PROCEEDINGS

—OF THE—

COLORADO

SCIENTIFIC SOCIETY

VOLUME III.

1888-1890.

PUBLISHED BY THE SOCIETY,
DENVER, COLO.

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Page 30. Line 7 from top for "orogenetic" read "orogenic."

Page 192. Last line for "trace of prismatic striation" read "trace of etched prismatic striation."

PROCEEDINGS

—OF THE—

COLORADO

SCIENTIFIC SOCIETY

VOLUME III.

1888.

PUBLISHED BY THE SOCIETY,
DENVER, COLO.

ABSTRACT OF MINUTES

—OF THE—

Colorado Scientific Society,

FOR THE YEAR 1888.

OFFICIAL PART.

FIFTIETH REGULAR MEETING.

FEBRUARY 6TH, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

Charles S. Palmer, Ph. D., of Boulder, was elected a member of the Society.

Resolutions were adopted in honor of the deceased member of the Society, Dr. S. F. Rouse.

COMMUNICATIONS.—The following named papers were read:

By P. H. van Diest, "On Some Volcanic Craters in Colorado."

By R. C. Hills, "Preliminary Notes on the Eruptions of the Spanish Peaks Region."

INFORMAL COMMUNICATIONS.—By Richard Pearce, "On Furnace Products."

FIFTY-FIRST REGULAR MEETING.

MARCH 5TH, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

Messrs. R. D. Hobart, W. C. Wynkoop and Sherman G. Sackett, all of Denver, were elected members of the Society.

COMMUNICATIONS.—The following named papers were read:

By L. D. Ricketts, "On some Soluble Salt Deposits near Rock Creek Station, Carbon Co., Wyo."

By F. F. Chisolm, "Notes on some Unusual Occurrences of Galena Crystals."

By W. F. Hillebrand, "Mineralogical Notes."

INFORMAL COMMUNICATIONS.—By W. P. Headden, "On Analysis of Water from a Spring in Platte Cañon notable for the amount of Strontia it contains."

FIFTY-SECOND REGULAR MEETING.

APRIL 2ND, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—There were no formal papers.

Discussion: "On the Rain-fall on the Plains."

FIFTY-THIRD REGULAR MEETING.

MAY 7TH, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—The following named papers were read:

By Geo. L. Cannon, Jr., "Quaternary Deposits near Denver."

By Richard Pearce, "Remarks on the Genesis of Ore Deposits."

INFORMAL COMMUNICATIONS.—By Dr. Headden, "On the Results of Some Experiments on the Precipitation of Copper in Zinc Assays."

FIFTY-FOURTH REGULAR MEETING.

JUNE 4TH, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—The following named papers were read:

By L. G. Eakins, "A New Sulphantimonite."

By T. E. Schwarz, "Notes on the Ore Occurrence of the Red Mountain District."

FIFTY-FIFTH REGULAR MEETING.

JULY 2ND, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—The following named papers were read:

By Geo. H. Eldridge, "On Some Stratigraphical and Structural Features of the Country about Denver, Colo."

By Whitman Cross, "The Denver Tertiary Formation."

INFORMAL COMMUNICATIONS.—By Wm. P. Headden, "On a New Rapid Method for the Direct Determination of Silica in Ores, Slag, etc."

FIFTY-SIXTH REGULAR MEETING.

OCTOBER 1ST, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

Mr. J. T. Kebler was elected a member of the Society.

The following addition to the Constitution of the Society was passed:

ASSOCIATES.

Art. VII. "Persons interested in the objects of the Society may become associates upon proposal and election in the manner provided for the proposal and election of members. Associates shall be entitled to all the privileges of members except voting and proposing candidates for membership."

COMMUNICATIONS.—The following named papers were read:

By F. Guiterman, "On the Determination of Iron and Copper in Ores and Furnace Products."

By G. L. Cannon, Jr., "On the Tertiary Dinosauria found in Denver Beds."

INFORMAL COMMUNICATIONS.—By Whitman Cross, "On Three New Localities of Garnet and Topaz in Rhyolite," and "On the Structure of an Improperly Called Crater."

By J. B. Farish, "On Meteorites Recently Noticed in Old Mexico."

FIFTY-SEVENTH REGULAR MEETING.

DECEMBER 3RD, 1888.

In the Society Rooms, County Court House.

The President, R. C. Hills, in the Chair.

Messrs. Charles F. Lacombe, of Denver, and Franklin B. Carpenter, of Rapid City, Dak., were elected members of the Society.

Section 6 of the By-Laws was adopted as follows:

"Officers of the Society shall be elected at the annual meeting, to be held on the third Monday of December of each year, to hold office during the ensuing year. They shall be voted on by ballot and a majority of votes cast shall be necessary for an election, except in the case of the Executive Committee, when the five candidates receiving the highest number of votes shall be declared elected. Members not able to be present may vote by letter. The business of the annual meeting shall be restricted to the election of officers, the delivery of the address of the retiring President and the installation of the newly-elected President and Secretary."

