pressure and the cost of fuel, coupled with the monthly repair bills, often made the mine manager wish he had never seen a machine drill. Then, too, he was caused no end of worry and trouble in getting good runners. One man would break as much ground as was expected of him, but in so doing, would likewise break side rods, pistons, pawls, etc. Another would get along with few repairs, but would not get results, evidently from fear of breaking the machine. One runner preferred one make of drill and another would not have it, so the manager was, to use a common expression, "in hot water all of the time." He could not have several different makes of drills on hand on account of the large stock of repairs he would be forced to carry, and as a consequence had to take such men as he could get and "break in" new runners. For these reasons, he kept at the drill manufacturers with suggestions to cut down the number of parts in their machines and make them less complicated and more substantial. His suggestions were taken in good spirit, perhaps, but the machine makers were loath to make any changes whereby the repair bills would be materially lessened, as their real income came from this source.

The larger manufacturers had men covering every camp, and when it became known that a certain property would soon be equipped with a compressor, the manager was besieged by drill salesmen who offered all sorts of inducements in order to get their machines introduced, knowing full well that it was not a question as to what they would make on the original sale, but what orders would come to them for repairs later on. The compressor bought, the manager was forced to decide on some make of drill.

A decision once arrived at, it was seldom that he could be weaned from his first love, and henceforth would be known as a Sullivan, Ingersoll or Rand man, and would spend hours arguing with some fellow operator about the merits of his pet drill, while in his letters sent with orders for repairs to the manufacturer, he would probably accuse this innocent person of sitting up nights figuring how he could change parts of his machine so that the repair bills would mount up. I know one large operator who has been using a certain make of drill for nearly twenty years, but who is always complaining about the maintenance expense and threatens to make a change on the next plant he installs. About the time he is ready to purchase, if approached by the representative of a rival concern, he will argue for an hour or so on the subject and will probably conclude by saying, "Well, I guess I'll stay with the old machine. If I buy yours, I expect I would be jumping from the frying pan into the fire."

As I said before, many changes have been inaugurated in the past three years in the methods of rock breaking, and from the subject of this paper you will naturally infer that I intend to show what results have been obtained by the use of the air hammer drill. Before offering any argument, however, on the advantages or disadvantages of this type of machine, it might be well to explain how the machine was first used in mining operations and how I came to be personally interested in its development.

Some seven or eight years ago I was employed on a property where a great portion of the value of the ore lay in a six- to ten-inch streak of honeycombed quartz which was "frozen" to the wall; in fact the gangue, which made up the major portion of a four-foot vein, contained little or no value. Our method of mining had been to strip the quartz and take it down on sorting sheets in a filled stope by the use of gads. This was rather slow and arduous work, but the value of the gold content was sufficient to leave a small margin of profit, even after excessive hauling, freight and smelter charges were paid. At this time I had occasion to go East to a directors' meeting

of the company, where the difficulty of saving the ore was fully explained and, in the discussion which followed, various methods of overcoming the obstacle were considered. At this time the pneumatic riveting hammer was coming into general use in boiler shops, and one of the directors, who was of a rather ingenious turn of mind, suggested that a hammer of this sort might be brought into play; and by the use of a gad in place of the riveting tool, be used to take down the ore. While I did not think the plan would prove feasible, I consented to visit a boiler shop and even experimented at driving rivets in an effort to ascertain what the possibility might be of using them for the purpose mentioned.

At that time the hammers were not as well designed as they are today, and the vibration was so great that I was forced to express the opinion that excessive wages would have to be paid the miners to get them to use the tool. In considering the question, however, one very important point, which has since been brought to light, was overlooked, i. e., that there was much less "kick back" in operating the hammer against rock than against a rivet in the shell of a boiler. The reason for this difference in the action of the tool is probably due to the fact that after the first few blows of the piston gainst the steel, the elasticity of the boiler sheet is such that it seems to spring back a trifle after each blow of the hammer. As the steel recoils it meets the next blow half way on the rebound and a shock is caused which is very trying on the nervous system of the operator. It has since been proven conclusively that with the improved type of hammers there is very little shock or vibration to inconvenience the operator, and that the remedy does not lie entirely in the improved machines. The conclusion is that, with a gad made properly tapering, at each blow of the piston, the tool is forced into the crevice and remains there until the next blow is struck. This leaves the operator with but the natural vibration of the hammer to contend with. In the later types of machines the piston is made to cushion on live air on the back stroke and no excessive jar occurs.

However, the tools were not put in use at the mine, and although I thought of the subject many times during the three or four years following, and before their trial as hitch cutters in various camps, it was not until nearly three years ago that I had the opportunity of trying them in Cripple Creek. At that time they were being tried for block holing and hitch cutting and the tool used was a 12-inch hollow piece of steel with some fourteen or sixteen cutting edges. The manufacturers were claiming great results for both of these purposes and for drilling as high as a four-foot hole, finishing about $1\frac{1}{8}$-inch in diameter.

It fell to my lot to attempt to drill a round of holes in a narrow stope in one of the Cripple Creek properties, and I must admit that the result of the test offered no encouragement. The makers of the machine had evidently based their somewhat astounding records on tests made in some very even cutting soft formation; for, when the drill was operated against Cripple Creek phonolite, it was soon discovered that unless some very radical changes were made in the drill bits they would not do the work. The greatest difficulty was experienced in getting the bits spread to a gauge so that they would follow. Then, too, the cutting edges were so fine that it was next to impossible to temper them to stand for more than an inch or two in that character of ground.

Another difficulty developed in the construction of the drill bits. These were made of $\frac{7}{8}$-inch hollow staybolt iron with 6 inches of hollow steel welded to either end for a shank and bit. It was found that crystallization would take place at the welds and either the shank or bit would jump off in a very few minutes. I decided, however, that the machine could be perfected, and with the assistance of my father, who is a mechanical as well as a mining engineer, set about remedying the faults mentioned. We turned our attention at first to the steel, and after careful experiments, found that the bits with six cutting edges, cut faster and held their gauge better than any other style. The cross bit was tried but was discarded on account of its tendency to "rifle" a hole and "hang up" in

crossing slips at an acute angle. We also found that with this shape of bit it was hard work to rotate the drill by hand in soft ground and while it cleared better, the six tooth bits gave much better results. Sharpening tools were made for the six tooth bits and little difficulty was experienced in drill sharpening after the blacksmith had acquired the knack of spreading the gauge.

Hollow steel was necessary in drilling down holes or flat holes in sticky ground as it was essential to force part of the exhaust air through the steel to clear the hole of cuttings. The welded bits would not stand in hard rock, and we were in a quandary as to how we would overcome this difficulty until it was discovered that a ⅜-inch hole could be drilled through a four-foot piece of steel in a gun barrel lathe. We used this class of steel for some little time until we found that we could purchase a brand of hollow rolled steel in Sheffield, England.

With these changes, we were able to drill four foot holes in any ground at a speed, varying with the formation, of from 1 inch to 10 inches per minute. In testing the machine thoroughly, however, we found that a cast steel cylinder would crystallize easily, and we were forced to change the material used in its construction, to the best grade of steel shafting, forming the complete cylinder out of the solid rock.

We then found that it was next to impossible to get men who would hold the machine over their heads and drill uppers. One could not blame the drill runners as it was certainly an awful task to set a man at, and only the very strongest could stand it for any length of time. The screw feed machine mounted on a light drift column was tried but finally discarded, when one of the manufacturers constructed an air feed attachment. With this machine it was possible to "set up" and "tear down" in less than a minute and the drilling capacity of the machine was increased 100 per cent. Machines of this type were placed in all of the larger mines of the country and it was soon found in competitive tests that they would out-drill any of the 2¼-inch machines.

The manufacturers of the old line machines soon found that they were rapidly losing ground and began to experiment on the same line themselves. Several new companies were formed, principally by mining men who realized the advantages of the air hammer drills as compared with the piston machines, and during the past year, many improvements have been made.

As this brings us down to the present time, it only remains for me to attempt to show why this new type of drill has come to stay, and wherein it possesses advantages over the old line drills. This I will attempt to do by taking up each class of work separately.

In the large cross-cut or railway tunnel, the large piston drill still holds the advantage, as it is possible to drill deep rounds and break the ground far more economically and rapidly than would be possible with the small hammer type. Even in this class of work, however, there is a place for the small drill as they can be used most successfully in block holing and in taking up bottom or trimming up the walls where projections are left, either on account of missed holes, or because the drill runner has miscalculated the load he had on a certain hole. They can also be used for drilling uppers in the roof for pipe hangers, or for putting in short relief holes in the heading where they will give the cut holes a better chance to break.

In shaft or winze work, however, they can be used for drilling the full round of holes and even in the larger sized shafts, records show a saving which is simply astounding. To those who are familiar with this class of work, the reason is obvious. With piston drills, even in the hands of the best of runners, more time is lost in setting up, tearing down, lining up, cranking in and out of holes and in changing steel, than is consumed in drilling. Where the ground is even and breaks well, it is not so bad, but where slips are encountered frequently, and time is consumed in preventing a "hang up" or where the formation is such that a great many holes must be drilled to break the ground, the air hammer drill has all

the best of the argument. The machine, steel and hose, can all be put into one bucket and the drill runner can be at work in five minutes from the time he goes on shift. The steel being loose in the chuck, he loses no time in changes, and he can start a new hole while a piston drill runner would be cranking out. Holes can be drilled in any direction and pointed to take advantage of any slip. No holes need be lost as it is practically impossible to get a "fitchured" hole even in the worst kind of ground. All of the holes can be drilled to any depth desired, up to four feet, except in very heavy sulphide ore, and the sump holes can be put in in any part of the shaft. With a piston drill, the runner may get a hole down three feet and then get hung up, and rather than lose time he will take a chance on breaking the ground and start another hole. On this hole he may have no trouble and he will perhaps drill it 6 feet deep. What is the consequence? When the shaft is cleaned up he will find he has no sump, or one corner of his shaft sticks out so that he is unable to get a set up which will enable him to drill his round to advantage. He may even have to drill a hole by hand and shoot it before he can get in to do any good with his next round. As a consequence, the shifts are thrown out and valuable time is lost. When timbering commences, the small hammer drill is indispensable for cutting hitches and taking out projections where they interfere with the sets, and for these purposes alone, will pay for itself in 30 days.

In a drift, a drill runner can either mount the air feed drill on a column or, where it is possible to pull the cut out of the top, he can work with the air feed alone and in any ordinary ground, one man can drill a round of holes in half a shift. Where the cut is pulled from the center or bottom, he can either drill the back and top cut holes off a bar or simply use a stick of timber and butt the air feed against it. I have known of one man breaking 42 feet in 19 shifts in a drift in granite and not only did he do all the drilling alone, but the tramming as well.

There is a diversity of opinion as to whether it is advisable to use a 2¼-inch piston drill or an air hammer drill in this class of work, and a decision, from an economical standpoint, can only be obtained by actual tests. As a usual thing, however, the hammer drill can be used advantageously in all drifts where a 4-ft. round, bottoming 1⅛-inch will break without leaving any "guns." With a piston drill of the size mentioned or larger, it is possible to make more rapid progress but the cost per foot will probably be greater as much more powder and air will be required and it is a hard matter for a drill runner to set up and tear down without some help from a timberman or trammer. In ground which breaks short, however, the piston drill usually has the advantage as a larger hole is drilled and the powder can be gotten to the bottom of the holes where it belongs.

In stope work the 2¼-inch machine does not have a chance against the air hammer tool and the records on some of the Cripple Creek properties show that their stoping costs have been reduced one-half since the introduction of the small machines. Where the values lie in small streaks of very high grade ore, the saving is enormous as the stopes can be carried even more narrow than it would be possible by hand as the drill can be run in any place a runner can get his body. I installed a small machine for a leaser in Cripple Creek some 18 months ago and he informed me after his lease had expired, that the little drill was worth $1000.00 a month to him. He was stoping on a 14 to 18-inch streak of 4 to 5-ounce ore and found that the ground was too hard to break by hand. He then put in a 2¼-inch machine and was forced to carry his stope 3½ to 4 feet wide. In doing this he lowered his values to $30.00 to $35.00 per ton. After the installation of the little air feed drill, he was able to break one-third more ore in an 18-inch stope than he had with the 2¼-inch machine in one 3½ to 4 feet wide. He ran his values back again $80.00 to $90.00, cut his hoisting and powder bills down to one-half, and his timber to one-third, and yet kept his production up to more than the tonnage he was able to get back of the 2¼-inch drill.

With the piston machine his air cost him $3.00 per shift, while with the hammer drill the charge was but $1.00 for the same length of time. He figured the difference in net returns and found that the small machine saved him a little more than $1,000.00 per month. The usual method of operating the machine in an open stope is to put in a couple of light sprags well up to the back and about 10 or 12 feet apart. By putting a 2x12-inch plank on the timbers and drilling off from it, a drill runner can fill a stope full of holes in half the time he would consume with a larger drill. Not only can he drill more holes, but he can drill them in any place he desires and take advantage of every slip.

The same method is used in upraising, and data furnished by some of the largest mines in the west, shows that a saving of 50 per cent. can be readily given as the average.

Not only can more work be done with the hammer drills than with piston machines, but the saving in repairs is well worth considering. In nearly all of the small hammer drills, there is but the one moving part and when properly made this should last for months. The rotation being accomplished by hand there are no pawls or springs to break and no rifle. nuts to wear out. As the machines are fed by air, no feed screws or nuts are required. Taken as a whole, with a properly made air hammer drill, the repairs are less than 25 per cent. of those of a $2\frac{1}{4}$-inch machine.

Working at a drill pressure of 100 pounds, a $2\frac{1}{4}$-inch machine requires 100 cu. ft. of free air per minute, while an air hammer drill of the valveless type uses but 25 cu. ft. at the same pressure.

Another advantage possessed by the hammer drill lies in the fact that it is not necessary to employ a first-class drill runner, as a good miner who knows how to point his holes will do just as much work after two or three days experience, as the best man one could hire.

While I could, perhaps, describe the various machines of this type manufactured, and give my ideas regarding the

merits and defects of the different drills now on the market, I believe that it would be wise to confine my remarks to the air hammer drill in general and conclude by saying, as the "old toper" did of brands of whiskey, "that they are all good but some are better than others."

Concretionary Terraces in Arikaree Sandstone.

Concretions in Arikaree Sandstone.

Pawnee Buttes From the North.

Butte Recently Isolated From High Plains.

Dissected Bluffs West of Pawnee Buttes.

Gulch at Chalk Bluffs Playing Out on the Lower Plains.

Terraces in Arikaree Sandstone.

TOPOGRAPHIC DEVELOPMENT OF CHALK BLUFFS AND PAWNEE BUTTES.

By JUNIUS HENDERSON

Read at the Meeting of the Society, March 2, 1907.

The topographic development of Chalk Bluffs and Pawnee Buttes is of importance because it is intimately connected with and part of the scooping out of the entire South Platte Valley. The importance of the subject is greatly enhanced by the fact that underlying the deposits forming the bluffs and buttes as well as beneath the valley are formations which contain great economic deposits such as coal, lime, building stone, brick and fire clay, oil and water. In order to know to what depth such deposits are probably covered at any given point in the valley or on the high plains it is imperative that both the stratigraphy and topographic development of the valley and its fringing bluffs should be understood. Such knowledge is also of greater importance in the economic construction of reservoirs and ditches to avoid excessive seepage than is generally supposed. Examples of reservoirs which were total failures because their dams were constructed upon porous sandstones of the Laramie Group may be found in Northeastern Colorado, together with ditches which permit of the maximum, instead of the minimum, seepage.

In order to understand the underlying formations it is necessary to know considerable about the past geological history of the region. This requires a careful study not only of the lithological characters of the various formations, but an intimate knowledge of the regional paleontology, for in

many cases the only means of tracing the stratigraphic horizons and determining the method of deposition is the paleontological evidence.

The bluffs and buttes under special consideration, forming the northern edge of the South Platte Valley in Northern Weld County, are chosen for this study because they present in a limited area easily comprehended evidence of the various processes by which present conditions have been produced—processes which are still in operation as actively, perhaps, as at any time in the past, so far as the actual erosion phenomena are concerned. Similar bluffs and buttes are found along the southern edge of the valley at various places, and it is believed that the formations composing them at one time extended entirely across the valley. The erosion of this valley and the consequent development of those striking features of Northeastern Colorado topography serve to explain some points which would otherwise be incomprehensible.

Starting from a very short distance within the foothills at Golden, Boulder or Lyons, and proceeding northeastward to Pawnee Buttes, one passes over the more or less upturned edges of strata from granite through late Paleozoic and Mesozoic to the Tertiary, thus obtaining a comprehensive view of the geologic history of the region, as it passed, with some fluctuations, from marine conditions through brackish and fresh water stages to present land conditions, together with a splendid view of the processes by which erosion has produced present land forms.

A geological section from the foothills eastward into the Platte Valley shows strata of great thickness steeply upturned along the mountain flanks, resting upon the granite and rapidly flattening out in the valley. This change in dip will be noticed to result in a corresponding change in topography and scenic effects. The reason is plainly that where the alternating hard and soft strata are steeply upturned the erosion of the yielding horizons leaves the resistant horizons standing out as sharp ridges, cut through at intervals by transverse streams flowing from the mountains, while in the valley where

the strata are nearly horizontal the tendency is to produce mesas or tabular forms rather than series of sharp ridges.

At the base of the sedimentary series we have the red conglomerates and sandstones formerly assigned to Triassic age, but now considered partly, at least, late Paleozoic and believed to be of marine origin. Higher up in the geologic column are red clays and limestones, considered of Jurassic age, at least in part, and likely consisting partly of marine and partly of fresh water deposits. Above this are the two strong sandstone members and the medial clays of what has been called the Dakota Group and usually considered a fresh water deposit, but fossil marine Mollusca in the medial clays show that at least part of it is of marine origin. This, together with differences in lithological characters, make it advisable to divide the Dakota into three members and to consider part, at least, lower Cretaceous.

It will be noticed that the basal red beds and the so-called Dakota form two ridges or "hog backs." After the deposition of the later came a long period of subsidence, during which in the neighborhood of 10,000 feet of fine-grained shales, limestones and sandstones were deposited upon the subsiding bed of a rather quiet sea. Through most of this period marine life was abundant and varied. In a single pasture I have found nearly 40 species of marine shells, some of them weathering out by the thousands. This long period of marine deposition includes the Ft. Benton, Niobrara, Pierre and Fox Hills groups, but during the deposition of the latter land was beginning to encroach upon the sea and the sea was shallowing. In a number of places we have found estuarine species mingled with true marine Fox Hill species. In Laramie time, which was the coal period of Northeastern Colorado, there was apparently a condition of low-lying brackish and fresh-water swamps and lagoons, the land surface being maintained so nearly sea level as to permit occasional invasions, perhaps. Molluscan life was at times very abundant and the plant life suggests a somewhat warmer climate than at present. On Crow Creek, southwest of Pawnee Buttes, we broke from a

single concretion small enough for a man to easily lift, several hundred specimens of Corbicula macropistha.   Above it occurs a stratum composed almost entirely of *Corbicula* of various species, *Campeloma multilineata*, etc.   Higher up is a stratum containing large numbers of *Ostrea glabra* and *Anomia micronema*, while still higher *Tulotoma thompsoni* abounds, mingled with *Physa felix, Bulinus*, sp., etc.

The Laramie witnessed the final retreat, perhaps forever, of the sea from the region under discussion, so far as the evidence goes.   This formation was then covered by Tertiary deposits several hundreds of feet in thickness, laid down apparently by streams of low declivity, swinging back and forth, and more or less extensive lakes.   The fossils of these deposits consist almost wholly of land animals—vertebrates, including nearly one hundred known species.   Among others may be mentioned three-toed horses, rhionoceras, elephants, camels, deer, dogs, cats, squirrels, opossums, tortoises, etc., all of course, of species long since extinct.   A careful search for miles along the bluffs failed to disclose a single fossil specimen of invertebrate animal or plant.   If anyone else has found any I am not aware of it.

During Tertiary time the entire region was lifted up about a mile above sea level and the strata at the west turned up sharply, thus furnishing favorable conditions for the enormous erosion which has followed.

The Tertiary formations overlying the Laramie in Northern Weld County consist of soft, yielding Brule clay below, and harder, resistant Arikaree sandstones and conglomerates above.   This fact has an important bearing upon the topography, the hard cap preserving the upper surface, while the formation is cut away at the edge by undermining, leaving nearly vertical and in many cases even overhanging walls.   Though the Brule clay is rather free from fine lamination and presents a decidedly massive appearance, it is stratified, as shown under certain conditions of weathering.   The sandstones are very distinctly stratified, often strongly cross-bedded and have a peculiar concretionary structure, the concretions running

vertically through the strata but ending in stratification planes above and below. They appear to have been formed by segregation caused by movement of underground waters controlled by stratification planes. These concretions are of primary importance in the production of terraces to be discussed. They are usually much harder than the nonconcretionary portions of the formation. A strong nonconformity is shown at the contact of the Arikaree and Brule members, on West Pawnee Butte, but is much more pronounced in other places.

The Arikaree formation is strongly conglomeritic in places, the conglomerates being usually, as would be expected in view of their origin, of slight horizontal extent. In the western portion of the area the conglomerates consist chiefly of debris from the mountains, but to the eastward the proportion of mountain debris becomes less, the pebbles smaller, with a considerable admixture of angular fragments of the Arikaree sandstone, which throw much light on the origin of these beds.

There is abundant evidence, in support of the belief that these formations once extended over the South Platte Valley, but have been eroded away from a large area, thus exposing the underlying Cretaceous formations. One could easily traverse the upper part of the valley from north to south without realizing it, masked as it is by numerous valleys of the minor streams, all of which have contributed toward the production of the one broad and comparatively shallow principal valley.

*An examination of the Tertiary map of Northeastern Colorado will help to clarify the matter. It is an important fact that in Sedgwick County, at the northeastern corner of the state, the South Platte River is cutting into the earlier Tertiary and has cut through the later strata, which now flank the valley on each side so as to leave no room to doubt that both formations once extended across. Proceeding up the valley it is clear that the same condition has existed there, but the valley gets wider and wider as one travels up stream, and

*For the Tertiary Map see Plate XXXV, accompanying N. H. Darton's 'Preliminary Report of the Geology and Underground Water Resources of the Great Central Plains,' Professional Paper No. 32, U. S. Geological Survey.

the Tertiary formations more remote from the river, so as to
make their relations less perceptible but none the less real.
These formations on the divides north and south of the valley
practically reach the foothills, but through the greater part of
the valley they have been eroded away, so that the streams are
now cutting into the Laramie, and nearer the foothills into
still earlier formations. All this has been accomplished by the
action of perennial streams, intermittent streams and general
denudation. The shape of the valley, wider at its western end,
is due to the work of important streams entering from the di-
vides to the southwest and northwest, and from the mountains
to the west, all flowing away through a common trunk.

The perennial streams have for ages been meandering
back and forth over their valleys, cutting ever deeper, the ele-
vation above sea level affording plenty of declivity for the car-
rying of the materials eastward and ultimately southward, to
aid in building the delta of the Mississippi.

I know of bluffs of Pierre shales 20 feet in height which
are being cut away at the rate of about one foot per annum,
and in softer materials the rate is often much more rapid.

Each slope from higher ground to the beds of the peren-
nial streams affords ample opportunity for storm waters to
carve out gulches and each gulch so formed exhibits two more
slopes in which other sets of gulches are cut, and so the dis-
section goes on at thousands of points at once. These storm
water gulches do not begin on the high ground and work
downward. They begin on the steepest part of the slope and
progress headward. This is a very important principle to
keep in mind in order to comprehend the topography of the
region under discussion, the bluffs and buttes being left by the
headward progression of innumerable series of gulches and
low denudation terraces. Material cut from these small
gulches is not usually carried far at any one time. Storm
waters rush down the gullies, carrying large quantities of ma-
terial downward until they reach a more gentle grade, where
the overloaded stream drops most of its load, and the stream
itself soon disappears by spreading out on the more nearly

level ground. The same material may be wholly or in part picked up by the next storm and carried further down, or it may lie there until gulches working into slopes at lower levels reach and attack the point in their headward progression. Thus we have continual cycles of erosion and deposition, but at every movement the material is carried downward.

At East Pawnee Butte we have a beautiful example of gulch erosion. One set of gulches is eating rapidly into the butte on the south side. Just below is a plain too nearly level for rapid erosion. Below this, however, is a rather deep gulch from which another set of gullies are eating toward the butte. Thus one set of gulches follows another up the slopes in constant succession, ever cutting headward and deeper into the formation. So where a slope is now dissected by innumerable gullies, a century hence may be a nearly level plain, and two centuries hence the plain again dissected by numerous gullies cutting in at a lower level.

Concurrent with the gulch cutting, erosion is proceeding by another process which, if not as noticeable, is of no less importance. On all the slopes of moderate declivity series of low terraces are formed by the cutting away of the soil where vegetation is thinnest, under the influence of winds and summer showers, leaving bare spots which rapidly extend their limits, preserving a semi-circular outline. In the meantime grass gets a foothold where the cutting first begins and follows up the retreating terrace, thus making a crescent of bare ground. The next terrace below, however, is also following up the hill, and soon again cuts away the newly formed vegetation. Thus series after series of these terraces chase each other up the hill sides. They do not follow in direct line, but overlap or "break joints," as a lather would say, so that by this process the whole slope is degraded. These terraces may be from two inches to a foot or more in height and up to several rods in horizontal dimensions, varying greatly with slope, soil, exposure and relative scarcity of grass. Aside from this terrace degredation, which is plainly visible on all sides, the vegetation being sparse in this semi-arid region, each shower carries

away great quantities of soil from between the grass roots without leaving any visible marks. Along the bluffs which divide the valley from the high plains larger and more extensive terraces frequently form at the heads of gulches, thus combining two of the processes.

Another important topographic feature is the playing out of the gulches as they leave the steeper slopes or bluffs and reach more nearly level ground. Most of these gulches convey only storm waters, bearing great quantities of the finer materials in suspension and dragging coarser sands along their beds. As they reach more gentle grades they drop their loads and spread them out in a broad fan, building up the plain by coalescence of these fans, the waterways entirely disappearing. The entire bluff region is characterized by these strong, abrupt gulches which extend from a few hundred yards to a mile or so out into the plain and there die, leaving a somewhat level or rolling and comparatively gulchless plain below, so that one may easily travel at a distance of a mile from the bluffs, whereas at closer range many gulches must be crossed.

In the field, the method of isolation of Pawnee Buttes and other similar hills of the Platte Valley is perfectly clear. The process may be seen in all its stages. For instance, west of Davis ranch several gulches have begun eating into the perpendicular bluff by cutting away the softer material and letting down the harder sandstone cap. The further in they get the more rapidly they cut. After getting in a short distance lateral gulches form on their steep sides, and these in turn progress headward. The primary gulches being parallel, it is clear that laterals extending away from their sides must sooner or later intersect and thus isolate a hill from the border of the high plains.

One more prominent feature remains to be mentioned. The slopes of the more extensive gulches in the bluffs present a decidedly terraced appearance, in many places reminding one of the Grand Canyon on a small scale. These terraces are the result of erosion in alternating hard and soft strata. When a gulch is cut in a formation which is uniform in its powers

of resistance, it widens by lateral erosion at the top with comparative regularity as it is cut deeper, the slopes converging regularly to the bottom and forming a V. If, however, a harder stratum is encountered the downward cutting proceeds much more slowly, while the lateral erosion proceeds as rapidly as before, thus carrying the walls above the hard stratum back and leaving the latter projecting as a bench or terrace. This is repeated with each hard stratum encountered, lateral erosion accomplishing its work on the upper terraces, partly by eating away the softer material beneath and so undermining them. This is what has happened at Chalk Bluffs and the other bluffs fringing the north side of the South Platte Valley. The whole upper part of the formation is harder than the underlying clays, which preserves the perpendicular face of the bluffs, while the hard capping sandstones vary in hardness within themselves and so form terraces. This variation in hardness is partly, though not wholly, due to the concretionary structure which we have already discussed, and so many of the terraces are found to be concretionary zones.

The influence of the wind in the production of land forms in the semi-arid region is now known to be very great, though its exact influence is hard to estimate. This shows plainly in the area under discussion.

AN EXAMINATION OF SOME COALS FROM ROUTT COUNTY, COLORADO.

By WM. P. HEADDEN.

Read at the Meeting of the Society March 2, 1907.

It is my intention to present the results obtained in the chemical examination of some Colorado coals which I collected about two years ago in the course of some work which fell to my lot. I do not propose in any sense to present a report upon the fields represented except in so far as a succinct statement of the conditions found on collecting the samples may partake of the nature of a report.

The coal fields of Colorado have been well described by Mr. R. C. Hills in a number of papers and discussions pertaining to this subject, some of which are found in "Mineral Resources for 1892."

The age of the important coal occurrences, known under the collective name of the Rocky Mountain Coal Fields, is generally accepted as Laramie. The occurrences of other ages are confined to comparatively small areas and yield, as a rule, coals of an inferior quality.

The difficulties presenting themselves in recognizing the line of division between the Montana and the Laramie are matters of common knowledge and have given rise to doubts as to whether some portions of this field may not belong to the Montana. The samples of coal, forming the subject of this paper, are largely from the eastern portion of the Yampa field in Routt County, which Messrs. Fenneman and Gale consider as occurring in the Montana. They use the following state-

ment in this connection: These rocks have been previously considered of Laramie age, but fossils collected from them during the past season's work were sufficient to determine definitely that they belong to the Montana group of the Cretaceous.[1]

I take it that the Grand River and Yampa fields, though now separated, formed at one time portions of a continuous measure, and if this is correct the Grand River field would be of the same age as the Yampa field. Messrs. Fenneman and Gale say nothing about the Grand River field. They recognize the Laramie as consisting of 900 feet of shales and sandstones in which indications of lignite are found at many horizons, but above the three series constituting the Yampa field. Mr. Hills is of the opinion that the Yampa and Grand River fields formed, at one time, a continuous measure, and concerning the age of the latter, he says:

"The sandstone underlying the lowest of these seams is here taken as the base of the Laramie group, since, notwithstanding that the stratigraphical difference is simply a progressive increase in the thickness of the sandstones and that fucoids and marine shells may be found 200 to 300 feet above, the horizon in question marks the first important introduction of widespread nonmarine conditions and separate the Montana group from what is economically one continuous series of Measures."

Mr. Hills published in 1892 what I take to be a resume of his many years' work on the Colorado coals, in which he includes:

The chemical composition and calorific value of coals from the various producing sections of the state, also from sections which, though not producing at that time, promised to become economically important as soon as made accessible by new railroads or otherwise. In a few instances the samples representing certain sections were investigated by Prof. William B. Potter. This work leaves but little to be desired in regard to those sections which were, in a commercial sense, accessible at the date of this report. Recently, however, the building of

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[1] Bulletin No. 285, Series A. Economics Geology 73, pp. 227.
[2] Mineral Resources, 1982, pp. 345.

the Denver Northwestern & Pacific Railroad through Routt
County, opening up the Yampa field, has attracted some at-
tention to this section.   The sixteen or more years that have
intervened, since Mr. Hills examined this section and collected
his samples for analysis, have witnessed some development of
old prospects and the opening of a number of new ones.   These
developments and the prospects that this section will become
an important source of supply in the near future, induced the
present coal mine inspector, Mr. John D. Jones, to incorporate
an account of the coal resources of this county in his report
for the years 1903-1904.   This account is conservative,
straightforward and accurate in its description of the locali-
ties and conditions as I saw them.

Mr. Hills gives in his account of the Yampa field ultimate
analysis of nine samples of coal with their calorific values.
Mr. Jones gives proximate analysis of fourteen samples, but
does not state by whom the samples were taken or what they
represent.   Messrs. Fenneman and Gale give proximate an-
alysis of fifteen samples taken in the course of their work,
which represent clean faces of coal as standing in the openings
at the time of their visits.   This may suffice to indicate that
while the present interest in this field is very considerable it
is by no means wholly new, though the work of Messrs. Fen-
neman and Gale and also that of Mr. Jones is quite recent.
There are still other analyses which have appeared in pros-
pectuses of mining companies, some of them giving the name
of the analyst.   The pamphlet entitled, "The Yampa Coal
Field," which is presented by Mr. W. Weston, M. E., to the
general manager of the Denver Northwestern & Pacific Rail-
road, also contains a number of proximate analyses.   This
constitutes the published analytical data pertaining to the
Yampa coals, so far as I know.   The older ones, by Mr. Hills,
are the most complete, though the later samples are probably
more nearly representative of the coals.

My visit to this section was a somewhat hurried one and
had for its object a general study of the section rather than
a specific study of the coals.   The presentation of my observa-

tions, but more especially of the results of my examination of the samples collected, may contribute in some measure to a fuller knowledge of the character and merits of these coals.

My observations were confined to that portion of the field lying eastward of a line passing from the eastern portion of California Park to the town of Hayden and thence to Hayden Gulch. The strata consist of sandstones and shales with three series of coal beds, separated by from 400 to 500 feet (estimated) of barren strata. The best view of these series and their relations was obtained in Hayden Gulch and Dry Creek.

The same seam of coal may vary in thickness from place to place, but in general the thickness of the seams has not been over stated in the various articles that I have seen The total thickness of workable coal that I saw was about 25 feet for the upper series, 30 feet for the middle series and 20 feet for the bottom series. There are said to be other seams in each of the series, some of which are of workable size. This is particularly the case with the bottom series in which I measured but two seams, while it is claimed that there are five and in some places six workable seams. From all that I saw I judge that there is not far from 75 feet of workable coal in the three series.

It is customary to designate the seams by the names of the creeks, the owners of the mines, etc. For my purpose I will designate the sections by the character of the coal in the area, which is a system already adopted in the case of the anthracite range; accordingly we will have anthracite coals, and the rest we will tentatively call bituminous coals.

The anthracite is, so far as I saw, confined to the middle series and the anthracization is due to the presence of intrusive sheets of basalt, as explained sixteen or eighteen years ago by Mr. Hills. I could not discover any data which would justify an estimate of the area affected by these intrusions, nor the extent of their influence on the character of the coal. Analyses to be given later will show that some of the coals have been altered to anthracite, a fact recognized by all persons who

have studied them, but the masses of intruded rocks do not seem to have been large enough to produce considerable changes in the character of the coals except in comparatively close proximity to them.

I did not go more than two and a half to three miles north of Pilot Knob, so I know nothing, except from the testimony of others, of the character or extension of the field beyond this point. The distance from the property of The Elkhead Anthracite Coal company to that of the Colorado Anthracite Coal Company, is about five miles. I could not learn that the coal had been proven to be continuous for this distance, but borings given me by Mr. Shelton from land belonging to the Colorado Anthracite Company proved to be anthracite, as subsequent analyses will show.

The samples analyzed represent the bottom and middle series. The top series, the third from the bottom, appears from my notes to have been acessible at one point only—on Dry Creek—where coal had been taken out for local use, but it had been standing for a long time and the coal in the face was badly weathered and evidently of inferior quality, so I did not take a sample. I was, moreover, not prepared to do the work that would have been necessary to obtain a good sample. This breast presented 11 feet of clean coal.

I will group the samples according to the series to which they belong rather than in regard to the location of the property from which they were obtained, though I shall give the latter as I have noted them. All samples were taken by myself unless otherwise stated. As I did not set out with the specific object of sampling these coals I had not provided myself with the means of sealing the samples, consequently the results are all obtained on air dried samples. It is further right that I should state that this work, having to be made secondary to that of the experiment station, was necessarily delayed. The samples, however, were carefully packed, boxed up and kept in the basement of the building, where the temperature is uniform and the air fairly moist. The condition of the samples at this time, though going on three years old, is to all

appearances unchanged; there is no checking or slacking shown by the larger pieces. I am not prepared to state that the coals of the bottom and middle series will not slack at all on exposure to the air, but they certainly possess excellent keeping qualities, as one can observe at the mines and in the deportment of samples broken and preserved in the air. The coal of the third series, that which I saw, slacked quite badly.