COMMUNICATION.—The following named paper was read:

By R. C. Hills, "The Recently Discovered Tertiary Beds of the Huerfano River Basin, Colorado."

INFORMAL COMMUNICATION.—By Geo. L. Cannon, Jr., "On the Footprints Found in the Dakota and Trias Sandstone, Used for Pavements in Denver."

ANNUAL MEETING.

DECEMBER 17TH, 1888.

Held in the Society Rooms, County Court House.

The following officers were elected for the year 1889:

President, ...RICHARD PEARCE.
Vice-President, ...HERMANN BEEGER.
Secretary, ...P. H. VAN DIEST.
Treasurer,.............O. J. FROST.

Executive Committee.

R. C. HILLS,	JOHN A. PORTER,
HERMANN BEEGER,	F. F. CHISOLM.
GEO. C. MUNSON,	

The installation of officers took place with appropriate remarks, and Mr. R. C. Hills delivered his address as retiring President.

On motion of P. H. van Diest, a vote of thanks was tendered to the retiring President for his instructive address and for the very capable and attractive manner in which he had conducted the meetings during 1888.

The following annual reports were submitted:

Report of the Secretary of the Colorado Scientific Society for the Year 1888.

MEMBERSHIP.

New members elected during 1888,	10
Members resigned, deceased and dropped,	7
Active members January 1st, 1889	60
Gain during year	3
Residents of Denver	21
Non-Residents	39

MEETINGS.

Number of regular meetings held	9
Total number of members present	94
Total number of visitors present	15
Largest number present at any meeting (July)	17
Smallest number present at any meeting	7

COMMUNICATIONS.

Number of members contributing original written articles	12
Total number of written articles	17
Number of informal communications	9

Report of the Librarian of the Colorado Scientific Society for the Year 1888.

The total number of complete volumes and current parts of volumes now in the library is 365; the number of pamphlets is 139; making a total of 504.

ACCESSIONS DURING 1888.

Complete volumes	51
Volumes and parts of volumes of periodicals	57
Pamphlets	2

PUBLICATION AND EXCHANGE.

Volume II, Part 3, of the Proceedings has been issued.

The number of Societies and Institutions with which the Society now exchanges is 53.

Report of the Treasurer of the Colorado Scientific Society for the Year 1888.

Dr. 1888.			Cr. 1888.		
Jan. 5. Balance on hand	$ 26	24	Books and stationery	$ 15	65
Membership dues collected	535	00	Janitor	30	00
Meteorite fund	55	00	Express and drayage	20	77
Proceedings sold	21	10	Meteorite	100	00
			Museum	9	95
			Miscellaneous printing	40	10
			Printing proceedings	217	32
			P. O. Box rent	2	50
			Stamps, postals, etc	35	40
			Subscriptions	9	50
			By balance on hand	156	15
	$637	34		$637	34

E. W. Rollins, Treasurer.

Museum of the Colorado Scientific Society.
Additions During 1888.

During the year ending December 31st, 1888, the following additions were made to the collections of the Society:

Mineral Specimens.—Donated: by W. B. Smith, 9; by Whitman Cross, 18; by P. H. van Diest, 1; by Geo. L. Cannon, Jr., 1; by L. D. Ricketts, 2; by F. F. Chisolm, 20; by R. Pearce, 16; by F. B. Carpenter, 2; by J. B. Farish, 4; by R. C. Hills, 2. Total accessions, 75 specimens.

Rock Specimens.—Donated: by R. C. Hills, 17; by R. C. Hills and J. T. Kebler, 151; by F. F. Chisolm, 4; by W. B. Smith, 4; by Whitman Cross, 2; by F. B. Carpenter, 4; by T. E. Schwartz, 2; by E. C. van Diest, 1. Total accessions, 185 specimens.

Fossil Specimens.—Donated: by Whitman Cross, 53; by Charles T. Charlton, 8; by R. C. Hills, 5. Total accessions, 66 specimens.

Ore Specimens.—Donated: by R. Keck, 2; by R. C. Hills, 2; by W. B. Smith, 1; by J. A. Porter, 1; by F. B. Carpenter, 14; by W. S. Baker, 1; by R. F. Wrigley, 1; by P. H. van Diest, 4. Total accessions, 26 specimens.

Miscellaneous Specimens.—Donated: by R. C. Hills, coal specimen; by F. B. Carpenter, ingot of tin; by Richard Pearce, alloy of silver and lead.

Specimens Purchased.—One meteorite from Costilla Peak; one meteorite from Tolusca, Durango; one specimen of astrophyllite. Also a lot of vanadinite, wulfenite and azurite specimens suitable for exchange.

Exchanges.—Duplicates were sent in exchange for the following: 20 specimens of South American minerals, including copiapite, coquimbite, rocmerite and melanterite; specimens of Renfrew, Canada, apatite and titanite, and 3 specimens of tourmaline from Gouverneur, N. Y.