While changes in the composition of my samples may have taken place before they were analyzed, they could scarcely have been material. It is impossible to give the whole of the analytical work done and the case is, in this respect, incomplete, still the reader can judge from the results given that it is not probable that any serious changes have taken place in the coals.

The bottom series: This series is represented by eight samples.

Sample No. 1.—Stevens property (Ledford and Ducey Mines). Seam, 5½ feet thick. Cleats at right angles, blocky coal. Roof slate and clay, overlain by a soft, clayey sandstone. There is a lower seam, not accessible at the time of my visit. This lower seam is said to be 16½ feet thick. The coal is bright, black and clean and has not been altered by the intrusive rocks of the neighborhood.

Specific gravity of coal, 1·377. Ash, reddish gray.

PROXIMATE ANALYSIS*	ULTIMATE ANALYSIS
Air Dried Coal	*Pure Coal*
Moisture at 100°.......... 6·535	Carbon 78.592
Volatile .... 38·477	Hydrogen .... 5·513
Fixed Carbon .... 50·273	Nitrogen .... 1·476
Ash .... 4·715	Sulfur .... 0·877
	Oxygen .... 13·542
100·000	100·000

Calorific value determined: Air dried coal 6873, calories, 12371 B. T. U.; pure coal 7743 calories, 13937 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 7717 calories, 13891 B. T. U.

Sample No. 2.—Sample taken from property of L. H. Green, Hayden's Gulch. Lots 1, 2 and 3 T. 4 R. 89 W. Thickness of vein 10 feet, 6 inches. Dip, 6½° N. 57° E. Breast, 135 feet from entrance. Breast shows 6 inches slate and bony coal 4½ feet above the floor. Sample represents breast above bony streak.

Specific gravity of coal, 1·334. Ash, gray.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	7.240	Carbon	80.247
Volatile	36.776	Hydrogen	4.493
Fixed Carbon	53.489	Nitrogen	1.617
Ash	2.495	Sulfur	0.688
		Oxygen	12.955
	100.000		100.000

Calorific value determined: Air dried coal 6764 calories, 12175 B. T. U.; pure coal 7494 calories, 13489 B. T. U.

Calorific value calculated from ultimate analysis, 7489 calories, 13480 B. T. U.

Sample No. 3.—Green's property; same as No. 2, but represents that portion of vein below bony streak. This seam is the third from the top of the series and is opened again four miles west of Green's on Berry's Gulch.

Specific gravity of the coal, 1·356. Ash, gray.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	7.320	Carbon	80.683
Volatile	35.478	Hydrogen	4.275
Fixed Carbon	53.372	Nitrogen	1.665
Ash	3.830	Sulfur	0.603
		Oxygen	12.774
	100.000		100.000

Calorific value determined: Air dried coal, 6785 calories, 12213 B. T. U.; pure coal, 7635 calories, 13743 B. T. U.

Calorific value calculated from ultimate analysis of pure coal, 7413 calories, 13343 B. T. U.

The fact that these two samples, Nos. 2 and 3, are parts of the same seam would lead one to expect them to vary but little in their composition and heating value. This view is supported by the analytical results, but the calorimetric results are not consonant therewith. We observe a difference of 222. calories between the number obtained and that calculated from the composition of the pure coal. This difference might be attributed to the inaccuracies of our work and, after all, when the numerous sources of error and the large factors used in our formula are considered it would not be surprising to meet with differences as large as this, but the close agreement in the analyses of the two samples is what one would expect. The analyses was, moreover, practically done in duplicate with close agreement, so that it is probable that the analysis is quite correct and the error, if any, is to be sought in the calorimetric determination of the heat value. This was repeated, the results differing by only 5 calories—practically an identical result. I think that this indicates a slight difference in the value of the coals themselves and that the theoretical value is a little too low.

Sample No. 4.—Sample taken from a property known as Scott's mine, located in a gulch tributary to Hayden's Gulch, and about one-quarter mile from the Green property. This seam shows 10 feet, 6 inches of clean coal. The roof is slate, overlaid by a brown friable sandstone. Beneath the seam occurs a 30-foot stratum of a feebly cemented sandstone. I estimated that this seam is 75 feet higher in the series than the Green seam.

Specific gravity of the coal, 1·321. Ash, gray.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	6·525	Carbon	78·951
Volatile	39·259	Hydrogen	4·716
Fixed Carbon	51·436	Nitrogen	1·577
Ash	2·780	Sulfur	0·594
		Oxygen	14·162
	100·000		100·000

Calorific value determined: Air dried coal, 6752 calories, 12154 B. T. U.; pure coal, 7445, calories, 13401 B. T. U.

Calorific value calculated from ultimate analysis of pure coal, 7450 calories, 13410 B. T. U.

Sample No. 5.—Sample taken from lower, smaller seam opened on the James property, Oak Creek. Roof is carbonaceous slate, very tender, if not dangerous. This seam shows five feet of clean coal. What is left as a roof, however, is really only a parting in the seam, and it was stated that there was 3 feet of coal above this. The striking feature of this seam was the difference in the lustre and structure of the coal of its upper and lower portions, the former having a bright lustre and cuboidal fracture, the latter a much duller lustre and a decidedly flaky structure. This sample represents the upper 3 feet of the coal.

Specific gravity of coal, 1·315. Ash, reddish brown.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	5·185	Carbon	79·948
Volatile	39·165	Hydrogen	·4·828
Fixed Carbon	53·545	Nitrogen	1·884
Ash	2·105	Sulfur	0·903
		Oxygen	12·437
	100·000		100·000

Calorific value determined: Air dried coal, 7164 calories, 12895 B. T. U.; pure coal, 7728 calories, 13910 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 7608 calories, 13694 B. T. U.

Sample No. 6.—Same as No. 5, but represents 2 feet of coal near the bottom of the vein. This coal is used as a blacksmith coal, and it is claimed that it gives good satisfaction.

Specific gravity of coal, 1·315. Ash, reddish brown.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	4·855	Carbon	78·830
Volatile	37·189	Hydrogen	5·392
Fixed Carbon	56·101	Nirogen	1·888
Ash	1·855	Sulfur	0·759
		Oxygen	13·131
	100·000		100·000

Calorific value determined: Air dried coal, 7283 calories, 13109 B. T. U.; pure coal, 7806 calories, 14051 B. T. U.

Calorific value calculated from ultimate analysis of pure coal, 7677 calories, 13819 B. T. U.

Sample No. 7.—Sample taken from lower portion of what is designated as James' 14-foot vein. This seam shows 12 feet of clean coal. There is a streak of bone about 3 feet from the floor. This seam is from 70 to 75 feet above the seam represented by the preceding sample. They stated that there is a seam between these two, but I did not see it. The breast is 100 feet in a straight line from the entrance.

Specific gravity of coal, 1·327. Ash, reddish brown.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	5·680	Carbon	78·821
Volatile	36·278	Hydrogen	5·166
Fixed Carbon	56·162	Nitrogen	1·798
Ash	1·880	Sulfur	0·521
		Oxygen	13·694
	100·000		100·000

Calorific value determined: Air dried coal, 7088 calories, 12758 B. T. U.; pure coal, 7668 calories, 13802 B. T. U.

Calorific value calculated from ultimate analysis of pure coal, 7571 calories, 13628 B. T. U.

Sample No. 8.—Same as No. 7, but represents the portion of the vein above the bony streak.

Specific gravity of the samples is 1·327.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	5.120	Carbon	79.690
Volatile	33.800	Hydrogen	4.938
Fixed Carbon	57.060	Nitrogen	1.768
Ash	4.020	Sulfur	0.592
		Oxygen	13.012
	100.000		100.000

Calorific value determined: Air dried coal, 7104 calories, 12787 B. T. U.; pure coal, 7679 calories, 13822 B. T. U.

Calorific value calculated from ultimate analysis of pure coal, 7594 calories, 13669 B. T. U.

I observed, a little to the east and north of these openings, a sheet of lava—basalt, I think, but I did not have an opportunity to study its stratigraphical relations to these coals. Judging from what I saw the sheet is thin and probably has had no great influence, if any, on the character of the coal, but it did raise a question in my mind as to whether these seams belong to the bottom or to the middle series.

I have now presented the analyses of my samples representing the bottom series of seams These samples are eight in number and represent the extreme points of the territory visited. No. 1 represents the most northeasterly point; Nos. 2, 3 and 4 the southwestern point; the distance between these points being 26 miles in a straight line. Nos. 5, 6, 7 and 8 represent the southeastern point, which is 28 miles from the point where No. 1 was taken and 20 miles from that where Nos. 2, 3 and 4 were taken. The relation of the seams from

which the samples were taken to the other seams of the series was not determined, so it cannot be stated that the samples represent the same seams. It is probable that some of them do and would be comparable in this respect, but I do not know that this is the case.

An examination of these analyses will lead to the inference that these coals are essentially identical in composition, with no more variation than one would expect to find in samples taken within a few hundred feet of one another. The physical properties of sample 1 would lead one to judge it, if one were willing to make any distinction at all, to be inferior to the other samples. This was my impression when I was in the field and the ultimate analysis shows that it is lower in carbon and richer in oxygen than the other samples, but not materially so. We would scarcely have expected this, provided that the Pilot Knob eruptives had exercised any general and extended influence upon the character of the coals in that immediate neighborhood.

The very great similarity of the composition of these coals is shown by the ultimate analysis of the pure coals. The extreme difference in the percentages of carbon is 2·09 per cent.; of hydrogen, 1·1 per cent.; of nitrogen, 0·4 per cent.; of sulphur, 0·4 per cent.; of oxygen, 1·3 per cent. These facts are still more strongly emphasized by the calorimetric results which, by the way, show that number 1 is just as good a coal as the others. The range in the calorific value of these samples as determined by the bomb calorimeter is from 7445 to 7806, or an extreme difference of 361 calories; the range as shown by the values calculated from the ultimate analysis of the pure coal is from 7413 to 7717, an extreme difference of 304 calories. The formula used in calculating the calorific value from the ultimate analysis was $8080\ C + 34460\ (H - O \div 8) + 2250\ S$.

No special coking tests were made, but this group of coals showed the same deportment in the crucible, giving either a pulverulent or, at most, a very slightly agglutinated mass; in no case was there any coking, and whatever classification may

be made of these coals they will belong to the non-coking variety.

The middle series: This series is represented by ten samples, beginning with sample No. 9 of this paper.

Sample No. 9.—This sample was obtained from what I take to be the lowest seam of the middle series on the Crawford tract. The breast was 125 to 150 feet from the entrance and showed 11¼ feet of coal, with two streaks of slate, one of them 7 inches, the other 9 inches thick. The floor was not developed.

A sheet of lava passes under this seam at a depth of a few feet—it may be as much as 50 feet below it. The influence of this lava has been to convert the coal into anthracite. I do not know anything about the extent of this sheet under the seam. The sample is not a satisfactory one, as I was compelled to take such as I could get, which means that it is selected to a considerable extent, but is fairly representative of the coal.

Specific gravity of the coal, 1·445. Ash, white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	1·460	Carbon	90·230
Volatile	10·880	Hydrogen	3·062
Fixed Carbon	81·535	Nitrogen	3·239
Ash	6·125	Sulfur	0·807
		Oxygen	2·662
	100·000		100·000

Calorific value determined: Air dried coal, 7778 calories, 14000 B. T. U.; pure coal, 8417 calories, 15151 B. T. U.

Calorific value calculated from the ultimate analysis of pure coal, 8413 calories, 15143 B. T. U.

Sample No. 10.—This sample represents a 30-inch seam occurring, as far as I could see, next above the preceding with an interval estimated at 130 feet. I do not know whether there is any lava sheet included in this interval or not. The

opening was shallow and badly caved and the floor was not observable. The coal is bright, hard and has a conchoidal fracture.

Specific gravity of the coal, 1.605.   Ash, white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	2.565	Carbon	94.218
Volatile	5.391	Hydrogen	2.131
Fixed Carbon	84.059	Nitrogen	1.527
Ash.	7.985	Sulfur	1.041
		Oxygen	1.083
	100.000		100.000

Calorific value determined: Air dried coal, 7434 calories, 13381 B. T. U.; pure coal, 8311 calories, 14960 B. T. U.

Calorific value calculated from the ultimate analysis of pure coal, 8324 calories, 14985 B. T. U.

Sample No. 11.—This sample was taken from the third seam, counting from the bottom of the series and is possibly rather above the average of the coal than below it.   The tunnel is 125 feet long and the seam showed 12 feet of coal with a streak of slate 10 inches thick in its lower part.   Roof good; slate floor. The interval between this and the preceding seam is 50 feet, estimated.

Specific gravity of coal, 1.427.   Ash, white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	1.560	Carbon	86.224
Volatile	22.908	Hydrogen	4.154
Fixed Carbon	66.337	Nitrogen	1.767
Ash	9.195	Sulfur	0.926
		Oxygen	6.929
	100.000		100.000

Calorific value determined: Air dried coal, 7426 calories, 13367 B. T. U.; pure coal, 8322 calories, 14980 B. T. U.

The calorific value calculated from the ultimate analysis of the pure coal, 8121 calories, 14618 B. T. U.

The determined and calculated calorific values are rather far apart—201 calories, but the analysis on which the calculation is based was done in duplicate with close agreement throughout, 0·2 per cent. being the widest deviation in any case.   I, therefore, consider that the analysis is probably correct.   On the other hand the calorific value was redetermined after the discrepancy between the two determinations had been shown, but the redetermination of the calorific value differed from the one given by 10 calories only, so I have preferred to let it stand.

The fuel ratio of this coal, 2·89, classifies it as a bituminous coal, but it is not a coking coal. It was quite pulverulent after ignition.

Sample No. 12.—This sample was taken from a seam 100 feet above the preceding.   The breast showed 6½ feet of clean coal.   Slate roof and clayey floor.   The coal shows few slips; is bright, black and hard.   Drift, 140 to 150 feet long.

Specific gravity of coal, 1·395.   Ash, white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	6·840	Carbon	77·151
Volatile	37·348	Hydrogen	4·708
Fixed Carbon	52·572	Nitrogen	3·237
Ash	3·240	Sulfur	0·593
		Oxygen	14·311
	100·000		100·000

Calorific value determined: Air dried coal, 6553 calories, 11795 B. T. U.; pure coal, 7283 calories, 13109 B. T. U.

Calorific value calculated from ultimate analysis of pure coal, 7250 calories, 13055 B. T. U.

The four preceding samples represent a section of the seams of the middle group as exposed on the Crawford tract, owned by the Elkhead Anthracite Coal Company. The lower seams have been altered into anthracite; the third seam from the bottom, while not more than 50 feet above the second seam is a bituminous but not a coking coal, while the fourth seam is very similar in composition and properties to the coals from the Green, Scott and James properties, the calorific value differing but slightly from these, it being about 200 calories less.

Sample No. 13.—Sample obtained in breast of 165-foot tunnel located north of the road and west of a dry gulch tributary to Morgan Creek. The work had been done 10 or 12 years, and the face was in bad condition. The coal was badly mixed, but there was some good coal.

I failed to make mention in my notes of the relative position of this vein in the series, but I think that it is the lowest seam and that the sample is comparable with Sample No. 9. In this I may be mistaken, but the seams agree in thickness, 10 to 12 feet, and degree of anthracization. In other respects they are not at all alike.

Spcific gravity of coal, 1·609.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	1.860	Carbon	93.293
Volatile	6.114	Hydrogen	2.465
Fixed Carbon	81.781	Nitrogen	1.459
Ash	10.245	Sulfur	0.905
		Oxygen	1.878
	100.000		100.000

Calorific value determined: Air dried coal, 7355 calories, 13239 B. T. U.; pure coal, 8368 calories, 15062 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 8327 calories, 14989 B. T. U.

The next three samples were given to me by Mr. E. Shelton of Hayden. The samples were obtained in prospecting the

property of the Colorado Anthracite Company by a system of
drill holes. A good idea of the number of seams and their in-
closing strata is given in the following record of a drill hole
which I take from the report of the State Coal Mine Inspector,
Mr. John D. Jones, for the year 1903-1904. This record was
furnished by Mr. Shelton, but its location is not definitely
given and is probably not one of those which furnished either
of the samples which he gave me.

Record of drill hole one-fourth mile back from the outcrop.

	Feet	Inches
Clay	25	0
Coal, No. 1	5	0
Shale, gray	9	0
Sandtone, yellow	21	0
Shale, dark	8	6
Coal	·1	0
Shale	12	0
Coal No. 2	2	5
Shale, dark	8	5
Coal No. 3	6	3
Shale, dark	18	4
Coal	1	0
Shale, dark	25	6
Coal, No. 4	4	4
Shale	25	0
Basalt	1	0

The coals specified in the above section as Nos. 1, 2, 3
and 4 are not necessarily the same seams as those from which
the following three samples were taken, but they may be.

Sample 14.—Location D, Sec. 32, T. 9 N., R. 86 W. Seam
6 feet 5 inches thick, 101 feet from the surface to the bottom
of the seam.

Specific gravity of the coal, 1·542. Ash, white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	1·190	Carbon	92·624
Volatile	5·868	Hydrogen	2·492
Fixed Carbon	81·422	Nitrogen	1·339
Ash	11·520	Sulfur	1·679
		Oxygen	1·866
	100·000		100·000

Calorific value determined: Air dried coal, 7236 calories, 13025 B. T. U.; pure coal, 8288 calories, 14918 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 8300 calories, 14940 B. T. U.

Sample No. 15.—Location D, Sec. 32, T. 9 N., R. 86 W. Seam 3 feet 8 inches thick. Depth from surface, 117 feet 8 inches.

Specific gravity of the coal, 1·407. Ash, white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	1·035	Carbon	87·692
Volatile	12·509	Hydrogen	3·699
Fixed Carbon	78·731	Nitrogen	1·775
Ash	7·725	Sulphur	0·992
		Oxygen	5·842
	100·000		100·000

Calorific value determined: Air dried coal, 7611 calories, 13670 B. T. U.; pure coal, 8342 calories, 15016 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 8133 calories, 14641 B. T. U.

Sample No. 16.—Location C. Seam 2 feet 10 inches thick. Depth from surface to bottom of seam, 172 feet 6 inches.

Specific gravity of the coal, 1·398. Ash, nearly white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	0·790	Carbon	89·901
Volatile	14·710	Hydrogen	3·283
Fixed Carbon	80·845	Nitrogen	1·806
Ash	3·655	Sulfur	1·069
		Oxygen	3·941
	100.000		100·000

Calorific value determined: Air dried coal, 8005 calories, 14409 B. T. U.; pure coal, 8378 calories, 15080 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 8249 calories, 14848 B. T. U.

Sample No. 17.—This sample was taken at the head of Sage Creek, and represents the lowest seam of the middle series that I sampled at this place. I was informed that it was really the third from the bottom of the series, which at this point consists of four seams, of which, however, only the upper two have been opened, each by a single drift entering from the east flank of the hill. This seam showed 11 feet 5 inches of coal at the breast of the drift 75 feet from the entrance. Slips are few and indistinct.

Specific gravity of coal, 1·350. Ash, white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	7·085	Carbon	78·397
Volatile	38·583	Hydrogen	4·595
Fixed Carbon	49·782	Nitrogen	1·761
Ash	4·550	Sulfur	0·583
		Oxygen	14·664
	100.000		100·000

Calorific value determined: Air dried coal, 6589 calories, 11860 B. T. U.; pure coal, 7456 calories, 13421 B. T. U.

. Calorific value calculated from the ultimate anaylsis of the pure coal, 7299 calories, 13138 B. T. U.

Sample No. 18.—Sample taken from the top seam of the middle group; this seam has a thickness of 7 feet. The breast was about 75 feet from entrance. The partings were not distinct. The dip of the formation at this point is to the north and east, due to a fold transverse to the axis of the basin.

Specific gravity of the coal, 1·337. Ash, nearly white.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air Dried Coal		*Pure Coal*	
Moisture at 100°	7·800	Carbon	78.318
Volatile	35·856	Hydrogen	4.482
Fixed Carbon	54·809	Nitrogen	1·935
Ash	1·535	Sulfur	0·739
		Oxygen	14·526
	100·000		100·000

Calorific value determined: Air dried coal, 6672 calories, 12010 B. T. U.; pure coal, 7358 calories, 13244 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 7364 calories, 13255 B. T. U.

While there are ten samples representing the middle series, there are only three of them which represent coals which have not in some measure been affected by the presence of lava sheets. These three samples are Nos. 12, 17 and 18, two of them from the top seam and the third one from the next seam below it, or the third seam of the middle series. The composition and calorific values show these coals to be very nearly the same. The fuel ratios are 1·4, 1·3 and 1·5 respectively, while the calorific values are 7283, 7456 and 7358 calories—a maximum difference of 173 calories in the values as determined with the calorimeter.

The values agree still more closely if we take those calculated from the ultimate analyses.

In comparing the coals of the middle and bottom series, we find the latter to be a trifle the better coals, being rather

richer in carbon, very nearly the same in hydrogen, and con-
sequently poorer in oxygen. The difference in composition is
not great, being 1·47 per cent. in the case of carbon and only
0·4 per cent. in the case of the hydrogen. Slight and uncer-
tain as these differences are, they are consonant with differ-
ence shown by the determined calorific values, those for the
bottom series being slightly the higher, nearly 300 calories for
the two series. These statements do not, of course, pertain
to the anthracites. I have, however, included the coals from
the James mine in the bottom series. I mentioned the fact
that I observed the occurrence of a lava sheet near this prop-
erty, but stated that I had no opportunity of studying its re-
lation to these coals. I can do no more now than suggest that
the coals from this property may owe their character to the
influence of intruded sheets, which I failed to observe, for the
coal from these mines approach most nearly to coking coals
of any which I found in the field, but otherwise they are very
similar to the other coals of this series.

There seems to be some difference of opinion regarding
the classification of the coals of this field; some of it is, I
think, due to the indefinite meaning attached to the term
bituminous, and also, perhaps, to a somewhat varying use of
the term coking. None of the samples which I obtained proved
to be coking coals. This is in harmony with the observation
of Mr. R. C. Hills, but not with the statements of other ob-
servers.

In regard to the classification of these coals, I shall adopt
the carbon-hydrogen ratio. See Professional Paper, No. 48,
U. S. Geological Survey, p. 156 *et seq.*, where the subject of
the classification of coals is discussed by Mr. Marius R. Camp-
bell. In this instance I shall use the percentages for the air
dried coals on the assumption that the water retained by the
lignites on air drying constitutes one of the differences be-
tween the bituminous and lignitic coals.

Concerning some of these coals, the anthracites, there
can be no question about their classification, but concerning
the others there evidently is, as they are classed as bituminous

coals and also as lignites.   These two classes of coals unquest-
ionably pass very gradually into each other, and any dividing
line which may be adopted will be, to a greater or less extent,
an arbitrary one.   For the purposes of this paper I shall adopt
three of the Boulder County coals, commercially recognized
as belonging to the best type of lignitic coals, the Gorham,
Mitchell and Matchless coals, as the standard for a high grade,
black lignite. Two of the samples used were taken from cars
and represent the coal as delivered here for local use, and were
direct from the mines. The third sample was taken from a
storage shed and was not so fresh. These samples were treat-
ed and preserved in exactly the same manner as the Routt
County coals, so that while our carbon-hydrogen ratios may
be a little higher than they would have been had it been possi-
ble to have taken up the work and finished it while the sam-
ples were fresh, they are comparable with one another. The
moisture in these samples, determined at 100°, was 9·24, 9·67
and 9·65 per cent., and at 110°, 9·64, 10·16 and 10·97 per cent.,
which, adopting the water content as the basis of classifica-
tion, would place them close to the dividing line between the
bituminous and the lignitic coals. The carbon-hydrogen
ratios are consonant with this view, for they are 13·4, 13·8
and 13·7. While the ratio 13·4 may be too high to take as the
limit for black lignites in perfectly fresh samples, I think it a
perfectly proper one to take in the present case. It is, how-
ever, considerably higher than the limit suggested by Mr.
Campbell.   I shall give ratios for the samples in the order
that they have been taken up.

Sample	Locality	Ratio.
No. 1.	Stevens property, bottom series E. of Pilot Knob	14·3
No. 2.	L. H. Green's mine, Hayden Gulch.........	14·9
No. 3.	L. H. Green's mine, Hayden Gulch...........	16·6
No. 4.	Scott's mine, Hayden Gulch	17·0
No. 5.	James's mine, lower opening, Oak Creek....	14·7
No. 6.	James's mine, lower opening, Oak Creek....	14·3
No. 7.	James's mine, 14-foot seam, Oak Creek......	15·3
No. 8.	James's mine, 14-foot seam, Oak Creek......	14·4
No. 9.	Crawford's tract, lowest seam, Morgan Creek	27·8
No. 10.	Crawford's tract, 30-inch seam, Morgan Creek	38·7
No. 11.	Crawford's tract, 12-foot seam, Morgan Creek	20·1
No. 12.	Crawford's tract, top seam, Morgan Creek..	13·9
No. 13.	Crawford's tract, north of county road, Margan Creek	42·1
No. 14.	Location D, Colorado Anthracite Coal Co...	35·2
No. 15.	Location D, Colorado Anthracite Coal Co...	23·6
No. 16.	Location C, Colorado Anthracite Coal Co...	26·6
No. 17.	Lower opening head of Sage Creek........	14·3
No. 18.	Top seam, middle group, head of Sage Creek	14·2

These coals are plainly divisible into two groups, the first consisting of the coals from the property of the Elkhead Anthracite Coal Company, the Crawford tract, and those from the property of the Colorado Anthracite Company, Nos. 9, 10, 11, 13, 14, 15 and 16, the rest belonging together in another group, having, with three exceptions, ratios less than fifteen. Of the three exceptions one, No. 7, showed a slight tendency to coke; the other two are excellent coals, but show no tendency to coke. The first group is anthracite or semi-anthracite, but the highest classification that we can make of the rest of these coals, judging them by the carbon-hydrogen ratio, is to put them at or near the bottom of the bituminous coals, or probably with greater justice at the top of the lignites.

The case of No. 12, perhaps, is deserving of a little fuller notice because it is separated from No. 10, an anthracite, by not more than 140 feet of intervening strata, and has a carbon-hydrogen ratio of 13·9, while No. 10 has a ratio of 38·7, according to which the former is an excellent lignite and the latter a very good anthracite. I may add that an intervening

seam, represented by Sample No. 11, has a ratio of 20·1, which would place it among the bituminous coals, but it resembles the lignites in its physical properties, shows no sign of coking, and contains 7·25 per cent. of water. This coal seam is only 35 feet above the thirty-inch seam of anthracite, and one would be justified in expecting to find much more distinct evidences of the action of the underlying lava sheet than is shown.

It seems to me unfortunate that we have to use the term lignite, either with or without the modifying adjective black, in classifying these coals. I am fully convinced that these coals are properly classified as black lignites according to the standard adopted. It is, however, not my intention to intimate that they are inferior coals, for they are, on the contrary, good coals, which fact is shown by their composition and calorific values. The moisture in the air-dried coals is quite uniformly below 7 per cent., and the calorific values range from 11562 to 13109 B. T. U. In the older classifications we find Canyon City and Gunnison River coals among the lignites, but these coals are not distinguishable from bituminous coals, either in their physical properites or in regard to their calorific values, which in these instances are given as 13097 and 14240 B. T. U. respectively.

We can not use the term semi-bituminous in this case, because this is used to designate a class of coals above and not below the bituminous. We have, at present, no term designating the coals belonging to the lower portion of the bituminous and the upper portion of the lignites, neither is there any resonably sharp line of division between them. The term semi-bituminous might be applicable, but it is now in use in a specific sense, and to use it in another sense would only lead to confusion, which, by the way, already exists. There could be no objection to classifying these coals as lignites if this name were not used to designate a very different coal. The designation as black lignite is, perhaps, the best one so far suggested, but it carries with it a suggestion of inferiority which is not just.

A STUDY OF SOME COLORADO COALS—A COMPARISON OF SOME COALS FROM BOULDER, ROUTT AND DELTA COUNTIES.

By Wm. P. Headden

Read at the Meeting of the Society April 6, 1907.

The samples of coals presented in this note represent two different and well known fields, the South Platte and that portion of the Grand River field lying along the North Fork of the Gunnison. The South Platte field is represented by three samples from Boulder county, the Mitchell, Matchless and Gorham coals. The Mitchell has been analyzed by Mr. Hills, Mineral Resources 1892, p. 363, but the Gorham and Matchless, though considered to be good coals of this variety, have not, so far as I have been able to find, been studied.

My analyses have been made on air-dried samples because I wished to compare the results of these analyses with others which circumstances compelled me to make on air-dried material, for this reason they were all brought to as nearly the same basis as possible.

The only analyses of coals from the Boulder district, of which I have any knowledge, are those presented by Mr. Hills in Mineral Resources, 1892, and one by the committee in charge of the coal testing plant at St. Louis, or Professional Paper, 48 U. S. Geological Survey. Of these analyses only three give the calorific values of the coals, though they all give the ultimate composition of the samples.

The primary object I had in view in making these analyses was to determine the carbon-hydrogen ratio of a recognized lignite which had been preserved just as my other samples,

Routt county coals, had been. A ratio of 11·2 has been suggested as the limit for a lignite, but I understand the suggestion to apply to a fresh lignite, air-dried under definite conditions, but not such as those under which my samples were preserved. My second object was to increase the number of analyses and, perhaps, get a closer estimate of the value and character of these coals.

Matchless Coal—Sample taken from a car load lot.

Specific gravity of coal, 1·367. Ash. light brown.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air-Dried Coal		*Pure Coal*	
Moisture at 100°	9·680	Carbon	77·113
Volatile	29·056	Hydrogen	4·532
Fixed Carbon	55·684	Nitrogen	1·683
Ash	5·580	Sulfur	0·385
		Oxygen	16·287
	100·000		100·000

Calorific value determined, air-dried coal, 5997 calories, 10795 B. T. U.; pure coal, 7077 calories, 12739 B. T. U.

Calorific value calculated from the ultimate analysis of the coal, 7081 calories. 12744 B. T. U.

Mitchell Coal.—Sample taken from a car load lot.

Specific gravity, 1·318. Ash, reddish to light brown.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air-Dried Coal		*Pure Coal*	
Moisture at 100°	9·645	Carbon	75·638
Volatile	32·245	Hydrogen	4·541
Fixed Carbon	54·735	Nitrogen	1·588
Ash	3·375	Sulfur	0·386
		Oxygen	17·847
	100·000		100·000

Calorific value determined, air-dried coal, 6132 calories, 11038 B. T. U.; pure coal, 7074 calories, 12733 B. T. U.

Calorific value calculated from the ultimate analysis of the coal, 6917 calories, 12451 B. T. U.

Gorham.—Sample taken from storage shed.

Specific gravity 1·358.   Ash, reddish to light brown.

PROXIMATE ANALYSIS	UYTIMATE ANALYSIS
Air-Dried Coal	*Pure Coal*
Moisture at 100°.......... 9.240	Carbon 77.270
Volatile 36.114	Hydrogen 4.435
Fixed Carbon 50.740	Nitrogen 1.596
Ash 3.906	Sulfur 0.707
	Oxygen 15.992
100.000	100.000

Calorific value determined, air-dried coal, 6321 calories, 11378 B. T. U.; pure coal, 7087 calories, 12757 B. T. U.

Calorific value calculated from the ultimate analysis of the coal, 7079 calories, 12742 B. T. U.

These coals are recognized as among the most desirable coals of Boulder county and of the South Platte field. They represent a very high grade of the black lignites. It may, therefore, be well to compare them. The proximate analyses show that they contain almost identical quantities of water i. e., 9·65, 9·68 and 9·24 per cent. In so far as the water content of an air-dried coal has any value as a criterion for the classification of the coal, these could scarcely be any more nearly alike; the ash is a variable and largely an accidental constituent; especially when the coal is taken in car load lots as these were. But here we find 3·38, 3·91 and 5·58, an agreement which speaks pretty well for the coal miners, as these coals were directly from the mines and were such as are sold in the local markets; the fixed carbon varies but little in these three samples, 50·74, 54·74 and 55·68 per cent. We have the widest range in the portion designated volatile carbon, i. e., 29·06, 32·25 and 36·11 per cent. I have examined the analyses of a large number of coals and I think that I am correct in stating, that the volatile portion is composed of about 50 per cent or

one-half carbon, the usual ratio of the difference between the fixed carbon and the total carbon as calculated from the ultimate analysis, to the volatile as given by the proximate analysis is quite close to 1:2; it varies, being 1:1 1-3 in a few instances, but it is usually very close to 1:2. In the samples here presented we have an unusually large range, 1:1·5, 1:1·7 and 1:2, which is the only indication of any difference in the coals.

If we examine the calorific values we find these remarkably close together, whether we take them as fuels, *i. e.* including moisture and ash, or as pure coals. As fuels, we find the values 5997, 6132 and 6321 calories, or eliminating the moisture and ash we have 7077, 7074 and 7087 calories. These are the results of the direct determinations of these values; the indirect determinations, those calculated from the ultimate analyses of the coals, agree almost as well as the preceding, these give us 7081, 6932 and 7079 calories. The theoretical values do not agree as closely as they might, still they show that these coals are of almost equal value, a conclusion to which we come, whether we consider them in the light of the proximate analysis, the determined heat values, the ultimate analysis, or the theoretical heat values.

The object had in view in examining these coals was twofold namely, to learn their value as definitely as possible, but more especially for the purpose of using them as provisional standards for this class of coals, black lignite, of which they are recognized as good types. Their properties are those which we recognize as characterizing this class—a comparatively low specific gravity, high content of water, slacking more or less badly on storing, burning with a short to medium long flame with but little soot, and without any signs of coking. The fuel ratio for the Gorham is 1·43, the Mitchell 1·7, the Matchless 1·7. These ratios would indicate that these coals belong above many of the bituminous coals. The calorific values are not in harmony with this result, as they are lower than the values obtained from recognized bituminous

coals. *The ultimate analyses, moreover, show percentages of
oxygen too high for bituminous coals, but the oxygen content
has not to my knowledge ever been suggested as a means of
classification. Every analyst knows that the sum of the plus
and minus errors of an analysis is contained in the oxygen
determination, still in a tabulation of complete analyses and
calorific values, it will be observed that the latter together
with the carbon-hydrogen ratio decrease rapidly with an in-
crease of oxygen and the latter together with the carbon-
hydrogen ratio may serve an excellent purpose in classifying
the coal. I doubt whether any bituminous coal will show as
much oxygen as these samples show, viz. about 16 per cent of
the pure coal. The compiled analyses of bituminous coals
from Pennsylvania and West Virginia given by Poole contain,
as a rule, less than half this amount of oxygen.

The Indiana coals contain about the same percentage, 13
to 18 per cent, and the latter coals are placed by Mr. Campbell,
Professional Paper No. 48, U. S. Geological Survey, p. 170, in
the lowest group of the bituminous coals. None of the methods
of classification, which have been proposed as yet, seem to
have proven applicable to all kinds of coal. The fuel ratio
gives fair satisfaction with some coals, other criteria, per-
centage of carbon, the percentage of hydrogen, etc., have been
tried but the lignites have given trouble in all of these classi-
fications being, as a rule, higher in the classification adopted
than they should be, according to the known properties of the
coals. The carbon-hydrogen ratio proposed by Mr. Campbell
seems to give the best results of any so far suggested. In cal-
culating this ratio the moisture in the air-dried coal is consid-
ered as part of it. We find for these coals 13·7, 13·8 and 13·4
for this ratio. These figures are higher than the limits sug-
gested by Mr. Campbell for lignites, and places them in his
group H which is next to the lowest group in the bituminous
class. They, however, stand close together, and quite close to
the Indian Territory coals which we find among the bituminous
coals, with ratios of 13·1, 13·6, 14·1 and 14·3. The Boulder

*For Pennsylvanian Octuminous Coals, see Poole, Calorific Power of Fuels, p. 218; for
West Virginian Coals, see same, p. 219.

county coals calculated to an ash free basis give 6351, 6337 and 6511 calories, but the Indian Territory coals give, calculated to the same basis, No. 1, 7820, No. 3, 7757 and No. 4, 7305 calories.   So there is no agreement according to this standard, and we could scarcely expect that there would be, as the classification according to the calorific value is not satisfactory, though its special weakness is in the higher classes of coals, anthracite often falling below bituminous coals according to it.

While the line of division between the lignitic and bituminous coals, as shown by the carbon-hydrogen ratio, is not sharp it seems to be the best that we have, any uncertainty which may arise being confined to the lower grades of bituminous and the better grades of lignites. The samples in question belong to the lignites, as previously stated, judging them by the properties enumerated, i. e. burning with a comparatively small, clean flame, slacking on exposure, burning without coking and having a low specific gravity.   And yet the carbon-hydrogen ratio indicates that they belong to the lower section of the bituminous coals.   There can, however, scracely be any second opinion, but that these coals belong to the class generally recognized as black lignites.   Neither can I doubt the correctness of the analytical work which received great care throughout.   The conclusion to which I am forced is, that the high grade lignites may show a carbon-hydrogen ratio of 13·4, while a considerable number of the bituminous coals may show a smaller value for this ratio.   Our Routt county coals present this difficulty to a still greater extent, possessing the characteristics of lignites, except that they slack to a slight extent only, and in one case there is a slight tendency to coke, but their carbon-hydrogen ratios are still higher than those of the Boulder county coals.   There is no doubt but that these coals, especially the last mentioned ones, are excellent coals of this class, and their excellent qualities, as well as the carbon-hydrogen ratio indicate that the class of black lignites should be held as of equal rank with the lower grades of bituminous

coals. I have suggested that the oxygen content might be of value in deciding our classification in such cases.

It is trite to state that the process of carbonization, in its main feature, consists in the elimination of oxygen and hydrogen from the woody tissue. Still I may be pardoned for calling attention to the fact that while we have formulas expressing the manner in which this process may take place, we do not know what the course of the process is and that the process probably varies in the case of different coals, so that the amount of oxygen remaining may be indicative of more than we have suspected. If we examine the ultimate analyses of the recognized bituminous coals we will observe that it is only the lowest members of this group whose oxygen approaches or exceeds 16 per cent. In the bituminous coals of W. Va. the percentage of oxygen ranges from 3·0 to 7·6 per cent, moisture and ash included with the coal; the ash ranging from 5·0 to 11·5 per cent. In those from Pennsylvania the oxygen percentage ranges from 2·7 to 8·2, with the ash usually less than 9 per cent. The various methods of classification so far suggested, while holding good for a large number of coals, have all failed in some cases, and particularly in placing the lignites. I take it that it is agreed that there are differences between the lignites and the bituminous coals and that, if they really come under the same classification, the lignites should stand lower than the bituminous coals. There are no questions concerning the higher grades of the bituminous coals, but so far as classification is concerned there is a question whether such coals as we have in Routt county should be classified as bituminous coals or as lignites.

Our knowledge of the changes whereby the vegetable matter has been converted into the various kinds of coal is by no means definite, and while the process has been one whereby hydrogen and oxygen have been eliminated in conjunction with hydrocarbons, there is no reason why we should assume that the individual features of the process may not have varied, perhaps materially, so that we would not be justified in trying to classify all coals by the same stand-

ard. The lignites may be the result of changes leaving more oxygen and producing no fusible products, the hydrogen and oxygen being left in combination in such manner that gases relatively poor in carbon are generated when the coal is burned or degasified, a fact which would help to explain the difficulties in classification.

Our Routt county coals deport themselves as lignites, as the term is used among us, and differ but little from our Boulder county coals in their general features and deportment, but they do not slack to nearly the same extent. If, however, we apply the methods of classification in vogue, we find that they are bituminous coals. Classifying them according to the carbon-hydrogen ratio, which seems to be the best for the classification of these coals, they would be included among the bituminous, but their deportment, as stated above, places them among the lignites rather than among the bituminous coals. I appreciate the fact that I appeal from the results of a chemical classification to the common judgment based on physical properties, but this is the means by which we judge the value of the chemical classification.

With the idea that the differences between the lignites and bituminous coals may be one of chemical constitution, as well as composition, I have brought together a number of bituminous coals and their oxygen content. We all recognize that the sum of the plus and minus errors of the whole analysis is contained in the percentage of oxygen, but our work was done in duplicate and the results are close to the truth. The following data are taken partly from the report of N. W. Lord in Professional Paper 48, U. S. Geological Survey and partly from the compliation of analyses by H. Poole, the Calorific Power of Fuels.

BITUMINOUS COALS.

No	State	Calories	C—H ratio ashless coal	Ash	Oxygen
1	W. Va.	8501	17.8	5.09	5.87
2	W. Va.	8254	18.8	7.36	6.39
3	W. Va.	7869	14.7	6.37	7.61
4	W. Va.	7621	15.5	10.37	6.09
5	Mo.	6191	12.9	20.38	8.46
6	Ky.	7955	14.6	4.44	8.80
7	Ky.	6966	12.7	9.38	12.69
8	Kan.	7322	14.5	10.79	7.40
9	Kan.	6891	13.9	13.14	8.30
10	I. T.	7205	14.3	11.32	8.91
11	I. T.	7011	13.6	10.35	11.38
12	Pa.	8201	15.3	8.75	6.90
13	Pa.	8304	14.6	5.93	7.22
14	Pa.	8248	14.4	9.25	7.12
15	Pa.	8324	14.5	8.86	7.05
16	Pa.	8165	15.0	8.70	6.90
17	Pa.	8256	15.3	4.95	7.28
18	Ind.	6326	11.9	13.81	14.99
19	Ind.	6410	12.3	13.51	12.56
20	Ill.	6724	13.9	11.59	12.99
21	Ark.	7450	18.9	12.88	4.70
22	Ark.	7756	19.3	9.24	3.20

The coals given in the above table are recognized as bituminous coals, this is the reason I have taken them and that without selection so that there is a variety of grades. This is shown by the range of the calorific values from 6200 to 8500 or an extreme difference of 2300 calories, the carbon-hydrogen ratio varying from 11·9 to 19·3, which is certainly a sufficiently wide range. If we consider the oxygen content in connection with the carbon-hydrogen ratio and the calorific value we find that, though there is not a close agreement, it is true that the calorific value and the carbon-hydrogen ratios agree fairly well for this class of coals, so well that instances of wide discrepancies would suggest the probability of an error. This holds very well even in those cases showing considerable percentage of ash, as in the case of No. 18, with a carbon-hydrogen ratio of 11·9 calorific power, ashless, 7351;

No. 19 carbon-hydrogen ratio 12·3, calories 7410; No. 7, carbon-hydrogen ratio 12·7 calories 7687; No. 5 carbon-hydrogen ratio 12·9 calories 7776. An inspection of the percentages of oxygen reveals the fact that of the 22 samples only one sample will show the presence of materially more than 14 per cent, when the percentage is calculated on the ashless coal, No. 18, an Indiana coal, gives 17·3 per cent, which I judge to be a very high percentage of oxygen for even a moderate grade of bituminous coal. I find but five other coals classed as bituminous coals having higher percentages of oxygen than this, and their calorific powers and carbon-hydrogen ratios are of course correspondingly low.

The Boulder county coals, black lignites, give the following results:

	Calories Pure coal	Carbon-hydrogen ratio	Percentage of Oxygen
Mitchell	7074	13.4	24.10
Matchless	7077	13.7	22.70
Gorham	7087	13.8	22.16

We have in these a very uniform calorific power, a close agreement in the carbon-hydrogen ratio and an oxygen percentage higher than that of the lowest grade of bituminous coals, so much higher that it is well marked. The calorific power and carbon-hydrogen ratios are on the other hand high enough to place them unquestionably among the bituminous coals.

If we now consider the Routt county coals in the same manner we shall have:

	Calories Pure coal	Carbon-Hydrogen ratio	Percentage of Oxygen
No. 1	7692	14.20	18.73
No. 2	7494	14.85	18.48
No. 3	7642	16.45	18.89
No. 4	7445	16.97	18.71
No. 5	7728	14.71	16.25
No. 6	7806	14.30	17.10
No. 7	7668	15.30	18.31
No. 8	7679	14.38	18.06
No. 11	8322	20.12	8.23
No. 12	7283	13.89	19.37
No. 17	7456	14.32	19.93
No. 18	7358	14.16	20.75

The other numbers, 9, 10, 13, 14, 15, 16, in this series were anthracite coals and have for that reason been omitted. We have in No. 11 a bituminous, or perhaps a semi-bituminous coal, which serves very well to emphasize the pronounced difference in the oxygen content of these coals. There is only one sample in this series, No. 5, which shows any sign of coking, and this is only slight. If we compare these Routt county coals with the Boulder county samples we observe that we pass downward from the Routt county samples into the Boulder samples without any very marked change. These Boulder county coals are as we know considered as lignitic coals, black lignites, but they have a higher carbon-hydrogen ratio than many of the unquestionably bituminous coals, also as high or even higher calorific powers, but they differ essentially in their percentages of oxygen as I have endeavored to show by the analyses of the 39 samples of bituminous coals given. The samples from Routt and Boulder counties represent the whole series, rejecting only the anthracites, and those that I have quoted have not in any sense been selected, but have simply been taken to fairly represent the bituminous coals of the various states.

It would be interesting to know the differences in the products of the destructive distillation of these coals, and those of the bituminous coals of West Virginia and Pennsylvania, but no such study has been made up to the present time, so far as I know.

These coals apparently form a distinct class which can not be easily brought into the classifications found to be more or less satisfactory for the older coals or for these, when they have been changed by heat or other agencies into advanced stages of carbonization, in which transformations different and deeper going changes are probably involved. The agencies to which we can appeal in the case of our coals are, heat, furnished by eruptive rocks, repeated and greater movements of the strata and pressure.

It may be urged that, if we may depend upon analogy for an explanation of the processes which bring about the conversion of the vegetable matter into coal, we would be justified in expecting that the elimination of oxygenated compounds in the earlier stages of carbonization would scarcely leave so much oxygen in the coals as we find in the black lignites. But we find this class of coals uniformly rich in oxygen and having at the same time a high carbon-hydrogen ratio.

I have three samples of coal representing that section of the Grand river field lying along the North Fork of the Gunnison. They represent the Somerset and Juanita mines, one located at the town of Somerset and the other a little farther down the valley. I do not know the stratagraphical relations of these seams. It is possible that they do not represent the same series of seams, in which case the Juanita would probably be the lower.

COALS FROM NORTH FORK OF GUNNISON RIVER. ......

Somerset coal, specific gravity, 1·497:

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air-Dried Coal		*Pure Coal*	
Moisture at 100°	2.565	Carbon	80.726
Volatile	35.72	Hydrogen	5.355
Volatile	35.725	Nitrogen	1.642
Fixed Carbon	55.195	Sulfur	0.503
Ash	6.515	Oxygen	11.774
	100.000		100.000

Calorific value determined, air-dried coal, 7293 calories, 13167 B. T. U.; pure coal, 8021 calories, 14472 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 7787 calories, 14017 B. T. U.

The calorific power of this coal was redetermined to see whether the wide difference between the determined and calculated values were due to mistakes of manipulation or to the coal itself. The two calorinetric determinations agreed very well indeed, as did also the analytic results. We have a descrepancy of 234 calories, amounting to nearly 3 per cent of the calorific power of the pure coal, but a repetition of the work changed this by only 19 calories.

Juanita, four and one-half foot seam.

Specific gravity, 1·351.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air-Dried Coal		*Pure Coal*	
Moisture at 100°	2.175	Carbon	79.918
Volatile	34.447	Hydrogen	5.033
Fixed Carbon	54.173	Nitrogen	1.813
Ash	9.205	Sulfur	0.968
	100.000	Oxygen	12.268
			100.000

Calorific value determined, air-dried coal, 7116 calories 12809 B. T. U.; pure coal, 8030 calories, 14454 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 7917 calories, 14251 B. T. U.

Juanita, fourteen foot seam.

Specific gravity, 1·318.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
Air-Dried Coal		*Pure Coal*	
Moisture at 100°..........	1·000	Carbon	82·920
Volatile	27·432	Hydrogen	4·479
Fixed Carbon	66·863	Nitrogen	1·746
Ash	4·705	Sulfur	0·643
		Oxygen	10·212
	100·000		100·000

Calorific value determined, air-dried coal, 7674 calories, 13813 B. T. U.; pure coal, 8138 calories, 14648 B. T. U.

Calorific value calculated from the ultimate analysis of the pure coal, 8004 calories, 14407 B. T. U.

This coal yields a hard, quite dark colored, close-grained coke.

Concerning the classification of these coals there is no doubt. The percentage of moisture in the air-dried coal is low, the carbon-hydrogen ratio is high and the percentage of oxygen in the ashless coal is much lower than in the Boulder county black lignites which, for the purposes of this paper, we have taken as standard for the typical black lignite, but it is still decidedly higher than that present in the bituminous coals of Pennsylvania and West Virginia, and the calorific value, though good, is less than that of these coals.

The North Fork Delta county coals give the following results:

Name	Calorific Power Pure coal	Carbon-Hydrogen ratio Ashless coal	Percentage oxygen ashless coal
Somerset	8021	14.2	13.76
Juanita, 4½ ft. Seam......................	8030	15.2	13.91
Juanita, 14 ft. Seam.......................	8138	18.2	10.99

In calculating the carbon-hydrogen ratio and the percentage of oxygen I have used the air-dried, ashless coals. The light in which we are to consider the water present in such coals is still, as I understand it, an open question. I have considered it as a part of the coal.

MOISTURE DETERMINATION.

As my work was necessarily distributed over quite a long period and as there is, even under the best conditions, some question regarding the moisture determinations, this point gave me some solicitude, but I am convinced that there was no occasion for it. The determinations recorded below show, it is true, some variations, but they are as a rule small. I cannot give the exact time elapsing between the two series of moisture determinations but the determinations by drying in the water-oven for exactly one hour, and designated as moisture at 100°, were made, at least, 3½ months previous to those made by drying in an air-bath at 110°, for exactly one hour.

Moisture in air-dried coal; determined by drying for one hour in the water-oven, and in the air-bath heated to 110°.

No. of Coal	Water-oven	Air-Bath
1	6.535	6.360
2	7.240	7.820
3	7.320	7.310
4	6.525	8.190
5	5.185	5.110
6	4.855	4.870
7	5.680	5.600
8	....	5.120
9	1.460	1.380
10	2.565	2.540
11	1.560	1.600
12	6.840	7.290
13	1.860	2.030
14	1.190	1.160
15	1.035	0.940
16	0.790	0.830
17	7.085	7.640
18	7.800	9.130
19	9.240	10.160
20	9.680	10.970
21	9.640	9.620
22	2.565	2.420
23	2.175	2.290
24	1.000	1.090

This series represents our black lignites, bituminous and anthracite coals. As the maximum difference found in determining the moisture by the two methods, at an interval of three and one-half months, is only 1.3 per cent it is not probable that any considerable error has crept into my results due to changes in the moisture or, for that matter, in the coals themselves during the period. The largest differences observed are in the cases of coals having pronouncedly lignitic properties. The samples were preserved in stoppered bottles but not sealed, nor were the bottles filled with the sample. Our atmosphere is as a rule relatively dry, but as explained in an article on the Routt county coals, the samples were pre-

served in well packed boxes in a rather moist basement until taken out for the preparation of the samples for analysis. We observed the wet and dry bulb thermometers during a part of the drying experiments; the dew point varied from 19·3 to 33, and relative humidity from 13·3 to 24·8, but if it made any difference, it was so small that it escaped our notice.

It is not practical to present all of the samples discussed in a brief review so I will simply present those which seem to be fairly representative. We have the three classes, in which statement I recognize our practical, popular classification of the Boulder county coals, as black lignite, as correct. I grant that the classification may be unfortunate and perhaps unscientific, but it is common to the western states and has found recognition by the students of this subject.

The Boulder county coals give us the following:

Name of	Calories Pure coal	Carbon-Hydrogen ratio Ashless coal	Percentage Oxygen Ashless coal
Mitchell	7074	13.4	24.10
Matchless	7077	13.7	22.70
Gorham	7087	13.8	22.16

ROUTT COUNTY COALS.

Middle Series.

No. 18	7358	14.2	20.75
No. 17	7456	14.3	19.93
No. 12	7283	13.9	19.34

Bottom Series.

No. 3	7642	16.4	18.89
No. 1	7692	14.2	18.73
No. 4	7445	16.9	18.71
No. 2	7494	14.8	18.48
No. 7	7668	15.3	18.31

DELTA COUNTY COALS.   North Fork of Gunnison River.

Somerset	8021	14.2	13.76
Juanita, 4½-ft. seam	8030	15·2	13·91
Juanita, 14-ft. seam	8138	18.2	10.99

Of the preceding, the Delta county coals are clearly bituminous and the Juanita 14 foot seam, cokes, but they all have a high percentage of oxygen with a high carbon-hydrogen ratio. The semi-bituminous and anthracite coals of Routt county have been omitted. The very high oxygen content of these coals will be made more apparent by a similar tabulation of a few samples taken from older, well known carboniferous fields.

	Calories	Carbon-Hydrogen ratio ashless	Percentage oxygen
Pa., Beaver Creek	8201	15.3	6.90
Pa., Carnegie	8304	14.6	7.22
Pa., Wampum No. 2	8256	15.3	7.28
W. Va.	8501	17.8	5.87
W. Va.	8254	18.8	6.39
Ky.	7955	14.6	8.80
Kan.	7333	14.5	7.40
Ark.	7756	19.3	3.20

If we should correct the oxygen percentages for the ash in the coals, it would not, materially change any of them, and every sample showing a carbon-hydrogen ratio of 13.5 or over will show a percentage of oxygen much lower than that found in our Cretaceous coals having the same or a higher carbon-hydrogen ratio.

The following properties of our black lignites characterize them as quite distinct from the bituminous coals, i. e. their physical properties, their burning qualities, their high oxygen content, their high carbon-hydrogen ratio, and good calorific values, whether calculated on the basis of pure coal or of fuel.

It is difficult, if not impossible, to bring the true bituminous coals and these black lignites under the same standards of classification. This may be due, as already suggested to different reactions or phases of the changes involved in the process of carbonization. We have been taught to look upon this process as consisting of the elimination of hydrogen and oxygen which is certainly correct as indicated by the end pro-

ducts, but no one, so far as I know, presumes to state that the
succession of changes has been essentially the same in char-
acter and order in all cases.   It may well be that at one period,
or under certain circumstances, water or oxygenated com-
pounds alone may be eliminated and at another, or under dif-
ferent conditions, hydrocarbons may be evolved.   Our lignites
probably represent a phase of the process which has produced
a coal relatively poor in hydrogen and rich in oxygen, while
the bituminous coals represent a different phase of the process
—one producing a coal relatively poor in both hydrogen and
oxygen, accompanied by the production of fusible hydrocar-
bons, in many case in sufficient quantities to produce the prop-
erty of coking.

THE SPONTANEOUS COMBUSTION OF COAL AND ITS EFFECTS ON THE SURROUNDING STRATA.

By Arthur Lakes

Read at the Meeting of the Society May 4, 1907.

Those who are conversant with the geology of the coal fields in this western region must have observed in various localities lines of reddened and altered sandstone and shale above the coal seams, marking out continuously or at intervals for miles the position of the principal coal bearing zone. Such phenomena are noticeable in the Grand River, Bookcliff and Mancos regions of western and southwestern Colorado.

This reddening and alteration of the strata adjacent to the seams is due to the effect produced by the spontaneous combustion of the coal. In some cases, as along the great hogback between Newcastle and Meeker and in the Mancos region near Farmington, this combustion is still active and demonstrates its presence by emanations of steam, smoke, and gases, issuing from cracks in the rocks. The escape of gas is said to be influenced by a rise or fall in the barometer, and people in the vicinity read the weather by it.

In many cases combustion appears long since to have ceased and its past effects are only noticeable in the coal or in the alteration of the overlying rocks. The effects are most pronounced when the coal seams are large, or there are many seams along a particular zone; also, according to Mr. R. C. Hills, in the lignitic or lignitic bituminous coal areas rather than in the coking ones, and in coal seams that show a broken rather than a compact face. We have not heard that bitumin-

ous and anthracite coal fields of the eastern states are affected similarly to the western fields.

The immediate effect on the coal itself is to destroy, at least near the surface, some of its valuable commercial qualities by reducing it to ashes, or by locally changing it to a worthless coke, or equally worthless anthracite. In some instances the injury may be superficial, but in others it may be deep seated.

The effect on the adjacent strata is to harden the shale to the consistency of a roofing tile, often of a yellowish or reddish color, upon which the remains of fossil vegetation may be traced; clinkers of the shale too occur like those around a lime-kiln. The overlying sandstones may be hardened and reddened for 50 feet or more according to the size of the seam or amount of coal that suffered combustion.

Burning out of the coal below has in some instances caused a collapse of the overlying strata and opened fissures, through which if combustion is still active, steam, smoke and gases ascend. Whilst locally the overlying sandstones may be reddened and altered a large coal seam at some distance below them may show no signs of combustion, the alteration effects having been produced by higher, smaller seams not plainly showing on the surface.

That this combustion, as well as the effects produced, is comparatively recent is shown in many ways, most strikingly when it is seen in active progress. The older effects seem to have taken place since the present canyons and ravines were excavated and not when the coal measures were lying beneath great thicknesses of rock in an undisturbed or uneroded condition. Strata may be altered and reddened on one side of a shallow ravine and appear unchanged on the opposite side, implying that the ravine had checked the progress of combustion and that its excavation took place before the ignition.

In considering what started this combustion, forest, brush or grass fires lighted by the Indians or others many years ago have been suggested. The localities where the alterations are most noticeable are not now remarkable for forest growth,

but the contrary. Lightning has been advocated, but this
seems improbable or inadequate. Ignition as a result of oxi-
dation of pyrite in the coal has been mentioned, but seems
also inadequate. It would appear in most instances to be a
case of spontaneous combustion in the coal itself.

The following by Mr. Vivian B. Lewes, in Iron and Coal
Trades Review, may throw light on the subject:

Spontaneous Ignition of Coal.

"Many coals containing a high percentage of pyrite are perfectly safe,
and have never been known to heat seriously or ignite, while other classes
of coal, practically free from pyrite, invariably suffer from spontaneous
ignition under conditions favorable for its production. A careful study
of the phenomenon occurring during the heating of a mass of coal leads
to the conviction that the pyrite present can only play a subsidiary part,
and that it is in reality the absorption of oxygen by the freshly won coal,
and the activity of the condensed gas in contact with the hydro-carbons
of the coal that are the active factors in causing the ignition. In the
seam the pores of the coal (for a trace of the original structure still re-
mains in it) are filled with methane, or a mixture of methane and carbon
dioxide, gases produced during the actions that led to the formation of
the coal. When this coal is mined and brought to the surface, the coal
exudes these gases from its surface, and in turn absorbs oxygen from
the air. The action, however, cannot go on to any great depth in the
coal, and while the pieces are fairly large no heat shows itself, but as
the coal gets more and more broken by jolting during carriage and shoot-
ing into the ship's hold, the surface becomes enormously increased, and
the mass of fine coal formed under the tip below the hatchways in the
ship is generally the spot at which heating and eventually ignition de-
velops. The mere absorption of the oxygen, however, is insufficient to
bring about serious consequences unless there be an initial rise in tem-
perature to start the action, and in coal-cargo ships it is found in the en-
hanced air temperature in the tropics, in ship's bunkers by contact with
the casings near the boilers, and in stores on shore by proximity to a
steam pipe or flue. In every case it was found that the spontaneous ignition
of the coal started at the point where the cause of the initial rise of
temperature was to be found."

Applying these ideas to the phenomenon observed in our
western coal fields, we may assume that the oxidation of pyrite
contained in some of our coals is inadequate to produce the
effects observed, but that the cause of spontaneous ignition

lies in the absorption of oxygen of the atmosphere, especially by the weathered coal outcrops, or by detritus from them or by coal faces of a broken character, and its occlusion and compression in the microspores of the coal. If according to Mr. Lewes this is insufficient to bring about ignition without an initial rise of temperature to start the action, then we may look to the heat of the midday summer sun, or possibly in some cases to forest, brush or grass fires.

This theory requiring the action of atmospheric oxygen explains why coal when deeply buried under overlying rocks has not apparently suffered combustion, but when edges of the coal seams were exposed by the excavation of canyons, atmospheric oxygen was admitted to the seam and sufficient heat being developed, spontaneous ignition followed.

It would seem likely that with increasing depth from the surface the supply of oxygen would diminish and ignition gradually die out and the coal resume its normal condition. At what depth this change might take place can only be proven by exploitation.

COMMERCIAL WATER SOFTENING AND PURIFICATION.

By CHARLES M. HAMPSON

Read at the Meeting of the Society May 4, 1907.

From the time that the steam generator came into service the greatest drawback to its use has been the difficulty in getting rid of impurities, carried into the boiler with the feed water.

Until very recently all expenditure of labor, money and inventive genius has been along negative lines. We have been wasting our energies in attempting to shut the door after the horse has been stolen.

Within a comparatively recent period, my attention has been attracted to a number of very successful installations of water purifying plants in various sections of the country. Some of them are affecting a saving of over 50 per cent annually on the entire cost of installation after deducting all charges for operation, deterioration, interest and taxes.

I am so thoroughly convinced that this is the solution of one of our worst engineering difficulties, wherever there is "bad" water to contend with, that on the principle that "an ounce of prevention is worth a pound of cure," I take pleasure in presenting to you this sketch on the purification and softening of water for commercial purposes.

As is usual in the preparation of papers of this nature, I have availed myself very freely of the recorded experimental work of others, among whom are Mr. Coggswell of the American Society of Mechanical Engineers, Mr. Greth of Pittsburg

and Mr. M. W. Mix of the Dodge Mfg. Co., all of whom have done much to simplify and popularize the various processes.

One of the most important uses to which these processes are now applied is the purification of boiler feed water, but there is a general and increasing demand for water softening for use in paper mills, laundries, ice plants, breweries, flour mills, sugar refineries, dying and bleaching establishments, and many other industries.

In many of the larger hospitals, water softening machines are installed. It is found that the chemical change effected in the water used for domestic purposes, greatly facilitates the cooking of foods; that as much as 90 per cent of the bacteria is removed and that soft water is much better for the hair and skin.

In a general way, all water is susceptible of improvement, or purification, as all natural waters contain more or less foreign matter. This foreign matter may be in solution or it may be in suspension, and I may, roughly, classify all waters, usable for commercial purposes, as follows:

    (1)   Rain or snow water.
    (2)   Creek, river or lake water.
    (3)   Well water, including of course, so-called artesian wells.
    (4)   Mineralized spring water.
    (5)   Sea or salt water.
    (6)   Mine water.

All of these waters are subject to impurities in a greater or lesser extent and probably the simplest general classification, without splitting hairs, would arrange this deleterious matter about as follows:

Impurities tending to cause Priming.

    Sodium carbonate.
    Organic matter, wood, leaves, grass, etc.
    The various alkalies.

Impurities tending to cause Corrosion.

Acids: Sulphuric, nitric, hydrochloric, carbonate, acetic, tannic, etc. Chloride of magnesia. Sulphate of magnesia. Organic matter. Sugars.

Impurities tending to cause scale.

Carbonates.
Sulphates: lime and magnesia.
Salts: soluble.
   Silica, oxides of iron, alumina.
Mud and sand in suspension and organic water.

Now, these are all enemies of the water user, whether he be manufacturing steam, chemical compounds, industrial products or washing clothes.

Let us consider the steam generator. We find that all three of the above classifications enter into the problem. We must then combat scale, corrosion and priming.

Taking these destroyers up in regular order, we find that the presence of scale in boilers means shut downs of greater or less frequency, causing much expense in labor and delay, costly repairs, and a fuel loss, varying from 13 per cent with, approximately 1-16 inches of scale to 60 per cent with ½ inch of scale.

Corrosion causes "pitting" and honeycombing of the tubes, shell and other exposed parts, rapidly weakening the boiler and thus rendering it dangerous. It may be stated as axiomatic that where there is scale in a boiler, there is danger. I believe that many of the so-called mysterious boiler explosions could be traced to the effect of acid water on the tubes where they enter the tube-sheet, the erosion having been later covered with scale; this scale being disturbed from time to time by the use of boiler compounds, sufficiently to allow the acid to take another bite at the iron.

Sulphuric acid, which is common in the mining country, is the most dangerous of the contaminating acids. In a less degree we have, hydrochloric, nitric, tannic, acetic and carbonic.

Priming and foaming are practically synonomous; that is foaming is merely aggravated priming. They are both extremely annoying and make various kinds of trouble. The efficiency of the engine is greatly decreased through water getting into the cylinders, and many cases are probably in your minds where cylinders have been wrecked, cross-heads and connecting rods broken and then the damage laid at the door of the engine manufacturer.

Those of you who have read the last report of the Railway Master Mechanics Association will remember the statement made, there, that one of the greatest causes of loss of efficiency in locomotives was priming caused by the prevalence of alkali in the waters of the middle and western states. They state further, that the cost of incrustation is annually $750 for each locomotive in service. We will now consider the logical remedy.

It is very easy to work out the chemistry of the steam generator. It is simple and comprehensive. The reactions are regular and positive.

We should, however, not put too much work on our friend the boiler. The boiler was primarily designed to manufacture steam. Manifestly then, if we try to combine the manufacture of scale as a by-product we are playing a losing game.

If this is so it is obvious that we do not wish to consider the use of "boiler compounds" because they are intended as purgatives and we do not wish to spend our time and money manufacturing scale just to have the fun of getting rid of it.

Besides the chemical treatment of water after it has been put into the boiler we have the further means of removal and prevention—filtration, blow offs, internal collecting appartus, heating feed water, electrical devices and the chemical treatment of water outside of the boiler. This last seem to me the logical solution and remedy.

What is the use of fooling with skimmers and compounds, when a moments thought will satisfy us that it is far simpler, more economical and permanent to arrange a device by which the water may be freed from its impurities before putting it
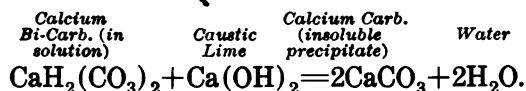
into the boiler? Here we return to our original proposition that "an ounce of prevention is worth a pound of cure."

There are many substances that will precipitate the carbonate of lime and magnesia also their sulphates and chlorides. The most economical re-agents are calcium hydrate, soda ash and caustic soda, all of which are cheap, and readily obtainable. At the present market prices, lime is worth about $\frac{1}{4}$c per pound, soda ash 1c and caustic soda 2c.
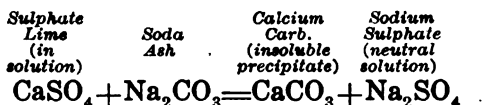
One pound of carbonate of lime requires ·56 lb. of calcium hydrate or 2·18 lbs. of tri-sodium phosphate.

One pound of sulphate or chloride requires ·85 lb. of soda ash. Tri-sodium phosphate is being experimented with to some extent. It is claimed that it readily precipitates both carbonate and sulphate of lime and magnesia, but is more expensive.

The chemistry of the lime process is:

| Calcium Bi-Carb. (in solution) | Caustic Lime | Calcium Carb. (insoluble precipitate) | Water |

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O.$$

The chemistry of the soda process is:

| Sulphate Lime (in solution) | Soda Ash | Calcium Carb. (insoluble precipitate) | Sodium Sulphate (neutral solution) |

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$

Water purification, or softening, is an exact science. Given the analysis and suitable apparatus the problem is readily solved and the expense is, usually only a penny or so per 1,000 gallons. In several water softening plants that have been successful operation for over a year the cost has ranged from $\frac{3}{4}$c to $\frac{7}{8}$c per 1,000 gallons of water treated, equivalent to 250 horse power per hour.

All we need to do in the majority of cases is to remove from the water free carbon dioxide. This renders the carbonate of lime, magnesia and iron, insoluble, they precipitate and are flushed out from the bottom of the decanting tank.

The sulphate and chlorides are precipitated by the use of soda ash. This re-agent attracts the acids which hold the mineral impurities in suspension.

The suspended matter and organic matter is readily removed by mechanical filtration.

Should the acid be excessive we can use re-agents, barite or witherite.

Following I give a comparative statement for six months showing the result of purifying water, before feeding to boilers in a 2,000 H. P. Steam Plant. This through courtesy of Mr. Greth.

MAINTENANCE BOILERS.

1903				1903		
Jan. 31	To Fuel,	110	$2271.50	June 30	By Profit and Loss,10	$16411.92
"	Cleaning (Heater and Boiler),	121	141.00			
"	Repairs,	126	43.00			
"	Incidentals,	130	18.00			
"	Labor,	133	90.00			
Feb. 28	Fuel,	138	2563.00			
"	Cleaning,	142	172.40			
"	Incidentals,	146	12.80			
"	Labor,	148	90.00			
Mar. 31	Fuel,	150	2496.00			
"	Cleaning,	153	162.34			
"	Repairs,	159	96.50			
"	Incidentals,	165	16.20			
"	Labor,	161	90.00			
April 30	Fuel,	164	2371.90			
"	Cleaning,	166	65.00			
"	Labor,	171	90.00			
"	Incidentals,	173	11.00			
May 31	Fuel,	778	2640.00			
"	Cleaning,	184	176.50			
"	Labor,	188	90.00			
"	Incidentals,	190	19.30			
June 30	Fuel,	192	2376.00			
"	Cleaning,	195	147.20			
"	Repairs,	197	49.00			
"	Incidentals,	200	23.20			
"	Labor,	203	90.00			
			$16411.92			$16411.92

1904				1904		
Jan. 31	To Fuel,	278	$2163.00	June 30	By Profit and Loss,10	$14332.45
"	Cleaning,	275	23.00			
"	Incidantals,	276	12.25			
"	Repairs,	277	94.00			
"	Labor,	279	90.00			
Feb. 29	Fuel,	281	2241.00			
"	Cleaning,	282	17.00			
"	Incidentals,	283	19.30			
"	Labor,	285	90.90			
Mar. 31	Fuel,	286	2164.00			
"	Laаor,	288	90.00			
"	Incidentals,	289	6.50			
April 30	Fuel,	291	2196.00			
"	Labor,	292	90.00			
"	Incidentals,	295	16.95			
May 31	Fuel,	297	2230.75			
"	Labor,	298	90.00			
"	Incidentals,	299	23.80			
June 30	Fuel,	301	2084.00			
"	Labor,	302	90.00			
"	Incidentals,	304	13.40			
"	Interest on Investment at 6%,	304	112.50			
"	Depreciation at 10%,	304	375.00			
			$14332.45			$14332.45

Cost of first 6 months,	*without*	Water Softening System,				$16411.92
" " "	*with*	" " "				14332.45
Saving "	"	"	"	"	"	$2079.47

The apparatus for producing this very desirable result is manufactured by several concerns and in various forms. One design includes a pre-heater, in which exhaust or live steam gives the water a temperature of from 200 to 208 degrees Fahr. A portion of the carbon dioxide is driven off and the bi-carbonates of lime, or magnesia, precipitate as carbonates into removable pans.

The partially purified water then passes into a precipitating tank, where chemicals are fed in by means of two small steam pumps from separate solution tanks, holding sufficient solution for eight to ten hours run or even longer. Here the remaining acids are neutralized and the scale substance settles to the bottom where it is blown out. The lighter particles of sediment are caught in a simple form of filter.

Another form of softener mixes the chemicals by means of paddle arms, actuated by a small steam engine transmitting power through gears located on the top of the tank. The tanks are in duplicate. While a charge is being treated in one tank the purified water is drawn from the other and vice versa.

One of these plants is treating 12,000 H. P. boiler water about 500,000 gallons, daily. Four tanks are employed, each having a capacity of 95,000 gallons and the accompanying filters have 400 square feet of surface.

Caustic lime and soda ash only were needed.

A later system, proving very successful, has done away with the extra tank and steam pumps for handling solvent solution and adopts an ingeniously arranged overshot waterwheel actuated by the supply water at the top of the tank. This transmits power by means of bevel gears to the stirring device which operates in a small tank at one side of the main tank. This system is extremely simple and requires no skilled labor and little if any attention.

It was my intention to include in this paper a description of water purification as applied in laundries, breweries, railroad water supply, dying establishments, distilleries and artificial ice plants, but it is long enough as it is.

In conclusion, it appears to me, that in our efforts to increase the efficiency of our steam plants, while we have produced good results by introducing multiple expansion, condensers covering our steam pipes, installing heaters, superheaters and economizers, that we overlook dollars to save dimes when we fail to purify our water before we put it into the boiler.

THE IRON ORES AND SYSTEM OF MINING AT SUNRISE MINE, WYOMING.

By B. W. VALLAT.

The Sunrise Iron Mine is situated about 125 miles north of Cheyenne, in Laramie County, Wyoming. It is connected by the Colorado & Wyoming Railway with the Colorado & Southern at Hartville Junction, fourteen miles west, and at Guernsey with the Burlington six miles west of the mine. The district is generally known as the "Hartville Iron Range." The property is owned and operated by the Colorado Fuel & Iron Company.

The iron ores present characteristics which are seldom met with in the ore deposits of the better known iron districts of the United States. They consist of two distinct varieties of high grade hematite; the soft red variety of greasy texture, and the hard blue hematite, intermixed, affording an ideal character of ore for working in the blast furnaces.

The occurrence of the two varieties of ore in the same body I believe is easily explained by the fact that the soft hematite is a secondary alteration of the hard due to the action of surface waters. This theory seems to be well demonstrated by the fact that at the surface of the ore-body the soft ore is in excess; at the two hundred foot level the hard ore is more in evidence; at 300 feet the hard ore is in excess, in fact with very little showing of the soft ore, which, in the diamond drill holes below this point, cuts out and gives way entirely to the hard blue ore. By experiment we have found that the two

varieties of hematite differ to quite an extent in the phosphorus and silica content, the hard ore containing the lower phosphorus and the higher silica, while the soft ore holds the higher phosphorus and the lower silica, a combination which makes it a difficult matter for the mine chemist to get a correct sample and analysis of the car shipments. Unless the sampler gets the proper proportion of the soft and hard ore in the car it is misleading, as it is impossible to check up at the steel works. For this same reason it is impossible to take any drift or pit samples ahead of the mining which will be of any value for close checking, as two samples taken in the space of one foot of ground will vary to quite an extent. This variation, however, applies only to the ore near the surface, where the alteration is most marked. As depth is attained the ore becomes very uniform with a low phosphorus and silica content.

The ore-body which we now have opened up occurs in irregular masses or lenses with no well defined walls as yet proven. The lenses of ore are surrounded by schist, which undoubtedly must be considered a part of the iron formation, as we will endeavor to show. Next to the schist lies a hard dolomitic limestone of an impervious character, which in all probability will prove to be the wall rock of the iron formation as our explorations and development progress. However, up to the present time we have not done enough in the lime formations to show what relation they actually bear to the iron. In exploring ahead of our producing ore bodies, we have as yet found nothing to guide us in looking for new ones, especially on surface, which, in the immediate vicinity of the mine, is capped by limestone. The ore is where we find it, and the diamond drill is the only reliable expert we have yet employed. The schist areas are badly folded and twisted, dipping at all angles from surface down to a depth of 300 feet, and having no well defined strike, so that it is impossible to follow them out with any degree of certainty.

As to the derivation of the ore, it is reasonable to assume that it is a product of the schists, having originally occurred in the schist in the form of pyrite and perhaps some magnetite.

The hematite then is no doubt a replacement of the schist, probably being responsible for the greasy character of the ore. The explorations up to date I think demonstrate this theory. On the east side of the main ore body, and deeper than we have yet explored in the mine, we find a dark gray biotite schist impregnated with pyrite. This I believe to be the original form of the iron bearing schist, the schist itself probably resulting from some igneous rock. As we approach the ore-body, we find a more altered phase of the same rock with a heavy iron stain, and the pyrite missing, and finally next to the ore the very much altered light gray to greenish schist, looking very much as if it had gone through the leaching process, as illustrated by the specimens at hand.

Besides these three forms, we have been fortunate enough to obtain some good examples of the replacement of the schist by the hematite. The specimens showing this will run about high enough in iron to make a low grade ore while the schistose structure is still well preserved.

SYSTEM OF WORKING.

In taking up the system of working the mine, which is very simple, it might be well to take up its history and follow through the interesting development.

The first mining, at what is now the Sunrise Mine, was done in the early nineties for copper. The copper deposit proved to be a pocket, which was finally worked out and the shaft with some small drifts bottomed in iron. This, together with a small showing of iron on a side hill below the copper, called attention to the possibility of the value of the immediate territory for iron.

In 1900 the Colorado Fuel & Iron Company first entered the field, leased a group of seventy-two claims, covering quite an extensive part of the district, and later purchased the same.

In the same year operations were begun on a small scale with a steam shovel in the ore which was exposed on the side hill. Up to the spring of 1901 about 81,000 tons of ore had

been shipped and nothing was as yet known about the existence of any more other than that actually in sight, which at this time was a very small quantity ahead of the steam shovel. At this stage Mr. J. D. Gilchrist, now manager of the Iron Mines Department, was summoned from the Mesaba Iron District of Minnesota to take hold of the property. He started immediately by introducing vigorous Lake Superior methods in the endeavor to locate and open up some available ore in the quickest possible manner, and at the same time with a view to the most economical future mining operations. Guided only by the fact that the old copper shaft was bottomed in iron, as above mentioned, and the trend of the ore already being worked, stripping operations on the overlying surface were started with a second steam shovel. The work was well rewarded by the uncovering of a good body of ore which was available for mining with the steam shovel, which is without doubt the cheapest method of mining where conditions are suitable. While this was under way, dimond drills were put to work and constantly kept busy proving up the ore. It was soon found that an ore body of large proportions was awaiting development.

As the ore had been located to several hundred feet in depth by the drills, the end of economical mining with the steam shovel was anticipated several years ahead, it being necessarily limited to the maximum grades on which the railroad locomotives could haul the loaded cars out of the ore pit. (It might be well to state here that the standard gauge tracks were laid direct to the steam shovel in the pit and the ore loaded into the cars for immediate shipment). To prepare for another system of mining then a vertical shaft was started in December, 1902, and sunk in rock to a depth of two hundred feet, where a level was started off into the ore body, as shown on the accompanying plat and sectional views. Later, sinking was continued to a depth of three hundred and forty feet. Another level was started off at three hundred feet, the remaining forty feet being for a skip sump and loading chutes. (The shaft is 6'x18' in the clear, with three compartments

consisting of two skip ways each 5′x6′ and a ladder way and pipe compartment 6′x6′8″). Drifts were rapidly pushed out into the ore and under the first steam shovel pit (a second steam shovel pit having been opened up just north of the original one). This was in preparation for the milling system, which ranks next only to the steam shovel work in cheap mining operations. Raises were put up from the underlying second level drifts to the open pit above, as shown on the map. These formed the mills through which the ore is picked down to loading chutes on the second level, where it is loaded into cars, hauled out to the shaft and hoisted to surface, dumped into shaft pockets by self-dumping skips, and thence into railroad cars. The system is very common in the Lake Superior iron districts, especially on the Mesaba Iron Range.

The prompt development of the ore-body under-ground not only brought the milling system into operation at the proper time, but also served to drain the ore with which more or less water is always associated, so that when the milling was started the ore was quite dry.

Drifting on the underground levels has gone on steadily until the mine has reached the stage of development best shown by the map. All drifts are in ore except where we have met with small talcose horses or seams of schist, which have been few for such a large area. The diamond drill is here in constant use. No drifting is done in waste rock until it is known that there is ore beyond. This is determined by not only putting a drill hole in on the course of the drift, but also fanning out with at least two angle holes on either side of the first one, especially where there is no knowledge of the ground in the immediate vicinity. We find this much more economical than drifting ahead blindly with the possibility of getting into undesirable ground. To give an idea of the extent of our diamond drill operations it might be interesting to state that the total number of feet of drilling done by the company in this district amounts to 50,648 feet, or 9·6 miles, of which 12,222 feet was done underground in the mine.

Since the summer of 1903, the development in drifting amounts to 18,815 feet, or about three and one-half miles. From the year 1901, with 97,000 tons, the production has increased rapidly, the last fiscal year showing 571,000 long tons of ore.

The underground levels are equipped with electric haulage, the trolley system being used, operating three five-ton Jeffrey electric locomotives. This makes it possible to handle the ore very rapidly in connection with the milling system. The main haulage drifts are electric lighted and arc lights are used around the open pit on the surface so that the milling work can be carried on at night.

The surface plant consists of two 125 k. w. direct current Westinghouse generators, belt driven by two enclosed high-speed compound Westinghouse driving engines; two cross-compound two-stage Rand air compressors of twenty drills capacity each, and one 20"x42" first motion hoist of the Corliss type, operating two five-ton skips in the shaft. The boiler plant consists of a battery of six 150 h. p. return tubular boilers. You will notice that the electric and also the air power is installed in two units each, rather than installing the same capacity in one large unit for each. The feature of this being the one unit in reserve in case of a break down in the other. At this time we are using but one generator and one compressor, having one unit of each always in reserve, but even though they were all working at once to get the desired capacity, half the power is better than none in case of an accident to one of the units.

One of the features in the equipment, which should not be passed over, is the new dry or change house recently built for the comfort of the men. It consists of a one-story brick building 40'x115', divided into a changing room 38x54', a wash room 38'x46', the mining captain and shift bosses' room, and an emergency hospital in the remaining space. The two large change and wash rooms are laid with cement floors on concrete base and sloping to a central drainage system. The whole floor space can thus be flushed out with a hose and kept

remarkably clean and sanitary with very little work. The change room is fitted with several hundred expanded metal individual lockers equipped with Yale locks, so that every man has a private and safe place to keep his clean clothes and valuables. On either side, and running lengthwise of the change room between the rows of lockers, are long hanging racks for the working clothes, fitted with steam coils underneath and large ventilating hoods overhead, which converge into stacks projecting out through the roof. This makes an ideal arrangement, as the steam coils below the racks (which, by the way, are for this particular purpose, the heating system for the building being installed in steam coils around the walls), dry out and air the clothes by creating a steady draft up through the ventilating hoods and thus disposing of the resulting foul air at once without having it distributed through the building. The wash room is connected with the change room by doorways, and is fitted with twelve shower-baths on one side, while on the other there are two long steel wash troughs, equipped with thirteen pairs of faucets each, and individual wash basins for as many men as are employed. The troughs each have a capacity for fifty-two basins. Both the showers and wash troughs are equipped with hot and cold water. I believe this is the most modern and best equipped change house at any mining location in this western country and goes a long way toward keeping good miners.
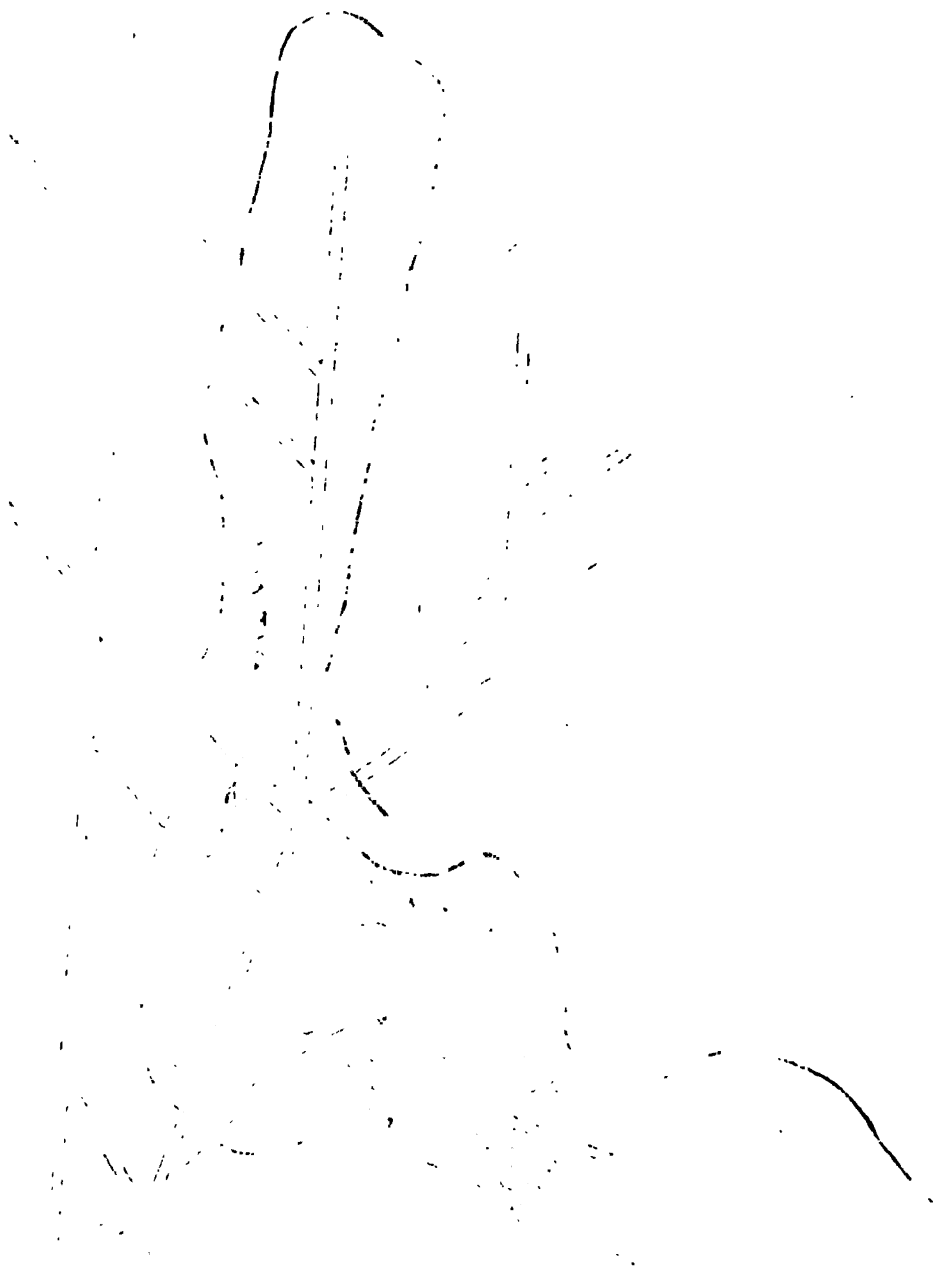
STEPS IN CYANIDATION.

By PHILLIP ARGALL.

Read at the Meeting of the Society Nov. 2, 1907.

About two hundred years ago the chance manipulation of impure chemicals by Diesbach, a Berlin color manufacturer, resulted in the formation of ferric ferrocyanide-prussian blue —the first cyanogen compound known. This chance discovery of a new compound and a new color, while of the first importance to Diesbach, was none the less portentous of the yet undiscovered cyanide compounds which have since revolutionized more than one industry, and added mightily to the gold production of the world.

The simple production of prussian blue was distinctly epoch making, and rightly takes rank amongst the greatest of chemical discoveries, if measured only by the present usefulness of the cyanogen compounds in the metallurgy of gold. At the time prussian blue was discovered in 1704 indigo was the only blue coloring matter known, and so we find Diesbach and his partner Dippel an alchemist, were quite early engaged in the manufacture of this new, and beautiful-colored, cyanogen compound. In 1710 Dippel presented a paper to the Academy of Berlin calling attention to the new compound, without however disclosing the method of its preparation. Fourteen years later, Woodward (1) an English chemist and Fellow of the Royal Society, not only succeeded in making prussian blue, but also made public the method of its preparation, and it is interesting to note that this method of Woodward's is practically the process by which prussian blue is prepared to-day. Macquer, in 1752, observed that when prussian blue is boiled

with caustic potash, oxide of iron remains, whilst a peculiar salt enters into solution which was named phlogisticated alkali, *or yellow prussiate of potash* (2). This body was shown to contain iron and prussic acid by Berthollet in 1787.

The actual composition of prussian blue was not known until 1782, when Scheele, 78 years after its discovery, obtained an acid from it which, in consequence he named "prussic acid," but even then the composition of the acid was not known. Prussic acid, hydrocyanic acid, or nitride of formic acid C N H occurs in certain plants, as for example in laurel leaves, peach leaves, and in kernels of several of the stone fruit. The acid, however, was first obtained in the pure state by Gay Lussac (3) in 1811, while four years later the same chemist discovered the radical cyanogen and showed that it was capable of existing in the free state. Hydrocyanic acid is said to have been known to the Egyptian Priests and used by them to kill traitors.

Cyanide of potassium was first made by the simple fusion of yellow prussiate of potash-ferro cyanide of potassium—in iron crucibles; when this operation is properly conducted the result is a mixture of carbide of iron and cyanide of potassium, the former adhering to the sides of the crucible, the latter in the midst of the mass. With a view to remedying certain objections to the foregoing process, Liebig proposed the ignition of dry ferro cyanide in the presence of dry potassium carbonate. At present much of the cyanide of potassium used in cyanidation of ores is produced by the Erlenmeyer process, which is based upon the action of sodium on ferro cyanide of potassium according to the reaction:

$$Fe(CN)_6K_4 + Na_2 = Fe + 4(KCN) \, 2 \, (NaCN)$$
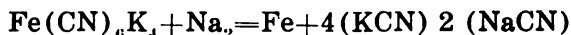
The resulting product is next treated with water, the solution evaporated, and the salt sold as potassium cyanide 98-100 per cent., but is really a mixture of 4 mol. of cyanide of potassium and 2 mol. of cyanide of sodium.

With the introduction of the aniline colors, prussian blue found but a limited use in the arts, while cyanide, formerly of

limited application in medicine, photography, electroplating and as a laboratory reagent, has, since the cyanide process was established on a full scale, been used in greater quantities than any of the cyanide compounds, even now over one half the ferro cyanide of potassium produced is used in the manufacture of cyanide of potassium.

Cyanogen, really a nitride of carbon, greatly resembles the halogens, and in many reactions behaves like a simple substance, or in other words, plays the part of an element. The radical cyanogen combines like chlorine with hydrogen and the metals; its compounds are comparable with those of chlorine, to which they have the strongest resemblances. Therefore as the halogens, chlorine, bromine and iodin all dissolve gold, as do also some of their compounds, it was but a natural inference that cyanide of potassium would dissolve gold, as pointed out by Hagen in 1806. Of the various cyanogen compounds, I shall now confine myself to cyanide of potassium K C N, and endeavor to show in a casual way the development of this salt as a gold solvent, on a practical scale.

It is reported that Dr. Wright, of Birmingham, England, used gold cyanide solutions for electroplating as early as 1840, in consequence of his investigations following the publication of Scheele's report on the solubility of gold cyanide in a cyanide of potassium solution. The brothers J. R. and H. Elkington made the first practical application of potassic cyanide as a gold solvent, and patented it in 1840, in connection with the electro-deposition of gold from cyanide solutions, or at least the first application I have been able to find, though it does look somewhat closely related to Dr. Wright's process above referred to.

The Elkington solution was made by dissolving salts of gold in cyanide of potassium, in their arrangement the articles to be gilded form a cathode, a plate of gold the anode, both immersed in the cyanide bath. The gold as deposited on the article to be gilded, was dissolved from the gold anode plate, thus keeping the auro-potassic cyanide bath of about the same strength; here we see that a solution of cyanide of potassium,

plus electricity, was at this early date (1840) a known and recognized commercial gold solvent, and with but slight modifications it is so used in electroplating to-day.

In 1843 the Russian Prince Bagration (4), while investigating the Elkingtons' process, discovered that cyanide can dissolve gold without the aid of electricity. It is said that in the course of his researches he poured some cyanide solution into a gilded vessel and on emptying the vessel some time later found the gold plating had been removed from the sides and bottom. After very thorough examination Bagration reached the following conclusion, which not only stands good to-day, but also quite fairly sums up our general knowledge of the action of cyanide of potassium on gold.

First, that cyanide of potassium will dissolve metallic gold; second, that if the gold is very fine it will pass rapidly into solution; third, that the electric current did not in the least help the solvent action of the solution of the gold; fourth, that heat greatly assisted the solution of the gold; that gold in cyanide solution can be precipitated on metallic surfaces without the aid of electricity, and lastly that the air has a very marked action in quickening the solution of gold in cyanide solutions.

We next come to Elsner (5), who in 1844 stated as the result of his researches

"The dissolution of the metals (gold and silver) is, however, the consequence of the action of oxygen, which, absorbed from the air, decomposes part of the cyanide."

This statement, showing oxygen to be necessary, is probably the most important fact connected with the use of cyanide as a gold solvent, and is rightly claimed as the second step in the dissolution of gold by means of potassic cyanide. The recent development of the cyanide process is the direct outcome of this theory. It should be noticed, however, that Elsner's work at this time was merely qualitative; that he did not even suggest an equation to show the possible reactions involved in the solution of the gold, and that the much quoted Elsner equation was only given to the world during an inaug-

ural dissertation at Göettingen 22 years later (1866). In 1857
(6) Faraday pointed out that gold leaf resting on the surface
of a cyanide'solution dissolves a hundred times quicker than
gold leaf that is only immersed therein. Faraday believed that
air voltaic currents are formed in these cases, and that the
gold is dissolved almost entirely under their influences. This
appears doubtful.

Up to this time strong solutions of cyanide were used. In
1866, however, Dr. Henry Wurtz (7) in the American Journal
of Science, made the important announcement that weak solu-
tion of cyanide would dissolve gold. In the following year
Julio Rae (8) of Syracuse, N. Y., patented an important
method for treating gold and silver ores, by subjecting them
to a cyanide solution and an electric current, following by pre-
cipitation on copper; also by electricity. Rae then, as far as
our knowledge goes, made the first application of cyanide to
ore treatment, and used agitation to hasten the action. It is
very doubtful, however, if this patent was ever put into even
experimental use on a working scale, passing over the inven-
tions of Thomas C. Clark of Oakland, California (9), Hiram
W. Faucett of St. Louis (10), and John F. Sanders of Ogden,
Utah (11), as immaterial, though cyanides were used by them
or claimed to be used under the patents applied for, yet their
processes do not bear the stamp of practicability, and have
long since been forgotten. They do, however, show that the
minds of American inventors were running towards cyanide—
scenting, as it were, the coming battle from afar.

The next inventor to hold the field is Simpson of Newark,
New Jersey (12), who patented, in 1885, a process for sepa-
rating gold and silver from their ores by means of subjecting
the ore to the action of a solution of cyanide of potassium and
carbonate of ammonia, precipitating on zinc, which he does
not, even at that date, claim as new. Simpson's great improve-
ments are, therefore, the introduction of an alkali to correct
acidity, dissolving the precious metals without electricity; and
also precipitating without an electric current. Simpson's pat-
ent covered the ground very fairly, but it was not pushed; was,

in fact, one of those great inventions that lie dormant for years, as if they had arrived before their time. It may be, however, that suitable ores were not available for Simpson, for we can hardly believe that had the Mercur (Utah) ores, since discovered, or those of Johannesburg been available, Simpson's process would, notwithstanding the then very high price of cyanide, not have been developed into a commercial success.

These American patents of Rae and Simpson attracted notice abroad, for we find W. A. Dixon, in a lecture before the Royal Society of New South Wales, in 1887, going somewhat out of his way to decry an American gold extraction process in which potassium cyanide was the solvent. His principal objections were the cost of the salt used, its instability and poisonous nature, quite pertinent and not unreasonable criticism at that early date; indeed, within the present year I have had almost precisely similar criticism leveled at a slight departure from the beaten path of cyaniding that I had intended taking, in which it was proposed that the ore be crushed, concentrated and agitated in dilute cyanide solution. W. Skey, the distinguished New Zealand chemist, called attention in 1875 to the fact that both gold and silver were soluble in cyanide solutions, and that considerable losses of precious metals occurred in amalgamation mills from the too free use of cyanide. (13).

From 1886 onward many chemists were at work on various cyanide schemes, none of which cut much figure until MacArthur and Forrest of Glasgow secured their patents in 1887 (14), and formed the basis of a successful working process, introduced by the Cassell Gold Extraction Company, but for some reason it was not applied on a working scale until 1889, when a plant was erected at the New Zealand Crown mines, Karangahake district. Here agitation formed a prominent feature of the process, but later was replaced by the percolation methods. The ores of the Karangahake district are very difficult to treat by the old methods; battery and amalgamated copper plate gave only some 15 to 20 per cent. of the

values; dry crushing and pan amalgamation gave about 60 per cent. extraction, while cyanide gave 90 per cent. of the assay value of the ore. The following year, 1890, the tailings from the Robinson mine, Johannesburg, South Africa, were successfully cyanided, and from that date it may be said the process bounded into general use all over the world.

WHO INVENTED THE PROCESS?

I have traced quite briefly the various stages leading up to the introduction of the cyanide process on a commercial scale, and we might now ask who invented the process? Like most other achievements, no one can lay full claim to its entire invention; in fact, it was not invented but grew in the minds of men, until the fullness of time and a suitable ore had arrived, and then success could not be prevented. Let us glance briefly at the MacArthur-Forrest patents, and their reception by the courts, to see who the law decided to be the inventor of the process:

The first patent, No. 14,174, the MacArthur-Forrest process (14), was taken out in England, October 19th, 1887, the specific claim being:

"1. The process of obtaining gold and silver from ores and other compounds, consisting in dissolving them out by treating the powdered ore or compound with a solution containing cyanogen, or cyanide, or cyanogen-yielding substance, substantially as heretofore described.

"2. The process of obtaining gold and silver from ores and other compounds, consisting in dissolving them out by treating the powdered ore or compound with a dilute solution containing a quantity of cyanogen or a cyanide or cyanogen-yielding substance, the cyanogen of which is proportioned to the gold or silver, or gold and silver, substantially as hereinbefore described."

In describing the method of separating the precious metals from solution, the patent states the solution is treated "in any suitable known way, as for example with zinc." Thus showing that in August, 1888, zinc precipitation was, in the opinion of the patentees, a suitable known method, and hence not claimed in the patent specification.

Coming now to the American patents of MacArthur and Forrest: The main patent is dated May 14th, 1889, No. 403,-202, the specific claim being (15) : "Subjecting the powdered ore to the action of a cyanide solution containing cyanogen in the proportion not exceeding eight parts of cyanogen in one thousand parts of water." In explaining their process the patentees state the invention consists in subjecting the auriferous ores to the action of a solution containing a small quantity of cyanide—*without any other chemically active agent.*

The next American patent (16) is 418,138, issued December 24th, 1889. It relates to the filiform zinc sponge for precipitating the gold from cyanide solutions, now almost universally used for that purpose, though just as satisfactory results can often be obtained by the use of zinc powder. This method, however, was the subject of a British patent issued to Astley P. Price in 1884 (17), which clearly anticipated the use of zinc as provided for in the MacArthur-Forrest process; nevertheless, the filiform zinc is in my opinion preferable, and it was both a new and a novel form of precipitation, and as such worthy of an enforcible patent. These various MacArthur-Forrest patents were taken out in the principal mining countries throughout the world.

The German patent was cancelled February 2nd, 1895, by decree of the Imperial German Court, based chiefly on priority of invention by Rae and Simpson in America. (18).

As to the exclusive use of cyanide by MacArthur against cyanide and carbonate of ammonia by Simpson, the court said:

"If the additions used by Simpson are, however, substantially immaterial for the purpose aimed at, then ammonia is certainly a simplification of the process, but not an alteration affecting the essence of the same. Furthermore, too, the monetary value of the addition is such a trifling one that the saving cannot be considered as industrial advance."

The second trial of the patent that I know of was conducted in England, November, 1894, before Mr. Justice Romer, a gentleman as widely known by his scientific attainments as by his legal learning. His decision goes over the ground of the Rae and Simpson patents and the chemical knowledge

universally known that cyanide was a solvent for gold, and states (19) :

"But in addition to the above, I think there is another ground on which this patent is bad. Even if the invention was one which could form the good subject of the patent, I think it was anticipated by Rae's and Simpson's specifications. Test it in this way: If the patent were held valid, would not Rae's and Simpson's processes, if now used according to the specifications published, be liable to be stopped as infringements? I think they certainly would. What chance of escape would a person have who took Rae's, for instance, and used the cyanide of potassium specially mentioned by Rae? It would be used against that person with crushing effect, that he was using the cyanide of potassium for the very purpose pointed out in the plaintiff's patent, viz.: to dissolve the gold in the crushed ore, and not the less because he tried to assist the process by the aid of electricity, which might or might not be of any real assistance, and certainly not the less because he used the electricity for another and different purpose. So, also, a person using Simpson's process would be liable to be stopped. For it would be proved against him that he was using the cyanide of potassium for the very purpose and in the very way pointed out in the plaintiff's specification, and that the addition of carbonate of ammonia made no material difference. To hold that Simpson's was not an anticipation would lead to a strange result. A person using cyanide of potassium alone would be an infringer, but, if he chose to add a slight amount of carbonate of ammonia (which is cheap and practically innocuous), he could not be restrained. Now, as the specifications of Rae and Simpson were published here before the date of the plaintiff's patent, all persons in this country are at liberty to use the processes there set forth, and that right is incompatible with those persons being liable, if they do use such process, to an injunction at the suit of the plaintiffs. For these reasons the action must be dismissed."

The decision of Justice Romer was reversed on appeal, or partly so, and in amending the patent to conform to the American claims, it became binding in England.

The South African Transvaal patent was the most valuable of the MacArthur-Forrest Company, and on it the most stubborn fight was made. Here again the selective action of weak solutions constituted the principal claim of the defendant company. The patent appeared to be similar to the English one having a first claim for the MacArthur-Forrest process being a discovery that a solution containing cyanogen would

dissolve gold. The second, being a less general claim, stating that a dilute solution of cyanide proportioned to the quantity of gold has to be employed.

Judgment of the full court:

"The plaintiff maintains that this so-called MacArthur-Forrest process is not a new discovery, and has been anticipated. With regard to the first claim, that a cyanide solution dissolves out gold from ore, we may take it as clearly established by the evidence that at the time when the patent was applied for and granted it was a well known fact that gold could be obtained from ore by a solution of potassic cyanide. The first claim, therefore, in favor of the MacArthur-Forrest patent, No. 47, cannot be sustained." (20)

In this case counsel argued strongly that MacArthur and Forrest showed that weak solution of cyanide dissolved gold, and had, as they claimed, a selective action for gold over the base metals in the ore. On this point the court said:

"Chemical affinity is, however, a law of chemistry, a law of nature, which, as Mr. Wessels argued, can no more be patented than the law of gravitation." (20)

The mere dilution of a chemical was held to be no invention. The patent was cancelled. Adverse decisions were also given in New Zealand and several of the Australian colonies.

Returning to the American patent: Pure cyanide solutions, without the aid of any other active chemical, will not dissolve gold. Oxygen is necessary, and this point alone would probably have invalidated the American patent, as the patentees limited themselves to cyanide alone, excluding the very active agent oxygen.

It is quite clear that the decisions of the courts have on the whole been unfavorable to the MacArthur-Forrest patents, and by these decisions the claim of the patentees to be considered the sole inventors of the cyanide process is set aside. Furthermore, if we rely on the almost unanimous verdict of the courts we must admit that the cyanide process is a distinctly American invention, and as I do not know any higher authority, I award the palm of discovery to the inventive genius of Rae and Simpson. No man, however, can deny that

MacArthur and Forrest introduced the first cyanide process that commanded universal attention, that they evolved order out of chaos, achieved a brilliant success where others had failed, and finally gave to the world in the process that bears their names one of the most marvelous, though simple, methods of ore treatment that the human mind ever conceived. For this, their names shall be emblazoned high on the banner of metallurgical fame, to be both remembered and honored long after the strife of patent litigation is forgotten and the doctrine of "selective action" shall have passed "as a vision of the night."

The MacArthur-Forrest process then consists of neutralizing the acidity in a given ore with an alkali (21), dissolving the precious metals with dilute solution of potassium cyanide (15), and precipitating the gold on filiform zinc (16). The modifications of this process are numerous. I will mention a few to illustrate the more important lines of departure.

The patent of J. C. Montgomery of Scotland, July, 1892, (22), employing sodium or potassium dioxide as an oxidizing agent in conjunction with caustic soda. The points provided for here were the furnishing of more oxygen and having a strong alkaline solution, as such solutions are more active than plain cyanide and water. The Kendall process of 1892 (23) for quickening the action of cyanide by means of ferrocyanide of potassium: here it would appear that an attempt is made to hasten the action of the cyanide as well as at the same time conserve its strength; the evolution of nascent cyanogen is probably also introduced for the first time as a feature of the process, imitating, no doubt, the evolution of nascent chlorine in another process, which is well known to greatly augment the dissolution of gold.

Almarin B. Paul appears to have originated wet crushing with cyanide solution in the batteries at the Calumet mill, Shasta county, California. In 1891 (24) he asks:

"Why not crush your ore in solution, when you introduce solution after crushing dry? The loss of cyanide by crushing with it is but nominal, and is greatly overcome by the cheapness of working and complete-

ness of cyanide distribution through the pulp in the tanks. This plan is so satisfactory to me that I am done with dry mills for the future."

Wet crushing with cyanide solution in the batteries was a distinct step in advance, but slime treatment apparatus was not in a sufficiently advanced state to meet the requirements of wet crushing in solution, and so it did not take immediate root in this country. We next hear—1896—of wet crushing in solution in New Zealand (25), and later it became the established practice in the Black Hills of South Dakota, from whence it spread over the mining districts of the west. Crushing in the cyanide solution in connection with amalgamation was practiced by me on concentrates obtained from roasted sulpho-telluride ores in 1897. Crushing in cyanide solution is, I believe, the process of the future, on either raw or roasted ore, and with modern slime agitation and filtering machinery, leaves little to be desired. In fact, the great advance in fine crushing appliances during the last few years, coupled with the slime treatment machinery above referred to, has well nigh rendered the treatment of sands obsolete. It is true that it costs more to grind a given ore to pass a screen of $0 \cdot 006''$ aperture than to pass $0 \cdot 02''$ aperture, but the increased extraction usually resulting from the finer comminution of the ore very materially exceeds the cost of griding, to say nothing of the saving in time and in equipment, for at best tanks are in this cold winter climate a very expensive installation, particularly when the housing of the tanks and the heating of the building is taken into consideration.

The Gaze process of 1892 (26), where the use of chloride, bromide and iodide of cyanogen were introduced as improved gold solvents in connection with potassic cyanide. Gaze found these halogen salts of cyanogen gave a wonderful stimulus to ordinary cyanide solutions, but failed to obtain a patent, on account, it is said, of the opposition of the MacArthur-Forrest Company in New Zealand. Later Sulman and Teed obtained English and American patents covering the use of bromo-cyanogen (27). It cannot, however, be said to have come into general use, except perhaps in Westralia, where bromo-cyano-

gen is used in the Diehl process, in the extraction of gold from
unroasted or raw sulpho-telluride ores, but even there the cost
of that chemical is often fully as much as the cost of roasting
and never as effective, so in the end the roasting process is
bound to prevail, as predicted by me in 1903 (28).

Many other oxidizing agents have been patented,—indeed
I believe I am quite safe in stating that the whole list of oxi-
dizers, or oxygen-furnishing substances, have been covered in
one way or another in the patents of would-be inventors, not
excepting hydrogen peroxide, which, as is well known, de-
stroys cyanide, and is perhaps the best antidote in cases of
cyanide poisoning. Of these various oxidizers but few have
been found to have any practical use in the every-day working
of the cyanide process.

A substantial improvement in the process of cyaniding
was the patent of MacArthur-Ellis, 1896, for the prevention
of sulpho-cyanides passing into solution, when treating ores
containing sulphides, soluble in cyanide solutions. This patent
provides for the addition of carbonate, acetate or sulphate of
lead, so that the insoluble lead sulphide is formed in advance,
and the working solutions freed from alkaline sulphides (29).

One of the greatest obstacles to successful cyanidation in
the early nineties was the omnipresent slime. My earliest ex-
perience indicated that even in dry crushing it was the better
practice to separate the dust from the sands and treat each
separately, and furthermore the same principle was still more
important in wet crushing, where it was usually imperative to
separate the slime from the sands. A United States patent was
issued to me in 1894 for apparatus to separate slime and dust
from ores (30), and was used in the Brodie mill at Cripple
Creek and the metallic works near Florence. My first method
for treating the separated fine material was briquetting and
roasting, then rough crushing and cyaniding. The very high
extractions made on the roasted product first turned my atten-
tion to the advisability of roasting in bulk the telluride ores of
Cripple Creek, at that time almost entirely oxidized, but with
the rapid development of the mines they suddenly changed

to sulpho-tellurides—in part at least—before we could get roasting furnaces installed in the works.

The decantation process of slime treatment should next be noticed. It was developed in South Africa, and at present practically all the slime on the "Rand" are treated by this method, which consists in agitating the slime in weak cyanide solution, usually by means of centrifugal pumps, circulating the sludge from one vat to another, then allowing the slime to settle, decanting off the clear solution, adding water and again agitating and repeating the process till the values in solution are reduced to the tenor of their practical requirements. The decantation process has been gradually worked up in South Africa by Butters and others; the process now in use was first successfully applied to the Rand ores by Mr. John R. Williams about the year 1896 (31).

One great advantage of the cyanide process over all other practical methods of gold extraction is the fact that it will dissolve gold and silver from raw or unroasted ores. This feature was naturally made the most of in early day advertisements by the MacArthur-Forrest people. It did not, however, apply on sulpho-telluride ores, in the treatment of which roasting became a leading feature of the cyanide process, first, I believe, introduced on a commercial scale by myself at the plant of the Metallic Extraction Company, at Cyanide, near Florence, Colorado, in the treatment of Cripple Creek ores in 1896.

Roasting introduced many difficulties and complications, chief of which were the sulphate salts in poorly roasted ores, but these troubles were gradually overcome, and to-day I can not only look back at the successful cyanidation of over a quarter million tons of roasted ore, but I can also affirm that my experience in cyaniding Cripple Creek ores has led me to the unalterable conclusion that my early efforts were in the proper direction, and that cyanide properly applied is the correct treatment for those ores, because they can be cyanided for about one-half the present cost of chlorinating them and with better extraction. Considerable difficulties were experi-

enced in the early days of cyanidation in securing good pre-
cipitation from dilute solutions, the introduction of the zinc-
lead couple by MacArthur (32), and the zinc-mercury couple
by Caldecott (33), however made possible the effective pre-
cipitation of the gold from the most dilute solutions; mean-
while an electrical process of precipitation by Siemens Halskie
had been introduced in the Transvaal and worked with con-
siderable efficiency on dilute solutions. The anodes were of
sheet iron, the cathodes of lead foil, weighing 0·19 lbs. per
square foot. When precipitating from 84 grains of gold per
ton of solution down to 8 grains per ton, it required 9,000
square feet of cathode surface to precipitate 100 tons of solu-
tion per day (34). Improvements in the process, such as the
substitution of Andreoli's lead peroxide anodes for the iron
plates and the use of high density current, did not succeed in
bringing it into general use, and though ingenious and some-
what successful, it cannot be said to have spread beyond the
control of those interested in the patents.

I will next direct your attention to the Clerici-Pelatan
process (35), in which the ore is reduced to extreme fineness
(slimed) and then treated by agitation in an electric vat with
dilute cyanide solution containing sodium chloride. The tank
bottom is covered with mercury or amalgamated plates, to
form the cathode of an electrical cell; the revolving stirrers
are the anodes; the gold is dissolved and precipitated in the
mercury. Many advantages were claimed for this process,
such as amalgamating coarse gold, dissolving and precipitat-
ing the gold in one operation and in one vessel; thus leaching
is abolished, as is also the use of zinc.

This process has been tested on a working scale in Colo-
rado and several of the western states of America, but is, I be-
lieve, not in use to-day, or at least to any extent. It proved too
expensive, for the sole reason, in my opinion, that the precipi-
tation of the gold from a muddy electrolyte on such limited
cathode surface took too much time; the gold goes into solu-
tion quick enough, but the power spent in agitating the mass
during the interval necessary to precipitate the gold from solu-

tion is at once the weak and expensive point. To illustrate this: In a test made for me by the patentees in 1894, $2.00 per ton in gold remained in solution after seven hours' opera-tion, while, by passing this solution through a zinc precipita-tion box, the gold could be reduced to 4 cents per ton in fifteen minutes. I was therefore compelled to report against the process to my principals, and subsequent events have con-firmed my conclusions.

The introduction of the cyanide process in Westralia to treat the sulpho-telluride ores has been fruitful in invention. These ores contain 15 to 20 per cent lime, and early developed the nasty trick of setting in the tanks like so much concrete. (I refer, of course, to the roasted ore). The first apparent success consisted of almagamating in pans the finely ground ore, then filter pressing to get rid of the acid salts resulting from bad roasting; next treating the cakes from the filter press with cyanide solution, and lastly filter pressing again to drive out the gold cyanide solution. This process cost about $10.00 per ton, but is much simplified and now reduced to about $3.00 per ton.

The process used at Kalgoorlie in its improved form con-sists of roasting the finely ground ore to break up all sul-phates and reach, when possible, a dead roast; next, grinding the roasted ore in pans or tube mills until 98 per cent. of it passes a 200-mesh screen; next, agitating in cyanide solution until the gold is dissolved, and, lastly, filter pressing direct from the agitators. This method of treatment is known as the all-sliming cyanide process. The fine grinding methods of ore treatment developed in Westralia introduced the filter press and the tube mill into the cyanide process, both, it is said, by Sutherland, in 1898, though West claims (36) that a one-ton Johnson filter press was in use at Hannan's Brownhill mine in 1896, and about the same time the Lake View Consols Com-pany were experimenting with a center filling filter press. McNeill (37) describes the Hannah's (West Australia) filter plant as first installed, but the date is not definitely referred to. Knutsen (38) claims that filter presses were first thought

of on the Kalgoorlie field in 1897, while Dr. L. Diehl used them on ores from Kalgoorlie, in Hamburg, Germany, as early as 1896. The tube mill, flint mill, or pebble mill, as it is variously called, had been in successful use in the cement business for some time prior to its introduction in practical cyanide work in Westralia. The tube mill, as I prefer calling it, has proven to be the best sliming machine so far discovered, but is nevertheless pushed hard by grinding pans of the Wheeler type even in the sliming of ores, while the pans excel as fine grinders to say approximately 100-mesh. The filter press had a short-lived victory, for by the time it was perfected from an ore treatment point of view, and the costs reduced to something reasonable, the development of the suction filters showed clearly that the massive, cumbersome filter press, extremely costly to install and expensive to operate, could not successfully compete with the simpler, cheaper and much more efficient suction filter, which is now rapidly displacing the filter press in many of the gold fields of the world.

The Diehl cyanide process, also used at Kalgoorlie for some time, and in fact elaborated for the treatment of those particular ores in the raw state, presents some interesting features, if not new departures, in cyaniding. Owing to the high cost of fuel, labor and power, roasting on this gold field is very expensive, and while the Diehl process only partially eliminated roasting, yet this method is extremely interesting, showing, as it does, the great possibilities of cyanidation, when the ores are reduced to an extremely fine state of division.

In its latest form the Diehl process is found in operation in Kalgoorlie: First, the raw telluride ore is stamped in dilute cyanide solutions in batteries, using the ordinary outside and inside amalgamating plates. Second, the crushed ore is passed over concentrating tables, and the concentrates resulting from this operation are roasted and amalgamated. The third step is grinding the tailings from the tables in tube mills to an impalpable powder, practically the entire produce passing a sieve of 200-mesh per lineal inch. In the fourth operation the slimed ore is agitated in tanks for two hours in a ·20 per cent.

cyanide solution; bromo-cyanogen is then added at the rate of
:04 per cent. of the dry tonnage of the charge, and agitation
continued for twenty-two hours. The charge is usually com-
plete in twenty-four hours' treatment, though it may require
a further addition of bromo-cyanogen (39). The last opera-
tion is passing the pulp through filter presses, the filtrate
going to the zinc precipitation boxes and the residues in the
form of cakes 39½'' square and 3'' thick to the waste dumps.
The cost of bromo-cyanogen in this process runs from 50
cents to $1.50 per ton in ores varying from ½ oz. to 1 oz. of
gold per ton. The Diehl process is based, first, on the removal
of the greater part of the tellurides by concentration and roast-
ing for the liberation of the gold before treating them to amal-
gamation in cyanide solution; second, sliming the tailings and
treating the pulp by agitation in cyanide of potassium solu-
tion, to which is added from time to time bromo-cyanogen,
which salt will partially attack the tellurides, insoluble in
straight cyanide. The success of the process, however, de-
pends chiefly on the thoroughness of the concentration, as
high grade tails from the concentrating mill invariably mean
high final tails after agitation with bromo-cyanogen. The
process in brief amounts to the removal by concentration of a
deleterious material from contact with the cyanide solution,
"to be handled by such other methods as the particular circum-
stances will indicate," as pointed out by me in 1894 (40) in
an attempt to show the scope of the cyanide process, and that
it could "be applied to ores direct, or as a combination pro-
cess, with amalgamation or concentration, or both, as may be
found most convenient for the economic treatment of the ores."
The credit for using bromo-cyanogen on telluride ores belongs
to Sulman and Teed (41). The Diehl process has made no
progress outside Australia, and even there it is declining.
Where roasting charges are high, the process has a fair chance
on ores below a valuation of eight to twelve dollars per ton,
depending on local conditions.

       Yet another Westralian process is known as the "Rick-
ens," an attempted improvement on the Clerici-Pelatan, in-

troduced at the old Telluride mill, Colorado City, about the
time of its abandonment at Kalgoorlie, the place of its birth,
the improvement consisting of an increase of the active surface
of the electrodes by the addition of side plates in the Rickens
vat against bottom plates only in the Clerici-Pelatan, and in
circulating the mercury so that in passing over the side plates
in streams it kept them soft and active. The precipitation,
however, was unsatisfactory, and filter presses were added to
the Westralian plants, so that the auriferous cyanide solutions
could be displaced from the residues and the value extracted
from them in zinc boxes. The process then failed in its most
important point, precipitation of the gold. To one who has
had experience in electrical precipitation from cyanide solu-
tions and is familiar, not only with the large cathode surface
required to obtain complete precipitation, but also the time
consumed in effecting it, this result is the only one to be ex-
pected. When we stop to consider that the gold in this finely
comminuted dust treated in the Rickens vat can be brought
into solution in two hours, without the aid of electricity, and
separated from the residue by a filter in a similar period of
time, and the precious metals precipitated on zinc in thirty
minutes, a total for the whole process of only four and one-half
hours, the uselessness of the process for the treatment of dust
and finely pulverized ores becomes apparent. Furthermore,
it scores another failure of the oft-repeated scheme so dear to
the process inventors, *attempting to precipitate gold from a
muddy and foul electrolyte*. Others have since attempted to
solve the same problem, but with like result. Hence it has
become common knowledge that clear solutions are conditions
precedent to successful precipitation from all cyanide solutions,
and so we come to the last step in cyanidation in which filtra-
tion is the dominant note.

Moore obtained a U. S. patent for a suction filter in 1903,
which was introduced at the Mercur mines (Utah) (42), but
on account of defective mechanical contrivances, the filters
were not quite satisfactory and were subsequently abandoned;
in other places, however, the Moore filter has been quite suc-

cessful. The Moore suction filter, as is well known, consists of a series of leaves or rectangular cells with permeable walls, through which the solution is forced, when a vacuum is created in the interior of the cell, leaving the solids (slime) to form cakes on the cell walls. A number of these cells are bound together in a so-called basket and immersed in a tank of slime until cakes of necessary thickness have formed; then the basket is lifted from the slime tank and transferred to a wash water tank and the vacuum maintained in the interior of the cell until the soluble gold has been replaced by wash water, when the basket is again hoisted, brought over the dumping place, and compressed air turned on to displace the cakes. A second patent was issued to Moore in 1904, covering some other features in his filtering process (43). The Moore filter might be briefly described as a *movable suction filter* in a fixed tank.

Cassell obtained a patent in 1904 for what might be briefly described as a fixed suction filter in a fixed tank (44). In this apparatus the slime and solutions are circulated around the fixed filters by means of a centrifugal pump, and when the cakes are finally washed, they are displaced by water or air and discharged through the doors provided for the purpose in the bottom of the tanks. Both the Moore and the Cassell filters provide vacuum pipes for lifting the filtered solution from the bottom of the cell to the discharge at the top—usually some six feet—but let us assume the head will be balanced by a pressure of 2·5 lbs. per square inch, and it will be seen that 25 per cent. of the vacuum usually obtained in mining districts of the west (10 lbs.) is not available for filtration in this form of apparatus. A third type, *the gravity suction filter*, will soon be on the market, with capacity for making 25 tons and 50 tons of filter cake at each cycle. This apparatus may be described as fixed filters with a movable tank and gravity flow from the bottom of the filter cells to the vacuum pump (45). When the tank is moved back all the filter cells are completely exposed and the slime cakes can be dumped practically dry. Lastly we have the Ridgway continuous filter, said to be oper-

ating quite successfully in West Australia. In this form of
suction filter a central rotating vertical axle carries arms with
depending filters which slowly pass through an annular slime
tank while the cake is being formed, thence through wash
water, and next to the dump, where compressed air is turned
on to displace the cakes, thus completing the cycle, and the
filter again entering the slime vat for the commencement of
the next cycle. The arms are automatically raised when pass-
ing from one division of the annular tank to another, and the
valves to the strong and weak solution and of the compressed
air line are automatically operated as the machine revolves.

Returning to my brief review of the cyanide process, it
is quite clear that no chemical improvement of any moment
has been made on the process as evolved by MacArthur and
Forrest. Weak solutions and filiform zinc are everywhere in
use to-day; ores are universally prepared for cyaniding by
neutralizing the acidity with lime, while lead salts are invari-
ably used in the cyaniding of heavy sulphides or badly roasted
ores.

Improvements have been almost entirely along engineer-
ing lines, in crushing or pulverizing in sliming, in agitating,
in filter press work, and in suction filters; in fact, all along
the line of mechanical engineering improvements have been
many and progress steady and continuous.

I have not by any means exhausted the subject of the so-
called modifications of the cyanide process, or of attempted
chemical improvements, but I will not weary you with further
references. Time would fail me to tell of the hydraulic, the
electric, the pneumatic, the agitative, the *Hot Air* and other
nostrums and alleged inventions, fabricated from wind, sup-
ported by the credulous, and sustained by that omnipresent
individual usually called in this western country "a sucker."

Having briefly glanced at the chief events in the develop-
ment of the cyanide process, it may be permissible to tabulate
the principal steps in cyanidation as they appear to me.

STEPS IN CYANIDATION.

Diesbach	1704	Discovers prussian blue.
Macquer	1752	Discovers ferrocyanide of potassium.
Scheele	1782	Discovers prussic acid.
Hagen	1806	Predicts that prussic cyanide will dissolve gold.
Gay Lussac	1815	Isolates the radical cyanogen.
Elkington	1840	Discovers that K C N plus electricity dissolves gold.
Bagration	1843	Discovers that K C N alone will dissolve gold.
Elsner	1844	Potassic cyanide a gold solvent.
Faraday	1857	That gold leaf dissolves much faster in cyanide solutions when exposed to the action of air.
Elsner	1866	That oxygen is necessary to dissolve gold, and gives the now well-known Elsner formula.
Wurtz	1866	Discovers that dilute cyanide solutions dissolve gold.
Rae	1867	Patents a cyanide process for disolving gold in ores with the aid of electricity.
Simpson	1885	Patents a cyanide process for the same purpose, using alkali.
McArthur-Forrest	1887	The cyanide process patented, basic claim dilute solutions.
	1889	The first cyanide mill, erected in New Zealand.
	1890	The first tailing plant, erected on the Rand, Transvaal.
Paul	1891	Wet crushing with cyanide solution in batteries.
Gaze	1892	Discovers the benefit of using bromo-cyanogen in solutions.
Argall	1893	Introduces and patents the separation of dust and slime from sands, subjecting each to a separate treatment.
MacArthur	1893	Patents the use of lead salts in K C N solutions.
Argall	1895	Introduces the roasting of sulpho-telluride ores as a preparation for cyanide treatment.
Williams	1896	Introduces the decantation process for slime treatment.
Sutherland	1898	Introduces the filter press process of slime treatment and also the tube mill. Dr. Diehl claims to have used these mills in 1896 on Kalgoorlie ores in Hamburg.
Moore	1903	Introduces the movable vacuum filter with fixed tank.
Cassel	1904	Introduces the fixed vacuum filter in fixed tanks.
Ridgway	1905	Revolving automatic suction filter.
Argall	1906	Introduces the gravity suction filter with fixed filters and movable tank.

The four vacuum, or, as they are most commonly called, suction filters, may be said to form the last step in cyanidation up to the close of 1906. One, or possibly two, of the four may survive the ordeal of every-day work on many varieties of ores, or some other method now in the womb of the future may eventuate, that will be more simple in construction and cheaper in operation than any of the suction filters described.

What, it may be asked, has cyanidation done for the advance of civilization, or for the benefit of the mining industry? A simple question, yet so hard to answer that I shall not attempt it. Measured as a factor in gold output, the direct influence of the process on the mining industry can be measured by its production of bullion; but the indirect influence of cyanidation cannot be measured. To give an example: the mines of the "Rand" would not as a whole pay to operate in the absence of cyanidation, and might to-day be lying idle and worthless, yet the actual amount of the gold extracted by cyanide does not perhaps exceed 25 per cent. of the bullion returns of these mines. Here, then, the direct influence of the process is 25 per cent., the indirect 75 per cent., and, assuming that without cyanidation the mines would be idle, then the entire production of the South African mines is indirectly attributable to cyanidation. In this sense, then, we will endeavor to show the part played by this process in the gold production of the world.

To properly appreciate the steadily increasing output of gold, it is perhaps advisable to briefly glance over. the last half-century's production.

"The world's gold production from 1850 to 1857 remained nearly constant at about $134,000,000.00, then decreased irregularly till 1883, reaching a minimum of $97,000,000.00, then increased irregularly to 1889, when the product was $120,000,000.00." (46)

A further glance over the period including the last three decades will, however, more readily enable us to reach independent conclusions regarding this important question.

The world's gold production for year 1887 . . . .$106,000,000.00
The world's gold production for year 1897 . . . . 238,719,755.00
The world's gold production for year 1907, say 400,000,000.00

The output last year was $407,658,920.00, according to the *Mineral Industry* (47), about 30 per cent. of which came from South Africa alone.   If we allow seventy million dollars for gold recovered from placers, by smelting and other processes, I believe it is fair to assume that one-third of the remainder has been recovered by cyanidation, a matter of one hundred and twelve millions—we will, however, call it one hundred and six millions—produced directly by the cyanide process; and if we estimate the direct and indirect influence of cyanidation on the gold output of the world, we must place the figure at not less than one hundred and seventy millions ($170,000,000.00), which approximates the world's total production of gold and silver fifty years ago, while the one hundred and six millions estimated as the direct production of the cyanide process in 1906 equals the world's entire production of gold when the process was introduced by MacArthur.   Thus the accidental discovery of Prince Bagration, 64 years ago, that a solution of cyanide of potassium would dissolve gold, was the fact from which eventuated a process that has been mainly instrumental in increasing by nearly fourfold the annual supply of gold, and accomplishing this in the short span of twenty years.

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SOME MATTES FORMED IN MELTING ZINC-BOX PRE-CIPITATES—THEIR COMPOSITION AND WHAT IT SUGGESTS.

By WM. P. HEADDEN.

Read at the Meeting of the Society Dec. 7, 1907.

At a previous meeting I called attention to a matte formed in the melting of the zinc-box precipitate obtained at a small cyanide plant at Florence, this state. The plant was at that time treating tailings from a chlorination plant, which I infer had not been very successfully managed. A very similar matte had been met with at the Dorcas mill. This matte proved so difficult to reduce that it was sent to the smelters—where it was sold, as I was informed, for from twenty to forty dollars per pound.

The ores treated were, I believe, exclusively Cripple Creek ores, which are usually very simple in their composition, pyrites and fluorite being the common associates of free gold and the tellurides, but galena, stibnite, gray copper and other minerals occur occasionally. The presence of copper and of other metals may be noticed by the assayers; if so, I have not learned of it. But my opportunities of late years have not been good for making myself acquainted with these facts.

MATTE FROM THE DORCAS MILL.

This matte had not been remelted. As received, it was a little over a quarter of an inch in thickness, its upper surface was covered with slag, evidently rich in borax. On removing the slag, I found a number of small plate-like crystals, whose

form and composition I did not make out. The matte is crys-
talline and has, on a freshly broken surface, a dark steel gray
color, with a tinge in blue. While it is possible that this blue
tinge may have been due to tarnishing, it seemed rather to be
the color of the matte. Its specific gravity is 5.3768. It is
quite soft, being easily cut, and shows, on the fresh cut, a
shining surface somewhat similar to that shown by argentite,
but lighter in color. When wet it emits an odor suggestive of
an alkaline sulphide. The matte fuses easily, but its reactions
before the blowpipe are unsatisfactory, especially on charcoal,
as it seems very difficult to decompose. When melted with a
flux composed of glass 1½ sodic carbonate 3, borax glass 1,
with the addition of nitre, it yielded no metal. The melt was
pulverized and fused again with addition of more sodic car-
bonate, some starch and metallic iron, when I obtained a
bright, crystallized matte with a nucleus of metal; this metal
reacted for silver and cadmium.

I do not know the details of the process which resulted

The amount of material at my disposal was small and I
was compelled to use one-half gram portions for analysis. Mr.
Barton, who called my attention to the matter, furnished me
all of the matte that he had, but this was only a small piece,
because, owing to its value—forty dollars per pound—it was
saved with considerable care.

I do not know the details of the process which resulted
in the production of this matte. In Mr. Barton's own practice
the zinc-box precipitate was treated with sulfuric acid and
washed with hot water, filtered, roasted and melted with
sodic carbonate, borax and sand.

The composition of this matte was found to be as follows: ·

MATTE FROM THE DORCAS MILL.

Ag. 30.03
Au. 5.54
Cd. 11.12
Pb. 11.39
Cu. 3.96
Zn. 3.54
Fe. 10.80
CaO. 0.74
SiO₂ 3.62
S. 19.02
Bi. .... Tr
Insoluble 0.60
                                              ———
                                              100.36

The matte is evidently a mixture of the sulfids of silver, cadmium, lead and iron. The gold was probably wholly in solution. I examined the matter carefully for prills, but could find none. The interesting point in this matte is the presence of cadmium and copper. The presence of zinc and lead is what we would expect, as the zinc may have escaped solution and the lead may have been derived from the commercial sulfuric acid used or may have been purposely added as a coating of the filiform zinc, but the presence of the copper and cadmium cannot be accounted for in this manner. While it is well known that zinc may carry a trace of cadmium, it would be a rare accident to find a zinc rich enough in cadmium to account for the formation of such a matte. If it were due to the zinc used, the matte would not be likely to be so uniformly produced and that at two different mills.

The presence of 0.01 per cent. cadmium in the zinc used would account for less than one pound of matte containing 11.0 per cent. of cadmium for each 1000 ounces of gold produced, but a very much larger proportion of matte than this was obtained. The assumption of the presence of 0.01 per cent. of cadmium in the zinc is so high as to be gratuitous. Our Missouri zinc and many others are entirely free from it.

It seems very probable that the cadmium in the matte owes its origin to the ores treated, though I am not aware that cadmium has been observed as occurring in the Cripple Creek ores.

Apropos to my statement of the presence of copper in this matte, Mr. Argall stated that copper was not generally considered as present in the Cripple Creek ores, but that, as manager of one of the largest mills treating these ores, he had considerable amount of copper matte to account for from time to time. This copper was never shown in the assays of the ore, but it was constantly accumulating as a by-product. It would be straining after an explanation for the formation of this copper matte to attribute it to the small amount of copper which may be present in commercial sulfuric acid. The copper in the matte under discussion is but a little more than one third of the cadmium and they are probably both derived from the ore.

The composition of some other mattes may be of interest in this connection, particularly as they show even more emphatically the extent to which elements present in the ores as mere traces may be collected in them in such quantities as to enable us to easily detect them and even determine them, while they can be detected in the ores with difficulty and then only as the result of skillful manipulation and the use of large quantities. These mattes will help materially I think, to remove any lingering doubts about the source of the cadmium and copper in the preceding matte.

The mattes which I will now discuss were produced in melting the zinc box precipitates obtained in the cyanide mill of the Camp Bird, Ltd., at Ouray.

The mineralogical individuals occurring in this ore are greater in number than those occurring in the Cripple Creek ores, so that the precipitate in the zinc boxes is likely to have a more complex composition than that obtained in the case of the Cripple Creek ores, and this is, in a measure, true.

The first sample, an analysis of which I shall give, is, as I understand it, a composite one representing a six months' run,

and was made before the burning of the mill. Large amounts
of zinc must have been used in the boxes and large amounts
of precipitate must have been melted in producing the mattes
represented by this sample, but you will see from the analysis
that it contained only 0·18 per cent. of cadmium, while the
Cripple Creek matte contained 11·12 per cent., and a second
matte from this source (the Camp Bird mill), contained only
a trace of cadmium. It would seem probable that if the zinc
used in the boxes were the source of the cadmium, these latter
mattes might be expected to carry a higher percentage of this
metal.

I do not know, as a matter of course, what zinc was used
in these different mills, but assume that it was, in each case,
an average quality of zinc. On the assumption that the zinc
used in these cases was an average zinc, the presence of less
than two-tenths of one per cent. of cadmium in either of the
two latter samples strengthens very materially the inference
that the cadmium in the other matte came from the ore, i. e.,
that some of the Cripple Creek ores must carry cadmium in
rather heavy traces.

The first Camp Bird matte analyzed had been pulverized to pass through a one hundred mesh sieve. The powder is black, sharp grained, and altogether different in appearance from that of the preceding matte; its composition was as follows:

MATTE NO. 1, CAMP BIRD, LTD.

Insoluble	2.02
Ag.	7.77
Au.	0.04
Cd.	0.18
Pb.	4.97
Cu.	43.77
Zn.	0.93
Fe.	15.28
CaO.	0.92
S.	18.88
Se.	0.99
Te.	1.68
K.	1.21
Na.	1.09
B_2O_4	Tr
Oxygen	probably present
	99.73

This matte had been purified by being remelted, with the addition of metallic iron, nitre, sand and flux.

The second matte from the Camp Bird, Ltd., mill was the refined matte representing the clean-up of the month of February, 1907.

MATTE No. 2, CAMP BIRD, LTD.

Insoluble 2.040
Ag. 3.538
Au. 0.080
Cd. ....   Tr
Pb. 7.109
Cu. 50.517
Zn. 0.832
Fe. 11.046
CaO. 0.640
S. 16.744
Se. 1.500
Te. 1.630
K₂O 1.899
Na₂O 1.523
B₂O₄ ....not det.
                                              _____
                                              99.337

These two mattes differ wholly in their constitution from that of the matte obtained in the treatment of the Cripple Creek ores.

In the matte from the Dorcas mill, obtained in the treatment of the Cripple Creek ores, we observe the presence of enough sulfur to form sulfids of the general type M_2S, and the matte is essentially a mixture of the sulfids of silver, cadmium, lead and iron, leaving the question in regard to the form in which the gold may be present entirely open. In the two Camp Bird mattes we have scarcely enough sulfur, selenium and tellurium taken together to form the sulfid of copper CwS, leaving the lead, iron and other metals out of consideration, consequently we must have either subsulfids or free metals present. Metallic iron was used in refining these mattes, but these mattes are wholly non-magnetic, and it is difficult to believe that they contain free iron. It is, furthermore, quite as difficult to believe that they contain free copper. It is true

that copper matte often shows free copper, but such mattes are very different from these in their physical properties, besides I have sought to find metallic copper in these mattes without avail. I am, therefore, led to consider these Camp Bird mattes as mixtures of the subsulfids of copper and iron, in spite of the doubts entertained in regard to the existence of the subsulfid of iron. This view leaves the silver and lead to combine as the equivalents of the selenium and tellurium, which is very nearly correct.

As in the preceding case, it is not so much the chemical character of the mattes as it is their composition that attracts our attention. In the case of the Cripple Creek ores the presence of copper and cadmium is suggested only by their presence in the matte formed in the melting of the zinc box precipitate, and in the case of the Camp Bird ores the presence of selenium and tellurium is proven by their presence in the matte obtained by treating the slimes with potassic cyanide and melting the zinc box precipitate. This statement is not strictly correct concerning tellurium, for Messrs. Purington, Woods and Doveton, in the Trans. Am. Inst. of Min. Engineers, February and May, 1902, page 11, say: "Unmistakable evidences of the presence of tellurium have been found in the richer portions of the ore."

The occurrence of tellurides in this ore must be very sparing indeed, for Mr. Richards, who has assayed many samples of the concentrates from this property, tells me that he does not remember to have ever noticed any indication of tellurium on reducing the iron solution with one of stannous chlorid.

At my request a sample of these concentrates was sent to me by the manager of the mill, whom I have to thank also for a set of samples of the mattes and much definite information regarding the details of their mill practice. This sample of concentrates represented seventeen different carloads and is certainly representative of the concentrates being produced at that time, which was also the time during which some of the mattes were produced. I took a quantity of these concentrates, equivalent to five grains of pure sulfids, and proceeded

with the utmost care, but did not obtain the faintest recognizable trace of either selenium or tellurium, even though the solution was saturated with sulfur dioxid and allowed to stand for twenty-four hours. As there is a possibility that both selenium and tellurium might have been added with the sulfuric acid used in removing the last portions of the zinc, which I will discuss later, it is very important to establish either the presence or absence of these elements, not in selected, rich specimens, but in the bulk of the ore as it passes through the mill.

In order to establish this point with as great a degree of certainty as possible, I treated 125 grams of the concentrates as before and obtained satisfactory proof of the presence of both selenium and tellurium, but the quantity is so minute that it would escape detection in any ordinary determination.

It is possible that the pyrites do not carry the selenium, but that it occurs in other combinations, as the tellurium certainly does, which, like these latter, flour easily and so pass for the most part into the slimes. This seems to me probably the case, in which event the concentrates would be very poor, as in fact we find them to be, in selenium as well as in tellurium. This is contrary to what, judging from our knowledge of the occurrence of selenium in pyrites, we would expect. The manager, Mr. A. C. Brinker, informs me that he does not know of the occurrence of any selenides in the ore, though traces of tellurium have been found. The sample of concentrates is essentially pyrites, though it contains both lead and copper, the former as galena, the latter probably as chalcopyrite, though the presence of a trace of antimony suggests the presence of some tetrahedrite.

In the case of the selenium we would ordinarily be justified as intimated above, in attributing its occurrence to the presence of seleniferous pyrites, but the pyrites contain only a very minute trace of selenium, if, indeed, this trace be contained in the pyrites, which I think doubtful, for if it were it ought to be almost wholly removed with the concentrates, which is evidently not the case, and we infer that the selenium exists in the ore in some other form.

Apropos to the occurrence of selenium in the Colorado pyrites, Mr. L. B. Skinner of The Western Chemical Manufacturing Co., in answer to an inquiry in regard to their observations on this point writes: "The writer has made thousands of selenium determinations on Colorado and Montana ores, most of the Colorado ores came from different parts of Cripple Creek, and has yet to find the Colorado ore in which selenium occurs, while it is quite common in Montana." I have often tested ores and even soils from Colorado for selenium, and I have yet to satisfy myself of its occurrence. The only instance aside from the present one in which I found a trace of selenium, and this I still consider doubtful, was in a sample of native tellurium from Boulder County. The only occurrence of selenium in Colorado that I know of with certainty is the Gunnison County sulfur. Mr. Skinner also corroborates this occurrence. It seems probable then that the selenium does not occur in the pyrites, but as some other mineral which passes into the slimes.

For the purposes of this paper we will not consider how the selenium and tellurium pass into solution, but let it suffice that they find their way into the matte and are derived from the ore treated, but concerning the latter point there is still a consideration which may throw serious doubt on this point, i. e., the introduction of these elements into the zinc-box precipitate by means of the acids used in removing the excessive zinc, etc. In the case of the Camp Bird mattes, the precipitates from which they were derived were first treated with hydrochloric acid, washed and subsequently treated with sulfuric acid, washed, pressed, washed, dried, roasted and melted. I have not definitely learned that the acids used were manufactured in Denver—if they were imported acids they may have contained selenium; if they were manufactured in Denver the sulfuric acid very probably contained tellurium. According to the tests that I have made of hydrochloric acid we may safely dismiss it, at least so far as containing selenium in solution is concerned. I have met with suspended selenium in hydrochloric acid in a case in which a seleniferous sulfuric

acid had been used in its manufacture, but this was an exceptional case in which the selenium appeared as a red sediment and could not escape the notice of even a novice. I think that the suggestion that the hydrochloric acid used might have been the source of either the selenium or tellurium may be dismissed as entirely too remote a possibility to deserve consideration. The sulfuric acid cannot be dismissed in any such summary fashion, for it is well known that sulfuric acid, in whose manufacture seleniferous pyrites have been used as a source of sulfur dioxid, is contaminated with selenious acid, which, if present, would be precipitate even in contact with mossy copper, if present, in the zinc-box precipitate. If the sulfuric acid used by the Camp Bird Ltd. is acid made by the Western Chemical Manufacturing Co., which I assume is the case, then the question regarding its being the possible source of the selenium is wholly removed; for I have used this acid for years, often for purposes which would reveal even traces of selenium, and I have yet to find the first sample containing it. Furthermore, I have tested the acid for selenium, with negative results, all of which is inferentially supported by Mr. Skinner's statement that the Colorado pyrites contains no selenium. They might use Gunnison County sulfur in the manufacture of their sulfuric acid, but owing to the absence of selenium from the sulfuric acid I presume that they do not.

In regard to the tellurium the matter stands very differently for the sulfuric acid of The Western Chemical Co. contains tellurium. This is an interesting fact, sufficiently so, I think, to justify me in making a digression, with the object of clearly establishing the fact of its presence and to determine what influence, if any, it may have upon the composition of the mattes.

In regard to the presence of tellurium in commercial sulfuric acid you will, I think, find nothing in the books, the enumeration of impurities being usually confined to lead arsenic, nitric oxids and iron, and sometimes the list is extended to include copper, selenium and thallium. It is seldom that any impurity contained in a crude chemical will have

the interest that the presence of tellurium as an impurity has for us in this case. These facts not only justify me in giving my reasons for stating that tellurium is present, but make it necessary that I should prove my assertion that it is present in this acid.

Several years ago the students, in doing one of the required exercises in the laboratory, *i. e.*, in determining the amount of oxygen in cupric oxid and also in stannic oxid by reduction in hydrogen gas, used commercial sulfuric acid to dry the hydrogen. The flask containing this drying acid quickly became coated with a dark brown film, the acid soon became dark brown, almost black, and on standing until the precipitate had settled, showed the purple color characteristic of the solution of tellurium in sulfuric acid. Here was an interesting series of reactions for pure hydrogen, that is molecular hydrogen, will not produce either of these reactions which were not intentionally introduced portions of the experiment. I will state briefly the results of my investigation of the matter which lay, of course, entirely beyond the students' work. First, I established the fact that molecular hydrogen will not reduce tellurous acid in a sulfuric acid solution; Second, I established the fact that there was, in the hydrogen generated by the students, antimoniuretted hydrogen which is broken up by strong sulfuric acid with the separation of elemental antimony. Whether the nascent hydrogen acted directly on the tellurous acid present or effected its reduction by first acting on the sulfuric acid liberating sulfur dioxid is difficult to tell, but it seems probable that the reduction was due to the direct action of the nascent hydrogen on the tellurous acid; for we know that it is a very difficult matter, indeed almost impossible, to reduce tellurous acid in a sulfuric acid solution by means of sulfurous acid.

This experience led me to test several samples of this commercial acid, in fact all the samples at my disposal, for the presence of tellurium, and so far I have found it to be uniformly present. Quite recently I mentioned this matter to the Messrs. Skinner and to Mr. Piwonka of the Western Chem-

ical Manufacturing Co., and at my request they kindly furnished me with a generous sample of the precipitate obtained by treating the crude acid with sulfuretted hydrogen. I sampled this and dried a portion of it at 110° for six hours, took 60 grams of it, this being as large a portion as I could conveniently manipulate, and determined the tellurium in it, and also, so far as my time justified, made a qualitative analysis of it, which showed the presence of arsenic, antimony, tellurium, lead, copper, bismuth and iron; the sulfur, whether free or combined, is of course neglected. The percentage of tellurium found in this precipitate was 0·702 per cent. The tellurium recovered in this determination was carefully tested for selenium, but not so much as a trace could be found.

The data so far presented concerning the tellurium is not sufficient to enable us to form any idea whether the sulfuric acid, provided that this acid is actually used, could possibly furnish tellurium enough to entitle it to consideration in this connection. I, therefore, took a sample of the Western Chemical Co.'s acid which I have in stock, and assuming that it is an average one, determined the amount of precipitate one kilo of this acid yielded when treated with sulfuretted hydrogen after dilution with two volumes of water and cooling. The precipitate, consisting of free sulfur and whatever impurities were contained in the acid precipitable as sulfids, amounted to 0·133 per cent. of the weight of the acid. This will enable us to make at least a somewhat accurate guess as to the amount of matte that would probably be obtained provided that its tellurium were derived from the sulfuric acid. On the supposition that they use 400 pounds of sulfuric acid monthly for the washing of their zinc-box precipitate, which, owing to the fact that they replace the sulfuric acid largely by hydrochloric, seems a liberal estimate, we would have 0·52 pounds of the sulfuretted hydrogen precipitate and 0·00364 pounds of tellurium. A single pound of their refined matte would require almost exactly five times this amount. I therefore conclude that though the occurrence of tellurium in the sulfuric acid may be interesting in itself it is not a factor of any importance in the for-

mation of these mattes, whose selenium and tellurium may be said to be wholly derived from the ores.

There are still a few things that I may mention; for instance, the set of matte samples from the Camp Bird, Ltd., represents the run of the mill for ten months, the first sample represents the mattes made during a period of six months prior to the burning of the mill. The next four samples represent the clean-ups for the months of November and December, 1906, January and February, 1907. I have examined each sample and find all to be rich in selenium and tellurium. I have said nothing about the slag formed in connection with these mattes, nor of the effect of the refining process on the composition of the mattes, as these are details of only very special interest. I, however, have one sample of matte, i. e., for November, 1906, not refined, in which I determined the Se and Te, finding 0.54 per cent. for the former and 2.29 per cent. for the latter.

As the cadmium and copper met with in the matte formed in the treatment of the Cripple Creek ores occur in such minute quantities that their presence in the ores has, as a rule, been overlooked, so in the Camp Bird ores the selenium occurs so sparingly that its presence has not been previously observed and the tellurium was only known as occurring in traces in rich specimens, while the mattes show that they must be generally distributed throughout the ore. But, perhaps, the most interesting point in connection with the selenium is that it is probably not contained in the pyrites, but occurs as some other distinct mineralogical form.

THE GREAT TUNNELS OF THE WORLD.

By Charles W. Comstock.

head at the Meeting of the Society Dec. 7, 1907.

The proposition recently made to bore a tunnel six miles long through the main range of the Rocky Mountains on the line of the Denver, Northwestern & Pacific Railroad has attracted so much attention to the subject of tunneling that it has seemed to me that it would be not without interest to give some account of a few of the great tunnels hitherto constructed. Such an account is necessarily somewhat disconnected but I shall endeavor to direct your attention to the salient engineering features of great tunnel projects.

To the layman the construction of a six-mile tunnel appears to be a financial rather than an engineering problem, and he will in general think of a twelve-mile tunnel as something requiring about double the time and costing about twice as much as one only six miles long. He is apt to think also that the only engineering considerations involved are those connected with breaking ground and transportation, and with these every mining man is familiar.

But men do not build long tunnels to avoid trifling rises or to reach small depths. The enormous outlay of money necessary for the construction of a great railroad tunnel is only warranted by the avoidance of heavy grades and long climbs and the corresponding decrease in operating expense. For this reason the depths reached by these bores are very great and the engineer faces all the problems peculiar to great depths as well as the more familiar ones common nearer the

surface. The Mont Cenis tunnel is 1,609 metres (almost exactly one mile) below the summit which rises above it; the St. Gotthard exceeds 1,700 meters in depth; the Simplon reaches 2,780 metres, while the proposed Mont Blanc tunnel would pass more than three kilometres below the surface—a depth of nearly two miles. Our deepest mines are in the neighborhood of 5,000 feet, and the few that reach this extreme are peculiarly fortunate in their locations.

It is well known that the temperature rises with increasing depth but the rate is extremely variable. This rate is generally greater in sedimentary than in the crystalline rocks. As the mean of 12,000 observations in the mines of Saxony, Reich found 42.00 metres to correspond to an increase of 1° C. in rock temperature. Other observations in the same region give results varying from 16 to 118 metres with a mean of 55.50 metres. Schwartz found from a large number of observations in the district of Schemnitz in Hungary 41.60 metres. At Anzin the geothermic degree varies from 15.36 metres to 26.73 metres. At Ronchamp, Ledoux, found 26.18 metres. In the Lake Superior copper region the value is 218.00 metres, at the Comstock mines 30.80 metres, at Bendigo in Australia 246 metres, and on the Rand in South Africa 111.40 metres. A bore hole 286 metres deep at Budersdorf, near Berlin, gave 19.87 metres, another 547 metres deep at Grenelle, near Paris, gave 32.17 metres, one 697 metres deep in Westphalia gave 29.53 metres, two holes in the Island of Java gave 22.75 metres for a depth of 728 metres, while the great Sperenberg bore, 1,272 metres deep, entirely in salt, gave 28.37 metres.

At the Mont Cenis tunnel the maximum observed temperature was 29.5° C. under a covering of 1,609 metres of rock. Assuming the surface temperature to be —2° C., the geothermic degree is 51.00 metres. Under a valley on the southern slope of the range the value was found to be 37.60 metres. At the St. Gotthard tunnel the corresponding figures were found to be 56.00 metres and 38.10 metres.

Notwithstanding the great range of these figures they give some idea of the high temperatures which must be expected at the great depths reached by long tunnels.

In addition to the ordinary rise of temperature due to increase in depth, there are frequently abnormal rises due to the presence of thermal springs or to chemical reactions in progress in the rocks, such, for example, as the kaolinization of feldspars. As illustrations of these abnormal rises may be mentioned the Yellow Jacket mine of the Comstock lode where the temperature was 52° C. at 820 metres and 77° C. at 930 metres, and the recently completed Simplon tunnel where enormous flows of water with a temperature of 46° C. were encountered in both headings. At Mont Cenis a spring with a temperature of 28.70° C. was met 7,000 metres from the southern entrance.

The observed rock temperatures at different depths during construction in three of the great Alpine tunnels were as follows:

MONT CENIS.

Vertical Depth below surface. Metres	Rock Temp. C°
457	15.60
519	20.60
912	27.80
1340	28.90
1460	27.80
1609	29.50

ARLBERG.

Vertical Depth below surface. Metres	Rock Temp. C°
91	8.90
213	11.10
304	11.70
396	13.30
488	15.60
580	16.70
700	17.80

ST. GOTTHARD.

Vertical Depth below surface. Metres	Rock Temp. C°
488	18.30
565	16.70
580	20.60
900	21.10
1004	26.10
1050	28.30
1065	26.70
1220	25.60
1220	30.00
1440	30.60
1485	28.30
1700	31.10

The mean initial rock temperature throughout the length of the St. Gotthard tunnel was 23·40° C. In February, 1880, the month in which the headings met, the mean rock temperature for the entire length of the tunnel was 22·60° C. In February, 1881, it was 19·30° C., and in February, 1882, 14·20° C.

With such rock temperatures as those above listed the air temperatures may be imagined. Ordinarily the air would probably be slightly cooler than the rock, but the vital heat of men and horses, the combustion of large quantities of powder and the flames of innumerable oil lamps all combine to raise the air temperature beyond that of the rock. In the St. Gotthard the temperature during the working periods sometimes reached 32·50° C. while after blasting 35° C. was common. Add to this that the air was saturated with water vapor and that the proportion of CO_2 was with difficulty kept down to twenty parts in 10,000 and it is clear that men and animals worked under the severest possible conditions. Even at 25° C. the saturation of the air was troublesome and at 35° C. it was intolerable. Any physical effort at higher temperatures in this saturated air was apt to be and frequently was fatal, while in pure dry air men can work continuously, though not very energetically, at 50° C. Under the extreme temperatures occurring in the Yellow Jacket the men worked in relays of ten to fifteen minutes and each man worked a total of two hours per day.

The average air temperatures in degrees centigrade during construction of the St. Gotthard tunnel were as follows:

	1876	1877	1878	1879	1880
North heading, working periods	19.40	21.10	24.00	26.40	30.30
North heading, after blasting	20.80	23.40	26.00	29.30	31.20
South heading, working periods	23.10	25.00	25.80	28.20	29.30
South heading, after blasting	26.60	28.50	29.30	30.70	31.00

These headings were holed through on February 29, 1880, and the figures for 1880 are for the portion of the year previous to that date. During the last month of work in the headings the large volume of compressed air discharged from the

drills and the ventilating pipes was only able under the most favorable conditions to reduce the air temperature 1·70° C. below that of the rock.

The engineers of the Simplon tunnel, after thorough examination of the region and careful study of all existing data, anticipated and provided for a rock temperature of 46° C. What they finally encountered was 55° C. The projectors of the Mont Blanc tunnel expected a temperature of 51° C. and if this tunnel is ever built (which seems doubtful now, since the completion of the Simplon) there will be no occasion for surprise if it is actually found to be in the neighborhood of 60° C.

So much for the difficulties due to temperature. The second point worthy of mention is pressure. Above the Mont Cenis tunnel there is about one mile of rock. Assuming the average specific gravity of this rock to be 2·8 the pressure at the tunnel level is 6,400 lbs. per square inch. At the Simplon tunnel the pressure is 11,000 lbs. per square inch. How many rocks are there which have so great a resistance to crushing, even in selected cubes, to say nothing of large masses? Left to themselves, great mountain masses find a position of equilibrium in which the difference between the principal stresses in any part is insufficient to cause rupture or flow. But let this equilibrium be disturbed by the creation of so large an opening as a double track railroad tunnel and a readjustment begins at once. The movement may be slow but it is well nigh irresistible. Prof. Frank D. Adams found that hard marble which had an ultimate strength of 11,400 to 12,000 lbs. per square inch when tested in cylinders one inch in diameter by one and one-half inches long, flowed like ductile metal under a pressure of 18,000 lbs. per square inch applied on the ends of the cylinders while the cylindrical surface was protected by a metal jacket offering sufficient resistance to prevent the development of cracks. Softer and more or less disintegrated rocks, particularly in large masses, will do the same thing under less pressures and the tunnel engineer must oppose this tendency

as best he may.   There can be no rules to guide him.   Each in-
stance is a problem in itself and only the most resourceful
man can hope to solve each one as it presents itself.

After this mention of some of the difficulties to be met and
overcome in works of this kind I will outline as briefly as pos-
sible the main features of some of the largest tunnels.   The
first is the Mont Cenis.   This was really the pioneer work of
the kind though the Hoosac tunnel was constructed about the
same time.   The Mont Cenis tunnel passes through the Alps
about fifteen miles southwest of the mountain whose name it
bears.   One end is in France, the other in Italy.   It is part of
the main line of the Paris, Lyons & Mediterranean Railroad
and until the completion of the Simplon tunnel last year gave
the shortest time from Paris to Milan.

In 1838 a Piedmontese peasant living in the neighborhood
ascertained to his satisfaction that the streams on the two
sides of the Alps at this point were at approximately the same
elevation and, further, that the Col de Fréjus was the narrow-
est point of the mountain chain, and proposed the construction
of the tunnel.   He agitated this matter at various times for the
next three years but without any apparent results.   However,
the idea had gotten abroad in the land and in 1845 the govern-
ment of Piedmont appointed Mauss, a Belgian engineer, and
Sismonda, an Italian geologist, to investigate the practicability
of the proposed tunnel.   They favored the plan and Mauss de-
signed and built a machine for excavating the full area of the
heading directly and without the use of explosives.   We have
heard so much of late of the wonders that are to be accom-
plished by such machines that it is interesting to note that the
idea is more than half a century old.   Mauss studied his ma-
chine carefully for some years, perfected and tried it in 1849
and abandoned it as impracticable in 1850.

In 1852 the physicist Colladon, of Geneva, proposed to use
compressed air for power and ventilation and to utilize the
mountain streams to compress the air.   This idea found much
favor and was elaborated by a number of engineers, notably
Germain Sommeiller, afterwards the engineer in charge of the

tunnel, and to whose genius, resourcefulness and tireless energy the successful execution of the work was chiefly due. This plan was approved in 1857 by a government commission. One member of this commission was the scholarly engineer and physicist Gen. L. F. Ménabréa who, in that same year, in a paper presented to the Academy of Sciences of Turin, announced what he called "The Principle of Elasticity" and has since become known as "The Theorem of Least Work," the basis of the most important and most complete method we have for the calculation of stresses and deflections in structures. This in passing.

On August 15, 1857, the Piedmontese parliament authorized the construction of the tunnel and agreed to advance the cost, estimated at 41,400,000 francs, the Victor Emanuel Railroad to return 20,000,000 francs upon completion of the work. Eventually, however, the entire burden of cost fell upon the Italian and French governments.

In 1862 a treaty was negotiated by which France was to pay to Italy 19,000,000 francs and a bonus of 500,000 francs for each year under twenty-five required for the completion of the tunnel. France actually paid to Italy 27,000,000 francs out of the total cost of 75,000,000 francs or nearly $15,000,000.

On August 18, 1857, the first shot was fired on the north side and on November 14, 1857, the first shot on the south side. The work was at first carried on with black powder and hand drilling but later dynamite was used and the holes were drilled by air-driven percussion drills devised by Sommeiller. On January 12, 1861, machine drilling began on the south side and on January 28, 1862, on the north side. The headings were holed through December 25, 1870, and the completed tunnel was formally inaugurated on September 17, 1871. Sommeiller lived to complete his work but not to see it inaugurated. He died early in September of 1871.

The alignment of the tunnel consists of a tangent 11,638 metres long together with a curve at each end bringing the total length between portals up to 12,849 metres. The tunnel was first bored through the mountain on the tangent to fa-

cilitate alignment and the curved portions constructed later,
making the total length of tunnel built 13,444 metres.

As originally planned the elevation of the south portal,
near the village of Bardonnechia, was 1,335·28 metres, of the
middle 1,338·43 metres and of the north portal, near Modane,
1,202·82 metres. It was, however, found necessary in the
course of the construction to lower the south portal nearly
thirty metres, thus altering the grades and giving the tunnel
a very peculiar longitudinal section. Beginning at the north-
ern portal there are nearly four miles of ascending 2·50 per
cent grade, then about three and one-half miles of descending
0·05 per cent and finally about 3,000 feet of descending 2·50
per cent. The effect of this on the ventilation is very bad.
Heavy trains ascending the grade from the north are con-
stantly surrounded by their own smoke. Trainmen and others
have been overcome on more than one occasion, and the corro-
sion of the rails is so rapid that about 300 tons must be relaid
each year.

The cross section of the finished tunnel varies somewhat
from point to point with the design of the lining but is ap-
proximately six metres in height by 7·50 metres in width. It
is lined throughout with masonry except two lengths of about
80 and 100 metres respectively which are in solid white quartz
so hard that the progress of the heading through them was
only about 0·60 metre per day. The tunnel is double tracked.

The rocks traversed by the tunnel are metamorphosed
sediments—slates, sandstones, conglomerates, limestones and
schists—of Jurassic age. As predicted by Sismonda and Elie
de Beaumont, no eruptive rocks were encountered. The di-
rection of the tunnel is approximately N. 20° W. and the
strike of the strata is about N. 35° E. with a dip of 50° to
the northwest so that the intersection is at a very oblique
angle. This condition of affairs was frequently troublesome.

The system of construction adopted was a slight modifi-
cation of the Belgian system. A central bottom heading about
2·50 metres high by 3·00 metres wide was driven in advance.
This was next raised to the top of the full section and the up-

per part widened. The arch was then turned, the bottom
heading widened, the arch underpinned and the side walls
built. The invert, where used, was built last. Machine drill-
ing was used only in the heading, the enlarging being done by
hand. It was found that the rate of advance in the heading
by machines was three times as great as by hand and the cost
about two and one-half times as great. Subsequently the rate
of advance was increased to five times that of hand work.
The cost of enlarging, timbering, walling and general charges
being the same whether machines or hand work are used in
the heading, the cost of completed tunnel with machines used
in the heading is about one-third more than when all the
work is done by hand and the time required is from one-fourth
to one-fifth.

From 1862 to the completion of the work the best
month's work in the southern heading was 90·60 metres in
May, 1867, and in the northern heading 91·30 metres in May,
1865.

There were drilled about 7·50 metres of hole for each cu-
bic metre of rock broken in the heading or about 19 feet per
cubic yard. The powder consumption was 2·25 kilogrammes
per cubic metre or 3·80 lbs. per cubic yard.

The total volume of rock broken in the work was 780,000
cubic metres or about 2,200,000 metric tons. How many
mines break so much in fourteen years?

The cost of the work reduced to our units was $356 per
lineal foot. The average wages paid, including foremen, were
2·50 francs per day.

Ten years after the completion of the tunnel the northern
portal was observed to be sinking and this difficulty became
so serious that it was necessary to bore a new entrance, begin-
ning about one kilometre from the first one and intersecting
the old tunnel about 600 metres from the old portal.

The Hoosac tunnel is entitled to some mention here since
it is the longest in America and since its construction cov-
ered the same period as that of the Mont Cenis.

The history of the Hoosac tunnel is practically the history of the development of the machine rock drill in America.

This tunnel was first proposed in 1825 as part of a canal scheme to connect Boston with the Hudson river. Subsequently the canal scheme was abandoned and the tunnel as a railroad project had a checkered career for twenty-five years.

Parenthetically it may be remarked that a tunnel was at one time proposed to take the place of the Culebra cut on the Panama canal. It was to have a width of 20 metres at the bottom, 24 metres at the water level, a depth of water of 10 metres and a height above the water level of 34 metres. The total section was to be 783 square metres and the length 7,720 metres, the total volume of excavation being about 6,000,000 cubic metres.

In 1854 the Massachusetts legislature passed an act authorizing the Troy & Greenfield Railroad to construct the Hoosac tunnel and pledging the state's credit to the extent of $2,000,000 to secure the advancement of the work. The estimated cost of the completed tunnel was slightly less than $2,000,000; the actual cost was $10,000,000.

In 1851 a tunneling machine was designed and constructed in South Boston for use on this work. The machine weighed seventy tons and was intended to cut a groove thirteen inches wide around the circumference of a twenty-four-foot tunnel, leaving a core to be removed by blasting. This was tried several times during early days at the Hoosac but was not a success. It cut a total distance of about ten feet.

In 1853 a somewhat similar machine designed to take out a core seventeen feet in diameter was built and tried near Harlem. Mr. Herman Haupt, one of the Hoosac tunnel contractors, spent a great deal of money experimenting with this machine but never put it to work on the tunnel.

The first work on the tunnel was done in 1854 but by the middle of 1861 a total of only 4,250 feet had been constructed. In 1862 the state foreclosed its mortgage on the tunnel property and completed the work for its own account. The final headings were holed through on November 27, 1873; the first

engine was run through on February 9, 1875; the first pas-
senger train on October 13, 1875, and the tunnel was formally
declared open for business on July 1, 1876.

The tunnel is double track, about 21 feet by 26 feet in
cross section. Its length is 25,031 feet and its alignment tan-
gent throughout. The eastern portal has an elevation of 768
feet above tide water. From here the grade rises at 0·35 per
cent for 2,000 feet followed by 10,000 feet of 0·50 per cent.
At the middle of the tunnel the track is level for 250 feet be-
yond which it descends on a 0·50 per cent grade to the west-
ern portal whose elevation is 765 feet above sea level.

The rocks through which the tunnel is driven are mica
schists and gneisses, for the most part very hard. The head-
ing was driven on top eight feet high by twenty-six feet wide.
The work in the heading as well as the enlargement was done
by machine drills. The greatest heading advancement in any
month of the work was 184 feet driven west from the central
shaft in September of 1873. In the headings the average of
three years work showed eleven feet of drill hole per cubic
yard broken.

Black powder was used in the early part of the work and
five pounds were required for each cubic yard broken in the
heading. Later nitroglycerine was used, the quantity vary-
ing from 2·25 to 3·50 lbs. per cubic yard.

The mountain does not rise more than 1,800 feet above
the tunnel level and there were, therefore, no high tempera-
tures to contend with. The flow of water was small at all
times and there was no very heavy ground. The English sys-
tem of bar timbering and full area excavation was used. All
things considered, there were very few obstacles to be over-
come and in view of this fact a comparison of the above rec-
ord with that made at Mont Cenis is not flattering to the van-
ity of American engineers.

The second of the great Alpine tunnels was the St. Gott-
hard. This tunnel is located entirely in Switzerland and ex-
tends from the village of Goeschenen on the north to Airolo on
the south. Its total length is 14,900 metres exclusive of the

alignment tunnel 165 metres long at the southern end. Its direction is almost due north and south. At the southern end a length of 145 metres is constructed on a curve of 300 metres radius; the remainder is tangent. The elevation of the track above sea level at the northern portal is 1,109·45 metres. From there the grade ascends at 0·582 per cent to an elevation of 1,154·27, followed by 180 metres of level track and a descending 0·20 per cent grade to Airolo.

The rock penetrated is gneiss, mica schist and hornblende schist throughout the greater portion of the length. At one place, however, the tunnel pierces a mass of Jurassic limestone. The general strike of the strata is northeast and southwest, cutting the line of the tunnel at angles varying from 45° to 80° at different points of its length.

On August 7, 1872, the Gotthard R. R. Co. entered into a contract with M. Louis Favre, of Geneva, for the construction of the tunnel. By the terms of this contract the company was to advance the funds to provide whatever plant and equipment the contractor deemed necessary, the amount so advanced to be charged to the contractor and deducted with 5 per cent interest from the amount due him on completion of the work. The amounts to be paid for the execution of the work were unit prices for the different classes of work, the principal item being 2,800 francs per lineal metre for excavation. The contractor furnished a bond for 8,000,000 francs and agreed to complete the work in eight years. A bonus of 5,000 francs was to be paid for every day from the completion of the tunnel to the expiration of the contract time, while if the work was not done on time the contractor was to forfeit 5,000 francs per day for the first six months and 10,000 francs per day thereafter.

The estimated cost of the work was 50,000,000 francs. The tunnel was not completed on time, there were several disagreements between the contracting parties, and the contract itself was several times altered so that the final cost of the completed work cannot be ascertained.

M. Favre engaged M. Colladon, the Geneva physicist who first proposed the use of compressed air at Mont Cenis, to design air compressors for this work. Operations were commenced immediately upon ratification of the contract and were pushed energetically. The headings met on April 30, 1880, and the tunnel was completed in October, 1881.

On the morning of July 19, 1875, M. Favre entered the tunnel for the last time and conducted a visiting engineer to the face. On his return to the portal he was taken suddenly ill and died within a few minutes.

The Belgian system was adopted as being the only one capable of the rapid advance necessitated by the terms of the contract. European engineers have repeatedly asserted that no other known system could keep pace with the advance of the heading by machine drills. Air driven percussion drills of several different types were used in the headings, the enlargement being done by hand.

The best month's work in the north heading was 146.00 metres in October, 1878, and in the south heading 171.74 metres in August, 1878.

The length of hole drilled per cubic metre of rock broken in the heading averaged about four metres, or a little less than ten feet per cubic yard. The powder used was dynamite (75 per cent nitroglycerine) and explosive gelatine. The consumption in the headings was about three kilogrammes per cubic metre of rock broken or about five pounds per cubic yard.

The difficulties encountered in the construction of this work were very great. The high temperatures have already been mentioned. At one portion of the work the flow of water from the south heading exceeded 6,000 gallons per minute. Shortly before the headings met the tunnel passed through some heavy feldspathic rocks which swelled with such irresistible force that granite arching one and a half metres thick and side walls two metres thick were crushed.

The tunnel is, of course, double track. Its cross section varies somewhat with the character of the ground penetrated

and the consequent shape of the lining but is in general about six metres high by eight metres wide.

The latest and greatest of the tunnels yet built is the Simplon—greatest in length, in depth attained, in difficulties overcome and in rate of driving.

This tunnel extends from Brigue in Switzerland to Iselle in Piedmont. Its general direction is northwest and southeast and its length 19,729 metres.

The first proposition to tunnel the Simplon pass was made in 1853 but it was forty years later before the work was seriously taken in hand. In 1875 the Simplon company consulted M. Favre, the contractor of the St. Gotthard tunnel, and he proposed the construction on very nearly the line actually adopted. The projectors were, however, afraid of the extreme depth reached by this line and in the next twenty years a number of routes were studied with a view to avoiding work at great depths. Some of these were higher up the mountain and all of them were broken lines with a view to avoiding the summit of Monte Leone, 3,565 metres above sea level. Finally, upon the advice of Herr Wagner, of Vienna, one of the engineers of the Arlberg tunnel, that a single peak rising above the tunnel was not likely to cause a temperature corresponding to an equal depth below the general surface of the earth, a low level line practically identical with that proposed by M. Favre was adopted.

On September 20, 1893, the Jura-Simplon Ry. Co. entered into a contract with Brandt, Braudau & Co. of Winterthur, Switzerland, for the construction of the tunnel, but it was not until several years later that proper authority for the work was obtained from the Swiss and Italian governments. By the terms of this contract the contractors were to receive 7,000,000 francs for the installation of the requisite working plant at both ends, and 47,500,000 francs for the construction of one of the two parallel tunnels which make up the completed structure together with a preliminary heading through the second. In addition to these sums the railway company had to expend 4,320,000 francs for land damages and

accessory works, while the completion of the second tunnel is estimated to cost 16,220,000 francs, making a total for the completed work of 75,040,000 francs or approximately $15,-000,000.

Work was begun on the headings on November 13, 1898. On November 22, 1899, Mr. Brandt died, the third great engineer to be sacrificed to the construction of an Alpine tunnel. The contract required the completion of the first tunnel by May 13, 1904, failing which the contractors were to forfeit 5,000 francs per day while a bonus of like amount was to be paid them for each day gained. The work was not completed on time but all records in tunnel driving were broken and this in the face of the most discouraging obstacles ever met underground or on the surface. The rock temperatures at various distances from the portals are shown in the following tables:

NORTH HEADING		SOUTH HEADING	
Distance from portal. Metres	Temp. C°	Distance from portal. Metres	Temp. C
500	12.40	500	13.40
1000	14.20	1000	16.20
2000	17.60	2000	20.90
3000	21.30	3000	23.70
3940	24.60	3400	30.50
4600	30.20	3600	30.90
5000	31.70		

On October 1, 1901, the south heading encountered a flow of water amounting to 8,100 gallons per minute and in three weeks this increased to 12,000 gallons per minute. This, however, had its compensating feature for the temperature of the water when struck was only 18·3° C. decreasing in a short time to 16·7° C. and thus helping to keep down the air temperature at the face.

On December 5, 1901, the temperature in the north heading was 33·4° C. and in the south heading 31·5° C. The flow of water in the north heading was 1,620 gallons per minute and in the south heading 13,800 gallons per minute. At times

this water had a temperature of 32·8° C. In March, 1902, the flow in the south heading had decreased to 10,740 gallons per minute, but on September 6, 1904, this heading struck a heavy flow of water with a temperature of 46·1° C., increasing the total flow at the south end to 13,920 gallons per minute. In July, 1902, with the north heading 7,461 metres from the portal, the temperature was 52·8° C. In June, 1904, a heavy flow of very hot water in the north heading compelled the suspension of work at the face. It was never resumed. The heading had passed the summit and was driving on the down grade toward Iselle. The face was six metres below the summit and the water could only be handled by installing a large pumping plant. In addition the temperature, 55° C., was nearly insupportable and it was, therefore, decided to abandon this face and complete the work from the southern end.

The headings were holed through on February 24, 1905, but it was not until April 2 that the first men passed through. On June 1, 1906, the first tunnel was opened for traffic and since August 1 of that year electrically operated trains have been running through it. The electric traction was estab- • lished on the three phase system with 3,000 volts on the trolley wires.

This is in outline the record of the most remarkable underground work ever carried to a successful outcome. In spite of all difficulties rates of advance of 150 to 220 metres per month were maintained in the headings during the working periods, while the average in each heading for seventy-six months from the beginning to the completion of the work exceeded 130 metres per month including all delays, stoppages and strikes. These figures have never been approached elsewhere.

The alignment of the tunnel is tangent for the greater portion of its length. At the Swiss end there is a short curved portion with a radius of 250 metres turning toward the northwest from the tangent. At the Italian end another short curve turns toward the east with a radius of 450 metres. The track elevation at Brigue is 685·7 metres above sea level. From

here the grade ascends at 0·2 per cent to elevation 704 m.; then there is a stretch of level track 500 metres long from which the grade descends at 0·7 per cent to elevation 632·9 m. at Iselle.

Just here may be noted the check measurements showing the accuracy with which the survey work was done. On August 14 and 15, 1905, line, level and distance were checked through the tunnel with the following results:

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Error in alignment..........................................0·202 metres
Error in level..............................................0·087 metres
Distance between end stations by triangulation..........19,756·31 metres
Distance between end stations by measurement through
    tunnel .............................................19,755·52 metres
                                                        ──────────────
        Difference  ...................................    0·79 metres
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The unique feature of this tunnel is its cross section. Instead of the usual double track tunnel there are here two parallel single track tunnels seventeen metres center to center. Each of these is six metres high by five metres wide inside the lining. Only one of these—the eastern one, known as No. 1—has been finished as yet, the preliminary heading two metres high by three metres wide having been carried through No. 2. This will be enlarged to full size when the traffic demands. The two parallel headings were connected every 200 metres by a crosscut.

This peculiar construction is justified on several grounds. First, the openings are smaller and much easier to maintain under the enormous rock pressures existing at such great depth. Second, probably in no other way could the enormous volumes of air required for ventilation and cooling have been circulated and controlled with such certainty. The air circulation amounted to about 39,000 cubic feet per minute in the north heading and about 66,000 in the south heading. Third, drainage was greatly facilitated and transportation was conducted without interference of incoming and outgoing loads and with vastly less confusion than would have occurred in a single tunnel.

The system of construction adopted was the Belgian modified as at Mont Cenis by the introduction of a bottom heading. The headings were driven by Brandt hydraulic driven rotary drills. The enlargement was done by hand.

While there were many novel appliances and methods used in the construction of the Simplon tunnel, it is probable that none of them contributed so largely to the unprecedented rapidity of advance as the Brandt drill. This machine is a rotary core drill running at slow speed—only eight or ten revolutions per minute—and kept up to its work by a hydraulic jack exerting a pressure of ten or twelve tons. The column on which the drill is mounted is also held in place by hydrostatic pressure and the drill is rotated through worm gearing by a two-cylinder hydraulic engine. Water is supplied under a pressure of eighty to one hundred atmospheres and the consumption is about two cubic feet per minute. Each drill requires about thirteen horsepower. The holes drilled are three and a half inches diameter or larger.

These drills were first put to work in the Pfaffensprung tunnel of the Gotthard R. R. in direct competition with an air driven percussion drill. The air drill was used in the top heading and the Brandt drill in the bottom heading, both working simultaneously and in the same rock which was hard granite. As a result of an extensive trial the heading driven by the air drill was found to cost $13.20 per lineal foot while that driven by the Brandt drill cost $7.62 per lineal foot. The cross section of the heading was seventy square feet and each lineal foot of advance by the Brandt drill required 6·60 feet of drill hole and 12·70 pounds of dynamite, corresponding to 2·55 lineal feet of drill hole and 4·95 pounds of dynamite per cubic yard of rock broken.

Soon after this the Brandt drill was put to work in the Sonnstein tunnel in Austria. In a heading with seventy square feet cross section the advance was six feet in twenty-four hours with a single machine. One hole 12·50 feet deep was drilled in two and a half hours and another 15·80 feet deep in four hours. The rock is described as "very hard dolomite."

The Brandt drill was then adopted in the Arlberg tunnel in the Austrian Tyrol. This tunnel is 10,270 metres long and was built in the years 1880-83. Heading advances of 5·55 to 7·40 metres per twenty-four hours were maintained throughout the work.

At the Simplon tunnel three drills were used in each heading. The holes were usually about one metre deep and the time required to drill one hole was from twelve to twenty-five minutes. Ten or twelve holes constituted one round as compared with the seventy or eighty in the same size heading at Mont Cenis.

In eighty-nine working days in the last quarter of 1899 there were excavated in the northern headings 6,409 cubic yards of rock with 26,600 lineal feet of drill hole and 44,000 pounds of explosive gelatine. This corresponds to 4·15 feet of drill hole and 6·86 pounds of powder per cubic yard. In this time there were 14,700 drills sharpened, each drill serving to bore 1·81 feet of hole. In the southern headings 6,700 cubic yards were excavated in ninety-one working days by means of 33,000 lineal feet of drill hole and 56,000 pounds of dynamite. This corresponds to 4·92 feet of drill hole and 8·36 pounds of powder per cubic yard. There were 61,293 drills sharpened for this work or each drill bored 0·54 feet of hole.

At the Swiss end the rock was principally schist containing some quartz, and occasional beds of gypsum and dolomite. At the Italian end almost all of the work was in an extremely hard gneiss.

The dynamite used at the Italian end contained 64 per cent. of nitroglycerine while the explosive gelatine at the Swiss end contained 83 per cent.

The Brandt drill weighs 120 kilogrammes while the column filled with water weighs 140. Three drills mounted on one column as used in the headings at the Simplon have a combined weight of 500 kilogrammes.

Although large volumes of air were circulated in the tunnel, this was not relied upon entirely to cool the working places. Immediately after firing a round of holes half a

dozen jets of cold water were directed against the face by opening a valve located at a safe distance. Because of its high specific heat, this water cooled the air more rapidly than could have been accomplished by ventilation alone. It also absorbed considerable quantities of noxious gases resulting from the explosion and helped to settle the dust. Water for this purpose was brought into the tunnel through a pipe ten inches in diameter laid inside of another sixteen inches in diameter with the annular space between filled with charcoal. In this way water was conducted nine kilometres with a rise in temperature of only 3°C. As a result of this system of cooling the men were able to resume work at the face within fifteen minutes after firing.

With a view to decreasing the time lost between blasting and the resumption of drilling operations, the experiment was tried of discharging a large volume of water under high pressure by means of a sort of compressed air cannon directly at the face simultaneously with the explosion of the blast. The expectation was that the broken rock would be "caught on the fly," so to speak, before it had time to settle into a more or less compact mass and washed far enough down the tunnel to leave the face clear for the drills. While details of these trials are not available they were probably not successful since the plan was abandoned.

A series of experiments in the use of liquid air were made at the Simplon tunnel, though without success. A plant was established at Brigue and operated under the direction of Prof. Linde, of Munich. This plant was capable of furnishing one-tenth of a gallon per hour of liquid air with an expenditure of seventeen horse-power. Explosive cartridges were made by causing the liquid to be absorbed by a mass of carbonaceous or other readily oxidizable material. It was found that the strength as well as the safety of the mixture thus prepared was largely dependent on the composition of the absorbent. Unfortunately it also happened that those mixtures which were most efficient as explosives were also most dangerous to handle. It was also found that with cartridges

less than six inches in diameter the evaporation of the liquid air was so rapid that a cartridge lost all its explosive power before it could be placed in a hole, while even with so large a diameter the loss of efficiency from the preparation to the explosion of the cartridge was very serious. After many elaborate and expensive trials the attempt to use liquid air as an explosive at the Simplon tunnel was abandoned.

Finally, a few words as to the most enormous tunnel project yet put forward—the tunnel under the Straits of Dover from England to France. This was first proposed to Napoleon by a French engineer in 1802 and has been agitated at various times in the past hundred years. The tunnel would have a length under the sea of thirty-five kilometres which the necessary approach grades would increase to forty-eight kilometres in all. It would be located one hundred metres below sea level with a minimum of forty-six metres of rock above it. So far as known it would be entirely in the chalk. A length of 1,840 metres of the advance heading have actually been constructed on the English side. This heading is circular, 2·06 metres in diameter, and was bored in one operation and without the use of explosives by the tunneling machine of Colonel F. E. B. Beaumont, of the English army. This machine made an average advance of 15·40 metres per day for fifty-three consecutive days, with a maximum in any one day of 24.80 metres. Work in this heading was discontinued on March 18, 1883.

This project has not yet passed the diplomatic stage and a discussion at this time as to its engineering features and possible difficulties would, therefore, be premature.

Ernest LeNeve Foster : — It is with much pleasure that I
have listened to Mr. Comstock's excellently prepared paper. It
contains much information upon a subject which is of deep in-
terest to us all, especially at the present time, when there is in
view the probability, I might almost say certainty, of the early
construction in our State and but a few miles distant from this
city, of a work of this class which will rank well with the large
tunnel enterprises of Europe of which we have just heard so
much. Mr. Comstock has ably laid before us the difficulties en-
countered in this class of engineering, but I was in hopes that
he would have entered more deeply into the subject of the rap-
idity of progress and the possibilities of still greater increasing
it. That progress has been made is evident, as the latest work
has been the most rapid. It behooves American engineers,
however, to look to their laurels, since the rapidity of driving
on this continent does not compare favorably with that at-
tained by foreign engineers. There must be a cause for this,
and therefore our mining engineers should search for it.

Two important matters suggest themselves at this time
to me, and there may be others of equal if not greater im-
portance which will be suggested by others. First, is it due to
the character of the machinery employed, or, secondly, has the
general system of conducting the work more to do with rapid
boring?

In the Simplon tunnel the progress made was remark-
able. In a heading 10 ft. by 6 ft. a speed of 20 to 22 feet
per day of 24 hours was maintained for long periods, and as a
maximum for a period of a whole month 230 metres—equiva-
lent to about 765 feet—or in excess of 25 feet per day was
extracted. In our mining tunnels which are approximately
of this area an advance of one-half that distance in a like
period is considered excellent work.

The American system of attack is almost universally by
deep holes (8 to 10 feet), whereas the European is by large
shallow holes (3 to 5 feet). This necessitates in the American

plan the explosive being spread over a long length of hole, whereas by the European plan the explosive is compressed into a smaller compass, and it may be that this difference alone is sufficient to make the energy exerted by the explosive much more effective. It may be argued that short holes mean more frequent attacks and consequent loss of time in setting up the drills. This is true, but is not this much more than compensated for by a perfect cleaning to the face of the part attacked instead of leaving long corners which have to be cleared out, either by hand or a subsequent attack by short holes for that particular purpose, frequently found to be the case in our American system.

In the Simplon tunnel and in some of the others mentioned, as was stated by Mr. Comstock, the Brandt drill was used, and, I have it from excellent authority, performed its work most satisfactorily from beginning to end of the Simplon tunnel. This, we have been informed, is a rotary drill working under hydraulic pressure, the pressure used being equivalent to 100 atmospheres, or over 20 tons on the face of each drill. In America I know of no case in which that drill has been employed, but invariably some type of the air drill is used. I have yet to learn, however, that the drilling speed is greater with the Brandt drill than by the air drill. From such information as has been at my command, I estimate that the rate of drilling with the Brandt drill is from 1¼ to 2 inches per minute. *In the Simplon tunnel the face was attacked with ten to twelve holes, those in the center being 3 feet 3 inches deep, whilst those round the circumference were 4 feet 7 inches. The time occupied in the attack was:

    Bringing up and adjusting drill, 20 minutes;
    Drilling, 1¾ to 2½ hours;
    Charging and firing, 15 minutes;
    Clearing away debris, 2 hours;

or a total of 4½ to 5½ hours, resulting in an advance of 3 feet 9 inches. This was during the second year of operation, the speed being subsequently increased.

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*Francis Fox. Paper on Tunneling before the Royal Institution of Great Britian, May 25, 1900.

So far as I have been informed, there does not appear to have been any special arrangement employed for mucking or the removal of debris in the construction of the Simplon tunnel, ordinary shoveling being relied upon, though perhaps Mr. Comstock could shed some light upon that subject.

As the actual drilling is not performed any more rapidly than our American drills do the work, must we not rather attribute the slowness of progress in this country to the system of attack in general use here and the lack of thorough organization of the working force, since by system alone can the loss of time between attacks be reduced to a minimum. There is, however, a further feature which may enter into this problem and handicap the American engineer, viz., the restricting by the workmen themselves of the amount of work to be performed for a day's labor. This point was partially overcome by Mr. D. W. Brunton when constructing the Cowenhoven tunnel at Aspen, in which probably the most rapid work done in America has been performed, reaching, I understand, as high as 500 feet per month. His plan was to pay a premium to the workmen on every foot of work performed each month, over a certain minimum, increasing their wages sometimes as much as $1.50 per day.

This subject is one which ought to commend itself to the most careful attention of those in charge of this class of work, if the American engineer desires to maintain himself in the foremost rank, as I am sure we all do.
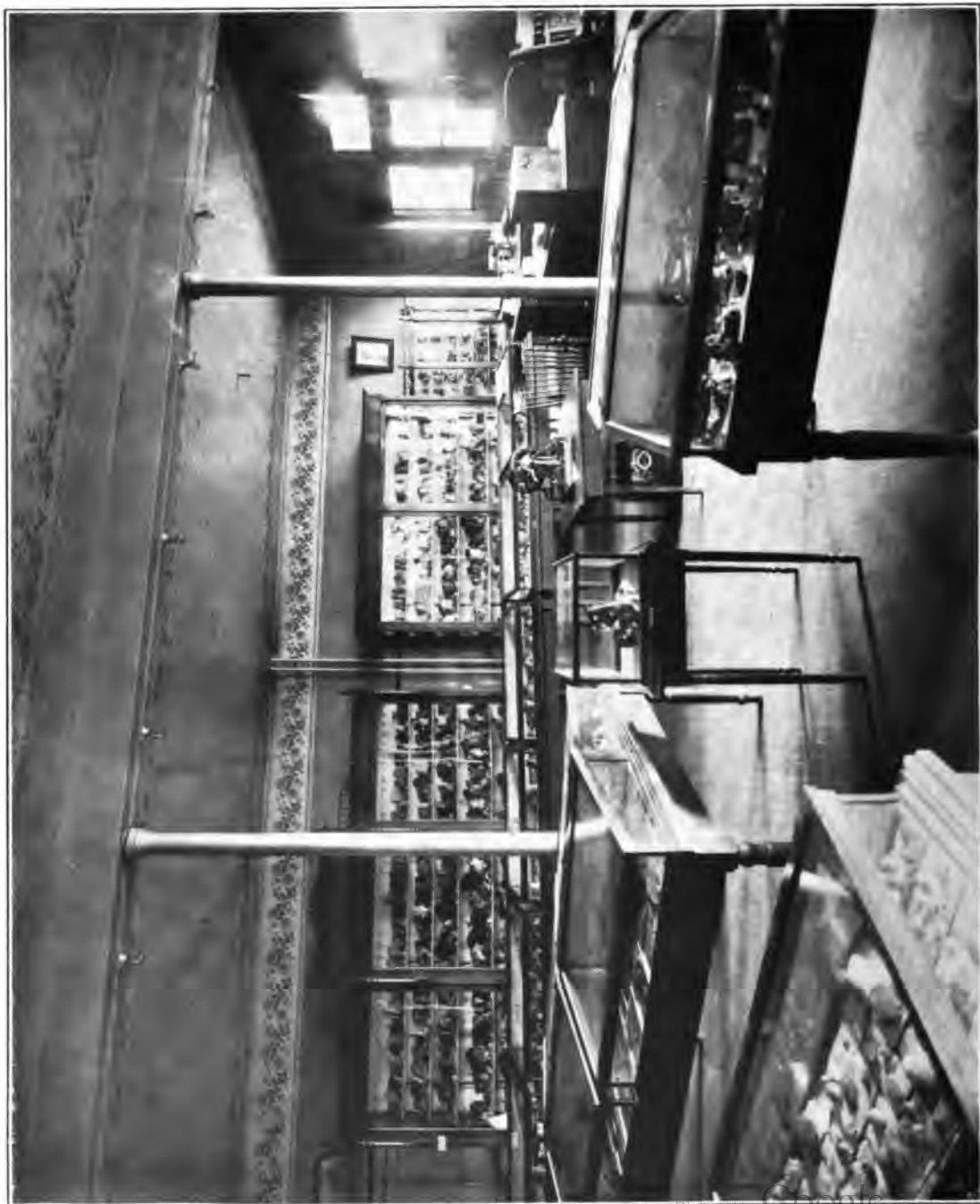
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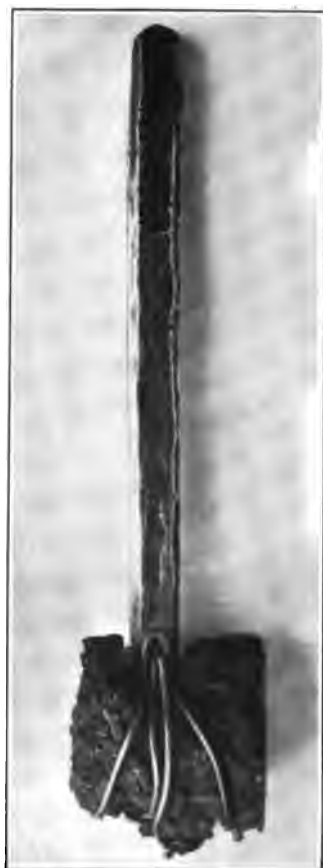
Silver Gavel presented by Mr. J. W. Richards to the Society.

THE CELEBRATION OF THE QUARTO CENTENNIAL OF THE COLORADO SCIENTIFIC SOCIETY.
1882-1907

The members and guests of the Society having assembled, and the meeting having been called to order, Mr. Edwin N. Hawkins presented the silver gavel, the gift of Mr. J. W. Richards, to the President.

Mr. President:

By the generous gift of Mr. J. W. Richards of the Colorado Scientific Society, this silver gavel becomes the property of this Society, and I present it to the Society through you, sir, with the compliments of Mr. Richards. This is a peculiarly fitting occasion for such a gift, and the quarter century in the history of the Society will always be associated hereafter with this gavel and the thoughtfulness and generosity of the donor. With great pains Mr. Richards secured the solid piece of native silver which forms the body of the gavel. It came from one of the large mines of Aspen, Colorado, and is in one piece. This head weighs 6 ozs. Troy. With even greater labor he gathered from ores of silver the amount of 5 ozs. Troy with which he has made the handle. The total weight of the gavel is 11 ozs. Troy. It is the wish of the giver and of the Society, Mr. President, that this insignia of authority may be wielded by you at many future successful meetings of the Colorado Scientific Society. Permit me, on behalf of the Society, to now make you custodian of this gavel.

The President received the gavel and said:

I accept this beautiful gavel, the gift of Mr. Richards, and presented by you, on behalf of the Colorado Scientific Society.

It is of pure silver, from this great state: it was mined here; it was refined here; it was fashioned here. It is entirely a Colorado product. It is of pure silver, as is befitting the occasion of the silver anniversary of this Society.

May the decisions of the presiding officer of this Society, with this gavel in his hand as his symbol of authority, always ring as true and clear as does this silver gavel.

ADDRESS OF THE PRESIDENT.

THOMAS L. WILKINSON.

Ladies and Gentlemen, Members of the Colorado Scientific Society:

We meet here tonight to celebrate the twenty-fifth birthday of the Colorado Scientific Society.

When those of the twelve founders who are still with us look back over the last twenty-five years and take account of the Society's work, I believe it will be with a feeling of satisfaction.

It will be with the feeling that when they met together on December 8th, 1882, in the rooms of the United States Geological Survey, on the sixth floor of the Tabor Block, to organize this Society, their labors were not in vain.

They were then young men, and (as they are today) enthusiastic in scientific work, but it is altogether improbable that any of these founders ever looked this far ahead, or even dreamed of the silver anniversary of the Society.

And we, the members of today, have a feeling of grateful appreciation, in that we have been the associates and followers of these founders in the cause of Science.

Webster, in a speech in the Senate, speaking of the country west of the Mississippi River, said that, so far as he was concerned, he would not vote to spend one dollar in its ex-

ploration or development. This Western country was a vast wilderness then, raw and undeveloped; but not so today. Many influences have played a part in its growth. How really marvelous has been this growth! and today they call it the Great West.

Science has been and is one of the factors that has made this rapid and yet substantial development possible. Its circle of influence is at all times widening. This Society, from its inception, has been a potent factor in the development of this Commonwealth. All these years the Society has performed its work quietly and effectively, and its influence has been felt.

The Society has grown from the twelve founders in 1882 to a strong and effective organization of 250 members today. The rooms of the Society, which are maintained in this building, with its mineral collections and its library, are the Mecca for many, even those outside the Society, in the work of scientific research.

Our library, in which we take great pride, though not so large in the number of its volumes as others, is without doubt the most valuable scientific collection in the West.

The Society also enjoys the correspondence and exchange of the publications of 135 learned scientific bodies in different parts of the world.

It has been the dream that some day the Society would be housed in its own home. Larger and probably more powerful organizations have been in our condition as to permanent quarters. This dream may some day be realized. A society which gives its best efforts, the results of its research work along scientific lines, to the upbuilding of the industries of the State and the West in general, certainly deserves some financial recognition at the hands of those who have been so bounteously profited through it.

Letters of congratulation on this occasion have been received, and I will read one of them, a letter from Mr. S. F. Emmons, the organizer, first president and now honorary fellow of this Society:

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Washington, D. C., Nov. 6, 1907.

Mr. Thomas L. Wilkinson,
     No. 213 Boston Building,
          Denver, Colorado.

Dear Sir:—It is with great regret that from the verdict of my physician I find that it will be impossible for me to attend the proposed quarter century meeting of the Colorado Scientific Society, to which during my stay in Denver last summer you gave me so cordial and flattering an invitation. It gave me great pleasure during that visit to note the flourishing condition of the Society; its large membership, its fine rooms and collections open to inspection and study for such as have occasion to make use of them. When I recall the Society's humble beginning, and our first meetings of organization during the winter of 1882-3 at the rooms of the United States Geological Survey, on the sixth floor of the Tabor Block, when those of us foresaw that Denver was likely to become the scientific center of the Rocky Mountain region, succeeded in gathering together a dozen men from various walks of life, who were willing to assume the responsibility of founding a scientific society, it is extremely gratifying to reflect how our hopes and anticipations have been more than realized, that its membership has increased more than twenty-fold, and its field of usefulness and scientific importance extended over the whole country.

It is rather a remarkable fact that, while at the time of its organization more than half of the original founders had passed their 40th year, now at this quarter century anniversary we have 75 per cent of them still with us, and though, for the most part, beyond Osler's age limit, still taking an active part in the occupation of their respective professions.

While we older men are naturally inclined to congratulate ourselves upon the part we have taken in promoting the interests of so important a scientific organization during its infancy, we must recognize that it is to the active work of its younger members, especially those at present in charge of its interests, that its present flourishing condition in its maturity is due. This condition is abundantly attested to, not only by

its fine scientific library and its large mineralogical and geological collections to which I have already referred, but even more significantly by its published volumes of proceedings which include many valuable contributions to different branches of science.

The record of the Society is doubly creditable from the fact that it started in a young and newly founded city, far removed from the centers of scientific research, and that even now, when this city has grown to be a prosperous and wealthy metropolis, the greater number of its members are men actively occupied in the engrossing duties of business, and, hence, have little leisure for abstract research. This record bears testimony to the appreciation among Coloradoans of the benefits the mining industry has received from scientific research, but may not a still further testimony be fairly looked for—namely, that among those who have accumulated large wealth through the development of this industry may be found a number sufficiently public-spirited to endow this Society with, say, the sum of $50,000, the income of which would enable it to publish its papers more regularly and spread them more widely abroad, as well as add to its library and collections, and thus render them even more useful to the public than they are at present?

I am, my dear Mr. Wilkinson, with the most cordial regards,

Your obedient servant,

S. F. EMMONS.

Twenty-five years of work of the Society have passed into history, and are recorded in the eight volumes of its Proceedings. A new series of years is before us, and, as we look forward, we deem it wise to celebrate the successful past, and we have asked you to join with us in this celebration. This feature will be an address on "Lightning and Lightning Protection," with experiments and illustrations, by a gentleman of high scientific learning and attainments, who has delved deep into scientific research work; a well-known educator of this State, who was the late head of the Department of Physics of Colorado College, and who is at the present time the dean of the faculty of the new Westminster University in this city. I have the pleasure of presenting to you Dr. John C. Shedd.

Paper by Dr. John C. Shedd.

LIGHTNING AND LIGHTNING PROTECTION.*

Mr. President:

The story of Lightning—if we may use the phrase—is the story of the progress of the human race upward from savagery to civilization.   Our prehistoric forefathers lifted terrified hands at the lightning flash and thunder-peal, dumbly praying the god of the air to spare them.   Later with the gift of fire Prometheus gave to man the secret of the lightning flashes, and they became the mighty fires in which the weapons of the heroes were forged, or again the awful thunderbolts forged by Vulcan and hurled by the mighty arms of Jupiter himself.

Later yet—after History had dawned on the world—more naturalistic ideas were advanced.   Thus Plutarch tells us that Anaxagorus believed lightning to be produced by the fall of little flames escaping from the stars.   Anaximander ascribes thunder to an explosion within the cloud—a curious approach to the truth—while Seneca seems to have thought that lightning was produced by the collision of clouds.   The poet, Lucretius, gives the following philosophic lines:

> "Quick lightning flies, when heavy clouds rush on,
> And strike as steel and flint, or stone and stone;
> For then small sparks appear, and scatter'd light
> Breaks swiftly forth, and wakes the sleepy night;
> The night, amazed, begins to haste away,
> As if those fires were beams of coming day.
> And first we see the light, and then we hear
> The noises; these but slowly reach the ear,
> Because the images of things do fly
> More swift than sounds; and quickly strike the eye;
> So while the noise moves slow, the winged light
> Flies swiftly on, and strikes the distant sight;
> Though both arose at once, that moves the eyes,
> Before the slow tongued thunder speaks, and dies."

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*Illustrated by many electrical experiments and lantern slides.

These Greek and Latin writers furnish us with a very small oasis in the desert expanse of the ages. From that time for many centuries man sought not to question Nature, but, worshiping at the shrine of the old masters—Hebrew and Greek alike—sought to interpret literally the meager words there found. When it is remembered that these allusions to lightning and thunder are almost altogether poetical in character, it is readily seen that the spirit of literalism arrested progress until a better day should come.

It were as if the student of the middle ages, realizing how far above him towered the prophets of old, in the realms of religious and philosophic thought, came to the conclusion that they must surpass him in like degree in science also. At all events, for centuries no additions are made to human knowledge but instead fantastic schemes are elaborated, each based on some word of Scripture or passage in Plato or Aristotle. Thus there slowly grew up an elaborate and grotesque theory of physical phenomena, as of lightning and thunder, hail, floods and storms of all sorts.

For example, the Church Father Tertullian, from sundry passages of Scripture, proves lightning to be identical with hell-fire, a view which the supposed sulphurous smell experienced during storms did much to support. Another sample of such reasoning is found in the work of the monk, John of San Guminiano, in the thirteenth century. Of 1,000 pages, over 200 are devoted to the heavens and the elements. Beginning with the Psalmist's phrase, "The arrows of the thunder," he tells us that these are forged out of a dry vapor rising from the earth and kindled by the heat of the upper air, which then, coming into contact with a cloud just turning into rain, "is conglutinated like flour into dough," but being too hot to be extinguished, its particles become sharpened at the lower end, and so like blazing arrows cleave and burn everything they touch. As late as the seventeenth century Majoli, in his huge book on "Dog Days," compares the thunder and lightning to bombs against the wicked and says that the thunder bolt is "an exhalation condensed and cooked into

stone." Again the Protestant scholar, Stoltzlin, in 1731 gives in a "Spiritual Thunder and Storm Booklet," "sighs for use when it lightens fearfully" and "cries of anguish when a hailstorm is drawing on." Each great storm is followed by an appropriate sermon, pointing out the direct connection of the thunder and lightning with the sins of the people. As a last example we will take the sermon of Dr. Prince, pastor of the Old South Church, Boston, preached in 1775, in which he expressed the opinion that the frequency of earthquakes may be due to the erection of "iron points invented by the sagacious Mr. Franklin."

From out of a great mass of records such as the foregoing an evolution of thought may be discerned. *First*, going back to the age of myth and legend is the identification of lightning with the heroes, demigods and gods, as in the Egyptian and Grecian polytheistic mythologies. *Second*, as polytheism gave way to monotheism there came the identification of lightning and thunder, either literally or poetically, with the voice of the deity. *Third*, Slowly as the pagan myths of Greece and Rome crept into the Christian Church there was a swinging back of the pendulum and the lightning and thunder are again in the hands of Zeus, Jupiter, of Thor and Odin, but they are no longer gods, but devils. This doctrine of diabolic agency in storms struck its roots deep and spread its branches widespread over Christendom.

Thus St. Jerome declares the air to be full of devils. St. Thomas Aquinas gave it his authority, saying "Rains and winds and whatsoever occurs by local impulse alone, can be caused by demons." "It is a dogma of faith that the demon can produce wind, storms, and rain of fire from heaven." Dante put it into verse and in Venice Bordone portrayed it on canvas in which he shows a ship load of demons approaching Venice in a storm threatening destruction to the city, while St. Mark, St. George and St. Nicholas attack the vessel saving the city from its hellish crew.

To the three stages here outlined there are corresponding attitudes of the human mind toward the lightning and

thunder. In the *first* stage it is worshiped in dread and awe. In the *second* stage the soul rises to the sublime height of listening to his Maker in the voice of Nature. Could this attitude of mind but have been prolonged there might have been hope for the progress of true science. But in the third there is a return to the abject and superstitious fear of the first stage. The race was like a child lost in a dark cellar full of ghosts, hopgoblins and all the uncanny creatures of the imagination.

The church was not slow to take advantage of such a situation. Indeed, it was largely responsible for the situation. Having fostered in every way the idea of diabolic agency in storms the church now joined battle with the demons of the air, and for centuries the contest went on. The first weapon that may be mentioned as foremost was *exorcism*, or the driving out of devils by adjuration in the name of God. The following is part of one ascribed to Pope Gregory XIII: "I, a priest of Christ,......do command ye, most foul spirits, who do stir up these clouds,......that ye depart from them," or again the priest, in the presence of all the people, addresses the clouds thus: "I exorcise ye, accursed demons who have dared......to stir up winds, gather vapors, form clouds, and condense them into hail......I exorcise ye ......that ye relinquish the work ye have begun, dissolve the hail, scatter the clouds, disperse the vapors and restrain the winds." So important did this sort of meteorlogical method become that manuals of exorcism were prepared: one such was entitled *"Exorcisms most powerful and efficacious for the dispelling of Aerial Tempests, whether raised by demons at their own instance or at the beck of some servant of the Devil."*

Another safeguard which was greatly prized was the *Angus Dei*, a bit of consecrated wax on which was impressed the image of a lamb. The advantage of this charm over exorcism was that it gave continuous protection to the bearer. Another means of protection was by means of holy water kept in the churches and in the bed chamber. The *Angus Dei* in-

creased in importance with the centuries; by special papal bull the blessing of them was reserved to the Pope himself, and he only performed the ceremony in the first and seventh years of his pontificate. Standing with uncovered head he prayed thus: "O God,......we humbly beseech thee that thou wilt bless these waxen forms......that at the touch and sight of them the faithful may break forth into praises, and that the crash of hailstorms, the blast of hurricanes, the violence of tempests, the fury of winds, and the malice of thunderbolts may be tempered, and evil spirits flee and tremble......"

Vying in popularity with the *Angus Dei* as a means of personal protection, there came in as a means of general protection the use of consecrated bells. This usage began in the days of Charlemagne and continues to the present day in some of the remoter parts of Europe. It is not unnatural that the cathedral bells should be consecrated before being put in place, and probably their use in the case of thunderstorms may have crept in by their first being used as alarm bells. However, since they were consecrated it would be most natural to suppose that they would strike terror to the breast of any roving demon. Since then the fiery thunder storm was the demons' work, surely the sound of the silver-tongued bell ought to abate the fury of the storm. This idea was rapidly developed so that the baptising of the bells became a ceremony of great importance. There was also frequently placed on the bell a legend declaring its power over the spirits. Thus a bell in Basle has on it "Ad fugados demones;" another in Lugano has on it, "The sound of this bell vanquishes tempests, repels demons and summons men." Yet another at Erfurt declares that it can "ward off lightning and malignant demons." Still another asserts "It is I who dissipate the thunders." In Switzerland is found the following:

"An der Tufel will ich mich rachen,
Mit der hilf Gotz alle bosen wetter zerbrochen."

Which may be rendered:
  "On the devil my spite I'll vent,
    And, God helping, bad weather prevent."

Such examples might be multiplied a hundred fold. That such devices were believed in as effective is clearly shown. Thus Oleus Magnus of Sweden, who was a close observer of nature and was the first to leave any record of observations on snow-crystals, in 1555, declares that it is a well-established fact that cities and harvest may be saved from lightning by the ringing of bells and the burning of incense. In 1673 Lealus, in Italy, teaches in a text-book the agency of demons in storms and the power of bells over them. So also the bishop of Treves, Binsfield, arguing for the credibility of the confessions of witches, gives a whole chapter to bells.

Looking back from the vantage ground of today, it is easy to smile at such purile devices as a protection against anything at all. Slowly this conviction gained ground, and it became necessary to meet the growing skepticism. As we consider the next phase into which the theory of natural phenomena passed two things stand out boldly.

First—The abject terror in which people stood of lightning, thunder and kindred disastrous manifestations of nature, backed, as they believed them to be, by the devil and all his hosts. *Second,* the tremendous earnestness with which they took the whole matter.

Finding that neither exorcism, nor charm, nor bell abated the fury of the lightning or the ravages of storm and flood, it was a natural inference that the hosts of the devil were winning the day, and that new methods must be raised up with which to meet the Evil one.

What more natural than that human agents should sell themselves to Satan and by diabolic power torment their righteous neighbors? Unhappy day for this poor world when this thought took lodgment. Unhappy day for Christendom when such a theory was put to the test. Says one writer: "Of all documents ever issued from Rome, imperial or papal, this has doubtless, first and last, cost the greatest shedding of inno-

cent blood." These words are spoken of the papal bull of December 7, 1484, dealing with the searching out of witches. Inquisitors were instructed to scour Europe, following the directions given in a specially prepared manual. Having committed themselves to this policy the church's doctrine of infallibility prevented any retreat. The result was that not thousands, but tens of thousands, of poor, ignorant, innocent persons, and especially women, were examined under torture until they confessed anything that was suggested to them. Typical of these confessions may be cited the case of one poor wretch: While she was being torn limb from limb, she declared "that returning with a demon through the air she was dropped in the confusion caused by the sounding of the church bells." Having thus admitted all that was suggested to her, the victim was condemned to the flames. If we include the whole of Europe, it is a conservative estimate to say that over 200,000 persons were executed on the charge of witchcraft, every one of them a victim of a more than false view of nature. The floodgates once opened, there was no closing them; a mad carnival of murder ran from Scotland to Spain through Catholic and reformed churches alike. To the American colonies spread the infection, and it only abated when the witch hunters were wearied with their labors.

It were too horrible as well as too long a story to follow this trail of blood, let us rather close the chapter and turn to the event that rang the death-knell of "sacred science" and ushered in a brighter and a happier day for humanity.

In 1752 Franklin flew his kite from the banks of the Schuylkill and proved forever that the lightning of the skies was identical with the electric spark of the laboratory. Franklin's lightning rods rapidly took the place of the consecrated bells and the number of disasters from lightning steadily decreased. At first the church stood indifferent, then indignant, but slowly accepted the device of the "arch infidel" as effective even if it were impious.

Two examples may be cited: St. Mark's of Venice had been damaged by lightning in the following years, 1388, 1417,

1489, 1548, 1565, 1653, 1745, 1761, 1762, and finally in 1766, fourteen years after Franklin's experiment, a lightning rod was placed upon the grand old cathedral. Since that time no repairs from lightning have been necessary. Perhaps the catastrophy which brought a convincing realization of the situation was the following: The Republic of Venice had stored in the vaults of the cathedral of San Nazaro 200,000 pounds of powder. In 1769, seventeen years after Franklin's discovery, a thunderbolt struck this church, exploded the powder, wrecking a third of the town and killing over 3,000 persons. From that time on no opposition was offered to those who preferred the new to the older method of protection against lightning.

To better appreciate Franklin's work it will be wise to briefly review the development of electrical knowledge up to his day*.

The earliest known observations on electricity are those of Thales of Miletus, 600 B. C. He observed that amber, when rubbed, attracted small bodies, such as bits of lint or dust. From his time to that of Gilbert, 1600 A. D., no advance seems to have been made. Gilbert, who was court physician to Queen Elizabeth, greatly extended the knowledge of his day. He found by direct experiment that other bodies could, by friction, be given the same property as could amber. He also coined the word "electricity" from the Greek word "electron," meaning amber. He classified objects as "electrics" and "non-electrics," according as they were or were not electrified by friction.

In the same century with Gilbert, Robert Boyle showed that the "non-electrics" lost their charge as fast as it was produced, while the "electrics" retained the charge. This question was more fully investigated by Hawksbee and Wheeler in the following century and led to the classification of objects as non-conductors and conductors, precisely as we know them today. Wall, in 1670, and also Gray, in 1734,

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*Free use has been made of Dr. E. L. Nichols' address, delivered at the bi-centennial Franklin Centennial, Philadelphia, 1906.

compared the spark and crack of the electric fire to miniature lightning and thunder. Newton, in 1675, noted that electric attraction took place through an intervening glass plate and suggested the hypothesis of an elastic fluid emitted by the charged body and capable of penetrating solids. Otto von Guericke, working between 1670 and 1700, discovered the repulsion between charged bodies and also observed that bodies could be charged by induction as well as by contact. This marks the best work of the seventeenth century.

Following Hawksbee and Wheeler, DuFay, in 1733, announced the discovery of two kinds of electricity, *vitreous* and *resinous*. He also announced the repulsion of like and the attraction of unlike charges. Thus originated the double fluid theory of electricity.

With improvements in apparatus more elaborate experiments became possible, such as the ignition of powder, the "electric chimes," the electrocution of small animals, discharges in vacuum tubes and other experiments. In 1745 came the discovery of Von Kleist and Cuneus of the so-called Leyden jar. From 1730 to 1760 public attention was directed to an unusual degree toward electrical experiments and discussions. Popular lectures and public demonstrations were the order of the day. Thus the Abbe Nollet amused Louis XV by sending a Leyden jar discharge through 180 of the king's guards. The feelings of the 180 guards seem to have been ignored. Still more striking (both literally and figuratively) was the same experiment tried upon a line of monks almost a mile in length.

This was in Europe; the colonies were too far from civilization to be reckoned with in such matters. However, in 1747, Peter Collinson sent to his friend, Benjamin Franklin, a present of an "electric tube," and Franklin soon outstripped all of his contemporaries. He wrote in this year: "I have, during some months past, had little leisure for anything else." Being so far away from other workers he was compelled to rediscover many things for himself. Of these he wrote long and interesting letters to Peter Collinson, who was not slow

to perceive their value.   Many of these letters Collinson
communicated to the Royal Society and later he issued them
in book form.   Thus Franklin soon became known as the first
electrician of the world.   Indeed, his book was translated into
most of the European languages and passed through many
editions.   Franklin soon discovered the action of points in dis-
charging charged bodies, and he investigated the Leyden jar,
shedding much light upon its properties.   In this experimenta-
tion his sense of humor had at least one occasion to come to
his rescue: To illustrate to some friends the effect of the
Leyden jar discharge, he set about to "electrocute" a turkey
and accidentally received the full discharge himself.   The ef-
fect was somewhat disconcerting to the great man and quite
alarmed his friends.   His first remark was, however, quite
reassuring: "I had thought to kill a turkey," said he, "but I
see that I came nigh to killing a goose."

Having mastered the Leyden jar, Franklin applied it to
the making of an electric motor—the first ever made.   Soon
after came speculations as to the identity of lightning and
electricity, followed by the invention of the lightning-rod.
His interest in atmospheric electricity was twofold; *first,* from
a purely scientific standpoint, and *second,* from a utilitarian
standpoint.   The first he expressed in various theories re-
specting thunder-storms, some of them wide of the mark, but
all showing originality and keen insight.   He rejected the two-
fluid theory of electricity and developed the single fluid theory
as more simple and equally satisfactory.   Franklin was also in
advance of many of his own and of our day in seeking to
test his theories by experiment.   Thus, no sooner had he
speculated as to the identity of the lightning flash with the
electric spark, than he projected experiments to prove his
hypothesis.   He thus describes his successful experiment:

"Make a small cross of two light strips of cedar, the arms so long as
to reach to the four corners of a large, thin silk handkerchief when ex-
tended; tie the corners of the handkerchief to the extremities of the cross
so you have the body of a kite, which, being properly accommodated with
a tail, loop and string, will rise in the air like those made of paper, but

this being of silk is fitter to bear the wet and wind of a thundergust with-
out tearing. To the top of the upright stick of the cross is to be fixed a
very sharp-pointed wire, rising a foot or more above the wood. To the
end of the twine, next the hand, is to be tied a silk ribbon, and where the
silk and twine join, a key may be fastened. This kite is to be raised when
a thunder-gust appears to be coming on, and the person who holds the
string must stand within a door or window, or under some cover, so that
the silk ribbon may not be wet; and care must be taken that the twine .
does not touch the frame of the door or window. As soon as any of the
thunder clouds come over the kite, the pointed wire will draw the electric
fire from them, and the kite with all of the twine, will stand out every way,
and be attracted by an approaching finger. And when the rain has wetted
the kite and twine, so that it can conduct the electric fire freely, you will
find it stream out freely from the key on the approach of your knuckle. At
this key the phial (Leyden jar) may be charged; and from the electric fire
thus obtained spirits may be kindled, and all the other electric experi-
ments be performed which are usually done by the help of a rubbed glass
globe or tube, and thereby the sameness of the electric matter with that
of lightning completely demonstrated."

One hundred and fifty years have elapsed since Franklin
asked Nature to tell him the secret of the lightning. During
this comparatively brief time other men have asked other
questions and have received equally honest answers. The
progress of science has gone forward by leaps and bounds un-
til today the youngest schoolboy knows more that is true about
lightning than did the savant of five hundred years ago.

Without further following the subject historically we will
now seek to present the important elements of the science in
logical rather than chronological order.

Lightning is a display of static electricity. The upper
cloud areas and the earth are conductors, while the interven-
ing air is not. The cloud and earth form the coatings of a
huge condenser with the intervening air as the dialectric. The
charge on the cloud induces an equal but opposite charge on
the earth. The uniting of several clouds may cause the elec-
tric pressure to rise to a value that causes a discharge to
earth, breaking down the dialectric as the glass of a leyden
jar is sometimes broken. The discharge is made manifest
mainly by the brilliant flash that we call lightning. This
flash is due to the intense heat generated by the energy of the

discharge as it overcomes the resistance of the air. The air, violently rended and expanded by the heat, rushes back into the partial vacuum that follows the flash, thereby causing the *thunder-clap*. The effect on the eye is prolonged (due to persistance of vision) after the flash has passed, the time of the flash being generally but an exceedingly small fraction of a second. The roll of the thunder is also prolonged by echoes from earth and cloud and may last for several minutes.

The effects of a lightning flash may be threefold: (1) The production of a very large amount of heat. (2) disruptive effects, as when a tree or crag is struck. (3) a nervous shock which may or may not be fatal to the unfortunate victim. The distance between the flash and the observer can be approximately determined by noting the interval of time between the flash and the noise of the thunder. Light travels at the rate of 186,000 miles per second, while sound at about 1,150 feet per second. If, then the time interval in seconds be multiplied by 1,150, the distance in feet between the observer and the flash is had. It is sufficiently accurate to count five seconds to the mile. This method of noting the interval between flash and sound is useful in determining whether the storm is approaching or receding. If the time interval grows longer with successive flashes, the storm is receding, while if this interval shortens, it is approaching.

Sources of Atmosphheric Electricity.—Science has not as yet furnished a satisfactory or complete explanation of the production of atmospheric electricity. The earth and air are generally at different potentials and generally the air is negatively charged. The electrification to which lightning is due is ascribed to several causes, including evaporation of water, which afterwards condenses into clouds; and the friction caused by the wind. This latter view is favored by the high electrification sometimes observed during snowstorms accompanied by a high wind.

Energy of the Discharge.—The amount of electrical energy present when a heavily charged cloud passes over a given region is frequently very great. It has been calculated that

the amount present in the case of a cloud a square mile in area one mile above the earth and charged to the flashing potential is no less than 70 million foot tons, or 157 billion foot pounds of energy. Were this energy to be released at one flash, that is to say if the whole cloud were to be discharged at once, the results would be terrific in the extreme. The expenditure of this amount of energy in one second would be at the rate of 285 million horsepower. Assuming that the flash to last 1·1000 of a second—a long time for a lightning flash—the rate or power of the discharge would be 1000×285 million, or 285 billion horsepower. Fortunately for man a cloud is not a *good* conductor, its component particles being somewhat separated, so that only a small part of it is discharged at any one flash.

The preceding figures arrest one's attention and questions as to their probable accuracy naturally arise. Dr. Charles P. Steinmetz, who is one of the keenest writers on electrical subjects, in a recent address on this subject, speaks as follows: *"Considering the discharge as in a uniform field, and requiring about 10,000 volts per inch, a lightning flash of two miles, or about 10,000 feet length, would require a potential difference of about 1,200,000,000 volts. The existence of such voltages in the clouds does not seem possible; a potential difference of 1,000,000,000 volts would produce a brush discharge of about one-half mile in length before the final lightning flash occurs. In the brush discharge the air is electrically broken down and conducting. But it is also mechanically broken down; that is, the molecules dissociated and re-combined after the discharge in all possible combinations. That is, we got ozone and nitric acid, and a lightning flash produced by 1,000,000,000 volts might be followed by a deluge of nitric acid. This, fortunately, is not the case. * * * To conclude, then the approximate values of magnitude of the electrical quantities in a lightning flash may be estimated as follows:

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*Taken from abstract in Electrical Review of address before National E. L. Association. Washington, June 13, 1907,
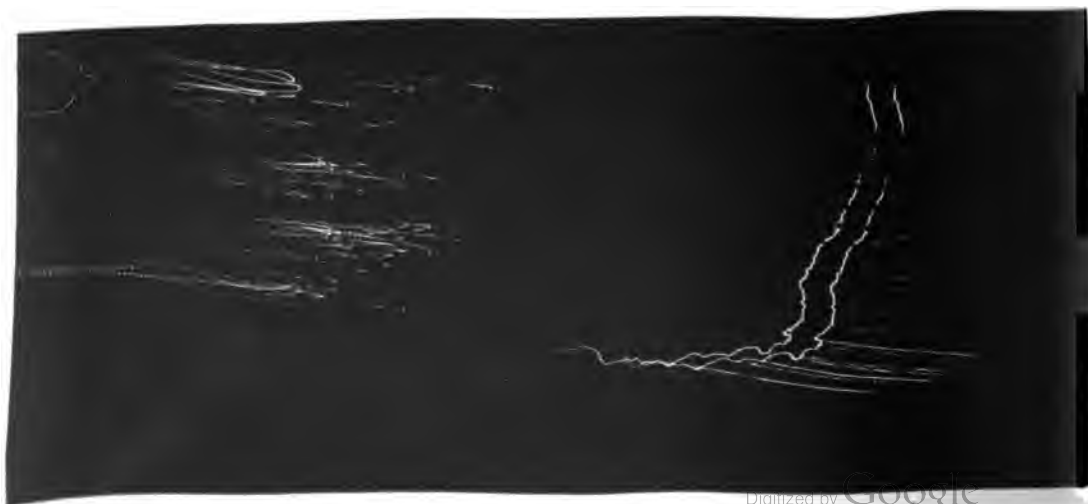
Figure 1,

Figure 2.

"Average potential gradient, 50,000 volts per foot at the moment of discharge. Average potential difference between different points of the cloud, 50,000,000 volts. Average current in the discharge, 10,000 amperes. Average duration of the discharge, 1.500,000 second. Average frequency of discharge, 500,000 cycles. Average energy of the discharge, 10,000 kilowatt-seconds, or 7,000,000 foot-pounds."

Kinds of Lightning.—There are four well marked forms of lightning flash. (1) Zigzag lightning, which may be in a single line or forked. In this case the flash probably passes from one small cloud mass to another, or from particle to particle of foreign matter present in the atmosphere. (2) Sheet lightning, also sometimes called "heat lightning." This is without much doubt the reflection of distant flashes too far away for the thunder-clap to be heard. (2) Multiple flashes. In this case a large cloud area is discharged, but not at once. The first flash prepares a heated path for another flash, which follows over the same path. In this way flash follows flash until the whole cloud area is discharged. The total duration of such a flash may be a considerable part of a second and the number of component flashes a dozen or more. In fig. 1 is shown such a flash with the component flashes separated. The separation is accomplished by taking the photograph by means of a moving camera. It will be seen that the interval between the several flashes is not the same, nor are the flashes of the same intensity. It may very easily be that many cases of so-called forked lightning are really cases of multiple flashes, where the lower part of the paths are not quite identical. In fig. 2* a double flash is seen and on the same plate there happened to fall the image of a distant arc lamp. By measuring the space between the dots made by the alternating current arc the speed of the moving camera was readily calculated. In this way the following values were gotten for the flashes of fig. 1:

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*Figures 1 and 2 are photographs taken by F. C. Jordan, now of Yerkes Observatory. They first appeared in Colorado College studies, October, 1904.

	Seconds		*Seconds*
Between flash 1 and 2........	0.12	Between flash 7 and 8........	0.016
Between flash 2 and 3........	0.05	Between flash 8 and 9........	0.004
Between flash 3 and 4........	0.09	Between flash 9 and 10.......	0.025
Between flash 4 and 5........	0.0012	Between flash 10 and 11......	0.206
Between flash 5 and 6........	0.0048		
Between flash 6 and 7........	0.025	Total duration of flash......	0.53

The irregularity of the time interval between flashes shows clearly that each successive flash discharged a different area of cloud, as indeed would be expected. (4) *Globular lightning*. This takes the form of a fireball moving somewhat leisurely along a wire, a pipe or over the ground. It may disappear quietly or explode violently. Not much is known of this rare form of lightning. The following letter,* addressed to myself is authentic and may be taken as a typical case of globe lightning:

"During the spring and summer of 1870 I spent most of my waking hours at the old M. & C. R. R. station in Harmer, Ohio, learning telegraphy.

"About 4 p. m. on the afternoon of June 2nd a violent thunder-storm arose. I had been sitting, practicing my letters at a bench or shelf near a window upon the broad casing of which, and some four feet above the floor, was the 'switch-board.'

"The only other occupant of the room, about fourteen feet square, was the agent, who had been listening to my efforts to form correctly the 'Morse' characters, and selling tickets for a train about to depart.

"Before the storm had reached its height, the agent stepped over to the 'switchboard' and 'cut out' the instrument upon which I had been practicing, and noting either my ignorance of the danger or indifference to it, had called me to his side. Scarcely had I reached him when a vivid flash, accompanied by a loud report as of the discharge of a pistol, filled the room.

"After an interval of a few seconds, say four or five, there appeared to our wondering eyes (unattended by sound, as far as I can recall, excepting a slight snapping referred to later) a ball or globe of light, apparently three inches in diameter, seemed to roll in through the window casing, following the convolutions of the wires down the switchboard; across and out at the opposite wires of the loop. In crossing the cut-out bar of the switch a slight snapping occurred, such as follows the scratching of

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*The writer was Wm. C. Gurley, at the time of his death, in 1897, director of the Gurley Astronomical Observatory of Marietta College.

the parlor match. The distance traversed by the ball in its passage over
the loop was perhaps twenty feet, and the time occupied about three sec-
onds. In color the ball was yellowish-white. Comparing the light from
the lightning flash to that of the electric light pulling a long arc, the ball
would be likened to an incandescent lamp that had seen service. I do not
think the light exceeded that of a sixteen candle power light. * * *"

Conditions Attending the Flash.—The flash of lightning
always takes place between two oppositely charged clouds, or
between a cloud and the earth. The flash may be precipitated
by either of two conditions. The first of these gives rise to
what is known as the *steady strain discharge,* and is as fol-
lows: A charged cloud approaches the earth; as it does so it
induces a charge of opposite sign on the surface of the earth.
The cloud and earth form a huge leyden jar with the air as
the dialectric. As the cloud gets nearer to the earth the dia-
lectric becomes thinner and thinner and the strain upon it be-
comes greater and greater, until finally the flashing point is
reached and the lightning flashes from cloud to earth. A
heavy rainfall during this time will help the opposite charges
to neutralize each other and may prevent a flash from taking
place. For this reason such thunder-storms are apt to be less
dangerous than when the rainfall is small. In addition to the
rain furnishing a relief to the electric strain, the presence of
numerous earth-connected points tends to discharge the
clouds quietly and to prevent a flash. This is the primary ob-
ject of lightning-rods, and it is immediately seen that the
larger the number of points the more effective will the pro-
tection of the rod be. Rods are comparatively ineffective un-
til they begin to fizz and spit, which in itself is an indication
that the electric strain is getting dangerously high. In gen-
eral the points, unless very numerous, are too slow to prevent
the flash entirely, although they undoubtedly diminish its vio-
lence. In the case of the *steady strain discharge,* the flash,
when it does take place, will follow the path of least resist-
ance, and this is very apt to include the lightning-rod. The
reason for this is that the silent discharge that has been going
on for some time from the points of the rod has decreased the
resistance of the air above them so that this is now the thin-

nest part of the air layer between earth and cloud. The function of the lightning-rod is, in the case of steady strain discharge twofold: (1) to prevent the discharge from taking place if possible; (2) to provide a suitable path for the lightning flash to reach the ground in case the flash occurs. Such discharges will take the path of the rod even when the rod is considerably lower than surrounding objects that are not pointed. Fig. 3 shows the conditions of a steady strain discharge.

Impulsive Rush Discharge.—In a thunder-storm it frequently happens that a flash takes place between a higher and a lower cloud. In this case there is a sudden change of potential of the lower cloud and a resultant increase in the dialectric strain existing between the lower cloud and the earth. The frequent result is that a flash immediately follows to earth. Under these conditions there is little or no time for the induction of the lower cloud to predetermine the path of the flash, and the flash generally breaks through the thinnest stratum of air without regard to what is struck. This may be a high tree, a crag, a tall chimney, a flagpole, a column of smoke or a lightning-rod. In case there are several objects of the same height, or of nearly the same height, one is as likely to be struck as another, and this irrespective of their size, shape or material.

The flash here described has been denominated by Oliver Lodge, who was the first to carefully study it, an *impulsive rush discharge*. It is of more frequent occurrence than the steady strain discharge, and it is impossible to absolutely protect one's self from it. In Fig. 4* the upper cloud is charged, while the lower cloud may or may not be charged. Upon the upper cloud discharging to the lower one, the flash to earth follows: Such a flash is often of great violence. Sometimes there will be several simultaneous discharges from the lower cloud. The likelihood of being struck under such conditions is so great that all lightning-rod protection seems inadequate and all but useless. This, however, is far from being true. Even if a

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*Figures 3 and 4 are taken from Oliver Lodge's book on Lightning Protection.

Figure 3.

Figure 4.

building is certain to be struck, it is better that the lightning should strike the rod and be conducted safely to ground rather than that it tear its way through the structure, leaving destruction and death in its wake. It is probably true that as the public learned that the ideas of Franklin with respect to the possibility of absolute protection were at fault and that there were circumstances under which a house was certain to be struck, they began to lose faith in all protection devices and to trust to the saying that "lightning never strikes twice in the same place." This extreme is foolish and unreasonable. It is beyond question that the number of fires from lightning has been greatly decreased by lightning-rod protection. As time goes on and better understanding is had of the subject, especially as regards the care of the rod, it is likely that the protection will become more and more effective.

Character of the Flash.—The flash may vary from an oscillatory discharge of a very high frequency, of perhaps one million oscillations per second, to a uni-directional current, which begins with a maximum value and falls rapidly to zero. The entire duration of the flash is exceedingly short, probably never greater than 1-500 second. The maximum value of the current can only be conjectured, but is undoubtedly at times very great; the average value is, of course, much less. The characteristics of a lightning flash may in some respects be illustrated by the behavior of a bent spring of considerable mass. The sudden release of the spring will represent the lightning flash. Under extreme conditions, e. g., a spring released in a vessel of stiff molasses, the spring would slowly unbend and come to rest. This would represent the uni-directional flash. When released in a less resisting medium, such as air, the spring would, owing to its inertia, swing back and forth many times before finally coming to rest. This would represent the oscillatory discharge, and would correspond to the great majority of lightning flashes. One of the principal factors that determines the character of the discharge is the resistance of the path. If this be above a certain critical value, the discharge is uni-directional, while if the resistance be

below this value, the discharge will oscillate. The number of oscillations will also depend upon the resistance of the conductor, being greater the less the resistance. It is thus seen that a rod of high resistance will reduce the number of oscillations. The energy of the flash as the discharge oscillates back and forth over the rod is gradually used up in heat, and when the energy is used up the lightning flash is over. It is thus seen that it is desirable that the rod have a high resistance, since this will dissipate the energy into heat faster and will also damp out the oscillations. It is, however, essential that the rod be of large enough cross-section to safely carry the flash without giving rise to fire risks.

Phenomena Observed During a Flash.—While the time involved in a flash of lightning is so very small, there are a surprising number of different phenomena that are to be observed, even in a single flash. These may be grouped under the following three heads:

Effects on the Rod.—Sometimes after a heavy flash part of the rod is found to be destroyed. This is evidence of the heavy amperage of the flash. It is not, however, a necessary conclusion that the rod was too small, for if the building has been protected, the rod has done its duty. In replacing it, therefore, the same sized rod would in general be used.

Multiple or Branching Flashes.—It frequently happens that the component discharges of a multiple flash will follow different paths, part going along the lightning-rod to earth and part taking a new path. The alternate course is frequently most strange and unaccountable: sometimes a part of its course will lie through a piece of metal such as a stretch of gas pipe, the barrel of a gun, a stove or stovepipe, a rain-gutter, or, perhaps, it may be a sooty chimney or a damp wall. More, perhaps, can be learned by noting where the flash left the conductor. This is apt to be a bad joint, a point where the conductor passes near to some metal mass, or where the conductor make a more or less sharp turn.

Side Flashes.—Anywhere within perhaps a mile's radius of the main flash, induced or side flashes may be observed,

caused by the main flash. These take place from any con-
ducting mass such as gas fixtures, electric wiring, rain-spouts,
tin roof or iron railing, to some other conducting mass. These
side flashes are surgings of electricity set in motion by the
oscillations of the main flash. Except in the immediate vicin-
ity of the main flash they are not a source of danger. In
this vicinity side flashes may be of sufficient violence to dam-
age the building or to menace life. In a very severe storm
many of the smaller flashes from cloud to earth no doubt in-
duced side flashes. They without doubt constitute one of the
gravest dangers from lightning.

Resistance Offered by the Conductor to the Flash.—
This is of a twofold character: First, *ohmic* resistance, sec-
ond, *inductive* resistance. The ohmic resistance is the resist-
ance offered by the conductor to steady currents. It is this
resistance that enters into the familiar expression for Ohm's
law,

$$I = \frac{E}{R}$$

The ohmic resistance of a conductor depends only upon
the length, cross-section and material of the conductor. It is
this resistance that must be depended upon to dissipate the
energy of the lightning flash, in so far as the conductor is to
be depended upon to do this. Its value also has a marked ef-
fect upon the number of oscillations of the flash, as has al-
ready been pointed out.

Inductive resistance is the resistance developed by a cur-
rent whose value is changing: it is most marked with oscil-
latory and alternating currents. Its value is determined by
the shape of the conductor and by the number of oscillations
per second, the greater this number the greater the inductive
resistance. The shape giving the greatest inductive resist-
ance is that of a coil or helix. In the case of solid conductors,
the current is confined largely to the surface of the conductor,
due to the inductive action of successive layers of current
upon each other. The greater the surface of a conductor com-

pared with its cross-section the less will be the inductive re-
sistance. It therefore follows that a flat tape has a smaller
inductive resistance than has a round conductor of the same
cross-section. It is also true that inductive resistance does not
dissipate any energy, but merely tends to prolong the dura-
tion of the flash until the energy is finally transformed into
heat by the ohmic resistance. In the case of lightning, the
number of oscillations per second is generally very great and
the inductive resistance of even a straight rod, unless very
small, may far exceed the ohmic resistance. Indeed, where the
number of oscillations is as high as a million per second, the
inductive resistance may be a thousand times as great as the
ohmic resistance.

There is one other point to be discussed, namely,
whether the material of the conductor has any effect of
the inductive resistance. To this it may be said that for
currents whose values are changing but slowly, as in a make
and break d. c. circuit, or in alternating currents of ordinary
frequencies, the material of the conductor has an effect. For
such currents conductors fall into two classes: (1) conductors
made of magnetic material, such as iron and nickel, and (2)
conductors made of non-magnetic material such as copper.
For the first class the inductive resistance is greater than for
the second class, other things being equal. The reason for this
is that the magnetic material is magnetized by the current
and this fact adds to the inductive resistance of the con-
ductor. On the other hand, it is experimentally found that for
alternating currents of very high frequency, to which class
the lightning flash belongs, the effect of the magnetic prop-
erty of the conductor is practically nil. For such discharges
we may then say that the fact that iron is magnetic is in no
sense an objection to its use as a lightning conductor. Fur-
thermore, its higher ohmic resistance, as well as its cheap-
ness, is a distinct advantage. In American practice iron has
always been more used than copper; in Europe the reverse is
the case. Dr. Lodge in summing up the matter says: "I re-
gard the use of copper for lightning conductors as doomed."

Protection of Buildings From the Lightning Flash.—We have seen that there are two classes of lightning flashes: it will therefore be natural to discuss the protection from each separately.   (1) Protection from the flash due to *steady strain discharge.*   Since in this case the dialectric stress increases slowly, protection is gained by the erection of a large number of sharp points which allow the discharge to escape silently and without disruptive violence.   To be effective the number of points should be as great as possible—several thousand on a large building.   It is not necessary or desirable that these points be elevated above the general level of the building, the effectiveness lies in the number of points and not in their elevation.   It may be said that with a sufficient number of points absolute protection can be had from this form of lightning discharge.   Even where the discharge is not prevented from taking place, the violence of the flash is much diminished and the rod affords an ample path for the escape of the electric current.

(2)   *Protection From an "Impulsive Rush Discharge"* —This is the case where a high cloud discharges to one lower down, which in turn discharges immediately to earth, there being no time for the action of points to relieve the electric stress.   If the building is a prominent object in the landscape, it is apt to be struck.   The lightning-rod points do not act as a preventive of the flash, and, indeed, if they project far above the building, may in a measure invite the flash. Since then it is impossible to prevent the flash from taking place and it is also impossible to divert it from the building, or to mitigate its violence, the problem becomes that of preventing it from doing serious damage on its way to earth. It is, of course, better that the flash strike a rod rather than the structure of the house, therefore the highest parts of the house should have points projecting slightly above them. Each chimney should have a conductor bent or arched over the opening so as to intercept a flash coming down the column of heated air.   The conductor should be so disposed along the highest parts of the building as to be unseen from

below and yet to afford place for the locating along it of as many points as possible.

Material of the Conductor.—There are but two metals used for this purpose, copper and iron. Copper has the advantage of greater durability. Iron is cheaper and less likely to be stolen. Once installed, the iron rod has some advantages: its higher resistance is an advantage in that it dissipates the energy of the flash faster, it has a higher melting point, which means that it is less likely to be destroyed by a heavy flash. We have also seen that the magnetic property of the iron does not add to its inductive resistance and hence is not a disadvantage. It thus seems certain that iron, galvanized to add to its durability, is the best material to use for lightning conductors.

Cross-Section of the Conductor.—The total area of cross-section need not be greater than that of a round rod one-half inch in diameter. The poorest form of cross-section is that of the circle, the best that of a flat tape. A hollow tube is permissible, but simply adds expense without any adequate return. The point to be kept in mind is that there should be as much surface to the conductor as possible. This can be gained by using a flat tape, or by using a number of small wires laid side by side. For cases where the appearance is not important, galvanized wire fencing one or two feet wide is excellent. Such a conductor would also have the advantage of having no joints throughout its entire length. It is a common custom when the conductor is a flat tape to twist it, with the presumable idea that it looks better. It is not likely that such twisting makes a noticeable difference, but so far as it goes it is in the wrong direction. Finally, it is well to remember that a lightning conductor need not be expensive, fancy shapes, extra large cross-section and gilded tips simply add to the expense without adding to the efficiency. The worst forms are the solid conductor and the wire rope; the best forms the flat tape and a number of small wires laid parallel a few inches apart with cross wires at frequent intervals.

The Mounting of the Conductor.—The top of the building should have as many points as possible along all of the ridges, and also on the chimneys. These points should be connected, all joints being carefully soldered. There should be conductors running from the system of conductors on the roof to the earth down each corner of the house and sometimes at intermediate points also. It is most important that these conductors should make as few sharp turns as possible. The path from roof to earth should be as straight as possible. The earth connections should end in damp soil with an enlarged plate to insure good contact. A very good plan is to bury the plate in a load of coke, and to have the spot occasionally soaked with water. The importance of a good ground connection can be over-estimated, but it should not be overlooked by any means. The manner of fastening the conductor to the building should be carefully looked to. The passing of the rod through glass insulators has an appearance of being effective, but is not much more than an appearance. A flash of lightning that will jump through a mile of air is not likely to be seriously obstructed by a half inch of glass. In fact it is useless to try to insulate the rod from the house and the near presence of the sharp ends of the nails or screws running into the building are so many danger points for the lightning to pass into the house by. The ideal fastening would be one made entirely of a non-conductor, and it is recommended that a rod of wood, or better, of fiber, be left projecting at suitable intervals from the house as the building is erected. The conductor can then later be installed through holes drilled in these rods and all metal fastenings avoided.

Protection from the two main types of lightning flash have now been considered. There yet remains the multiple or *branching* flash and the *side* flash to be considered. Branching flashes are favored by a high inductive resistance in the conductor, and hence the use of tape or of small wires laid parallel instead of the solid conductor. In putting the conductor up sharp turns are to be avoided. *Side flashes*: These are most apt to occur when the

conductor has a low ohmic and a high inductive resistance. They take place owing to the oscillations of the main flash setting up corresponding surgings of electricity in neighboring conducting masses. Sparks take place from the ends of such masses and not from the middle portion. The danger consists in the likelihood of the spark's igniting some inflammable material. The greatest liability is to be found in the case of gas. It sometimes happens that a gaspipe will have minute pin-hole leaks too small to be detected in any ordinary way, but still capable of furnishing a minute flame. Since the gas pipe is against wooden beams, such a flame, tiny as it is, will in time cause a fire. The procedure in securing protection is as follows: *Both* ends of such masses of metal as are near to the lightning conductor are to be metallically connected to earth. Metal masses at a distance from the rod are also grounded at both ends. All metal roofs, rain-spouts, gutters and ornamental iron work should be so treated. In some cases the number of such connections may be wisely increased. Masses of metal such as gas and water pipes are already grounded at one end. The end highest up in the house would best be connected to an earth wire, but not to the lightning-rod. So also with other extremities of the piping. This is the procedure with all metal masses that are to be touched, as are gas and water pipes. If the water pipe on the outside of the building is used as a ground for the conductor, this precaution is all the more necessary. It is, however, best not to use the service pipes entering the building as the ground of the lightning conductor. It is to be remembered that in the surgings of the flash all masses of metal directly connected with the conductor will share in the surgings of the main flash. During a thunder-storm it is wiser not to touch or to lean against metal masses.

General Considerations.—The material of the lightning-rod may be copper or iron. Copper will stand the action of the weather better; iron is cheaper. From the standpoint of theory, iron has a slight advantage.

All joints should be soldered, or better, electro-welded. It would be a simple matter to use a small welding transformer where a city lightning circuit is available.

Where a water pipe is used for a ground, it should be made sure that the joints of the water pipe for some distance in either direction are screw or lead joints. Otherwise an arc may be established across the joint and the pipe melted.

A good earth is made by having the conductor end in an iron plate which is buried ten or twelve feet below the surface. Around the plate place a load of fine coke mixed with a quantity of salt. An inch pipe coming to the surface, down which water can occasionally be poured is a good addition.

All lightning conductors should be periodically examined, and especially after severe storms. In case it has been found to have been melted off, it does not necessarily follow that the cross-section is too small, but in case protection nas been afforded, that it has served its purpose well. After a second case of melting, however, it probably would be well to enlarge the size.

The characteristics of a good conductor may be summarized as follows: A multitude of points, a flat tape, a straight course without sharp turns, all joints carefully riveted and soldered or electro-welded, such side connections made as inspection shows to be wise.

While *absolute* protection from lightning cannot be secured, there is no question but that a large measure of protection is possible. Nor can it be doubted that such protection should be placed upon all large buildings and upon buildings especially exposed.

PROTECTION FOR THE PERSON.

This resolves itself into the question, Where should a person go during a thunder-storm? The area surrounding a lightning-rod is dangerous, not only on account of the liability of a branching flash reaching the body, but also because the oscillations of the main flash will set up surgings over the

surface of the person's body as in any other conducting body. The shelter of trees is very dangerous, as trees are likely to be struck and the person beneath it is almost certain to receive a dangerous or fatal shock. It were far better to take a soaking in the middle of a field than to take refuge under a tree. Stables and barns are more likely to be struck than are houses, on account of the warm column of air ascending from them, due to the presence of vegetable or animal heat. For the same reason the shelter of a haystack is to be avoided. Records show that ice-houses are the buildings least struck by lightning. This is undoubtedly due to the fact that there is no ascending current of air over them. Probably the safest place in a living house is the middle of a room that contains no stove or chimney. Experiment shows that objects within a closed conductor are unaffected by outside electrical disturbances. It is practicable to construct sheet-iron storm shelters in which a person would be safe in the very midst of the severest lightning. The doors of such a structure would be covered with iron and the windows with wire gauze. In fact, both theory and experiment show that wire netting or gauze could take the place of the sheet iron on all parts of the strucure. If one cared to take the trouble it would be an easy matter to put wire netting within the walls, ceiling and floor of one of the rooms of a house and thus to make it lightning proof.

Protection for Powder Magazines.—Powder, oils and like inflammable materials can best be protected from lightning by being placed in buildings sheathed or lined with metal. It is of the greatest importance that the interior of such buildings be impregnable to surging discharges likely to cause sparks. It is therefore essential either to exclude all piping from the building or to carefully connect every entering pipe to the metal sheathing at the points of entrance into the building. Any electrical surgings from the earth will then pass from the pipes to the outer coating of the sheathing. For the purpose of protection the sheathing need not be grounded, such a ground connection is, however, desirable to avoid static shocks on entering the building.

Protection of Telegraph, Telephone, Light and Power Lines.—There are peculiar features associated with the protection of such lines.   (1) The object to be protected is itself a good conductor.   (2) The line may be struck at one point and the fatal shock or damage affected miles away from the storm area.   (3) The line voltage, while too weak to start a current across an air gap, may be able to follow the path of heated air established by the lightning flash.   (4) The condensor action of long lines is sometimes an annoying feature. This action is frequently increased during a lightning display.   (5) It is not necessary that a lightning flash strike the line to produce in it a dangerously high potential.   Induced flashes due to neighboring lightning discharges may be of sufficient violence to kill persons or to destroy instruments. These conditions are in a measure avoided by providing paths through which the high potentials may strike to earth, and relieve the stress before it creates its own path of destruction.   Although a lightning flash may seldom be prevented from taking place, a suitable path may be provided by which it may reach the ground.   The general basic principle upon which all lightning arresters are constructed is that a flash will leave a path of low ohmic, but high inductive, resistance and take a non-inductive path of high ohmic resistance in preference.

APPENDIX.

The following report is of interest in connection with the consideration of large steel structures.   The lesson to be learned from it is that even the slight damage done and the inconvenience suffered might have, in all probability, been avoided had the bases of the various steel columns been thoroughly grounded, as described in the foregoing pages.   It seems reasonable to conclude that no other lightning protection need be added for such buildings, in so far as the building proper is concerned.   In the case of the roof, a system of points, as herein described, could, with advantage, be installed and connected, at as many points as practicable, with the steel framework of the building.

Report on an investigation of a lightning stroke which struck the Antlers Hotel, Colorado Springs, June 20, 1904:

(I)   Data gathered from men in and about the hotel.

(II)   Conclusions drawn from this data.

(I)   The stroke took place on the afternoon of June 20, 1904, at about 3:30 p. m.

The point first struck was the north tower of the building the southwest corner being shattered, also the tile capping of the tower was broken; quite a number of tile on the part of the roof to the northeast of the tower were torn up. These tile were lifted off of the roof in several places in patches of several square feet area as if blown off from within. The cement below the tile was also broken.

Within the building there was evidence of the stroke as follows:

A waiter in the east dining room saw a blue flame rise a foot off of one of the steam radiators on the east side of the room. Guests seated at a nearby table were frightened by the flame, but were not shocked.

In the room containing the ice machine the attendant heard a crack as loud as a pistol shot from behind the switchboard.

In the laundry in the northwest corner of the basement the foreman, seated in his office partitioned off from the rest of the room, saw a flash. A workman at one of the centrifugal wringers had his wet hands on the iron frame of the wringer and his hip against one of the iron posts supporting the shafting. He received a shock from which he did not recover for over an hour. He was whirled about against a wooden partition. Where his hip was in contact with the post he found a burn as large as his hand having the appearance of hives. Across his chest he felt as if he had been dealt a heavy blow. At another point in the room some twenty feet distant and near the big ironing machine a bit of lint was ignited by a flash.

An attendant in the bowling alley at the south end of the building in the basement was leaning against one of the iron

The Antlers Hotel.

pillars with his shoulder in contact with the pillar. He felt a sensation in this shoulder like that caused by a large medical battery. On his shoulder he found a red spot at the part where the shoulder touched the pillar.

The steel pillar supports the iron framework of the ceiling and rests upon a foundation set into the ground.

Mr. Herscenfeld was standing at the door of his shop on the east side of Cascade avenue. He was blinded by the flash and felt a shock.

(II) *Conclusions Drawn From the Foregoing Data.*— The conclusions are given without giving the reasoning leading to the conclusion. This would needlessly lengthen the report.

(1) A multiple flash struck the tower, the component flashes passing in air 'to several points on the roof below, thus entering the steel framework of the building. The main flash passed to earth through the steel framework; perhaps the laundryman was struck by a branch of the main flash, but probably not.

(2) There were several induced side flashes set up by the main flash as follows:

a From the steam pipe system, evidenced by the flame seen in the dining room.

b From the electric conduit system. This is evidenced by the report heard behind the switchboard.

c From the water pipe system. The flash in the laundry may have been from this or from the steam pipe system. The flash passed through the man since the foundation of the wringer had a better ground than did the post against which he was leaning.

d The man in the bowling alley was affected by a small side flash due to a main flash passing down the pillar against which he was leaning.

e The man across the street was affected by a side flash due to the main flash.

(3)   That more damage was not done to the building was due no doubt to the fact that the framework of the building is of steel and afforded ample path for the main flash to pass to earth. The side flashes show (1) the oscillatory character of the flash; (2) that even large steel beams and pillars have considerable inductive resistance.

THE CELEBRATION OF THE QUARTO CENTENNIAL
OF THE COLORADO SCIENTIFIC SOCIETY.

1882-1907

HELD IN THE LARGE HALL
OF THE CHAMBER OF COMMERCE
DENVER, COLORADO, DECEMBER 14, 1907