ABSTRACT OF MINUTES

—OF THE—

COLORADO SCIENTIFIC SOCIETY,

FOR THE YEAR 1889.

OFFICIAL PART.

FIFTY-EIGHTH REGULAR MEETING.

JANUARY 7TH, 1889.

In the Society Rooms, County Court House.

The President, Richard Pearce, in the Chair.

Mr. Alfred Rickard, of Central City, was elected a member of the Society.

The President announced the appointment of R. C. Hills as Curator for the year 1889, and Messrs. Wynkoop, Kebler and the Secretary as members of the Publication Committee.

Communications.—The following named paper was read:

By P. H. van Diest, "Folding of Coal-beds in South Eastern Colorado and Northern New Mexico."

Informal Communications.—By Geo. L. Cannon, Jr., "On a New Family of Horned Dinosauria."

By Richard Pearce, "On Scorodite."

By R. C. Hills, "On a Semi-Coking Coal from Salt Creek, Wyoming."

FIFTY-NINTH REGULAR MEETING.

February 4th, 1889.

In the Society Rooms, County Court House.

Mr. R. C. Hills in the Chair.

Mr. H. O. Hoffman, of Rapid City, Dakota, and Messrs. Geo. S. Rice, Jr., W. Bowen Evans and John Frederic Main, all of Denver, were elected members of the Society.

Communications.—The following named papers were read:

By Geo. L. Cannon, Jr., "Horncores of Horned Dinosaurs."

By R. C. Hills, "Etching of Mt. Antero Beryls."

Informal Communications.—By P. H. van Diest, "An Iron Meteorite which fell in Brazil in 1784."

SIXTIETH REGULAR MEETING.

March 4th, 1889.

In the Society Rooms, County Court House.

The President, Richard Pearce, in the Chair.

Communications.—The following named papers were read:

By W. F. Hillebrand, "Analyses of Three Descloizites from New Localities."

By Geo. L. Cannon, Jr., "Aboriginal Remains near Denver."

Informal Communications. — By Richard Pearce, "Notes on Sperrylite," and "Notes on the Hot Springs at Glenwood Springs, Colo."

SIXTY-FIRST REGULAR MEETING.

April 1st, 1889.

In the Society Rooms, County Court House.

The President, Richard Pearce, in the Chair.

Mr. H. L. Wadsworth of Denver, was elected an associate member of the Society.

COMMUNICATIONS.—The following named paper was read:

By John F. Main, "Plasticity of Glacier Ice."

INFORMAL COMMUNICATIONS. — By P. H. van Diest, "Forest Destruction in New South Wales."

By Richard Pearce, "Rock Impregnation."

SIXTY-SECOND REGULAR MEETING.

MAY 6th, 1889.

In the Society Rooms, County Court House.

The Vice-President, Hermann Beeger, in the Chair.

Mr. H. M. Griffin, of Georgetown, Colo., and Mr. Fred. C. Knight, of Trinidad, Colo., were elected members of the Society.

COMMUNICATIONS.—The following named paper was read:

By Chas. S. Palmer, "Stereo-Chemistry."

INFORMAL COMMUNICATIONS.—By Geo. L. Cannon, Jr., "Horncore, of some Animal allied to the Ceratopsidæ."

SIXTY-THIRD REGULAR MEETING.

JUNE 3RD, 1889.

In the Society Rooms, Denver High School Building.

The Vice-President, Hermann Beeger, in the Chair.

Mr. John Gardiner, of Boulder; Mr. A. A. Blow, of Leadville, and Messrs. E. P. Martin, T. F. van Wagenen, T. B. Stearns and R. M. Hosea, all of Denver, were elected members of the Society.

INFORMAL COMMUNICATIONS.—By P. H. van Diest, "On Maps made in 1669 of the Salida Mine, Sumatra."

SIXTY-FOURTH REGULAR MEETING.

JULY 1ST, 1889.

In the Society Rooms, Denver High School Building.

The President, Richard Pearce, in the Chair.

INFORMAL COMMUNICATIONS.—By Geo. L. Cannon, Jr., "Loëss Formation in Eastern Colorado."

SIXTY-FIFTH REGULAR MEETING.

OCTOBER 7TH, 1889.

In the Society Rooms, Denver High School Building.

The President, Richard Pearce, in the Chair.

Mr. George C. Hewitt, of Aspen, and Mr. Harold Vyvian Pearce, of Denver, were elected members of the Society.

COMMUNICATIONS.—The following named papers were read:

By R. C. Hills, "Additional Notes on the Huerfano Beds," and "Additional Notes on the Eruptions of the Spanish Peaks Region."

INFORMAL COMMUNICATIONS.—By Geo. L. Cannon, Jr., "Results of a Month's Search in the Denver and Arapahoe Formations for Additional Vertebrate Remains."

By Richard Pearce, "Notes on the Occurrence of Sesquisulphate of Iron," and "Notes on Metallic Tellurium."

SIXTY-SIXTH REGULAR MEETING.

NOVEMBER 3RD, 1889.

In the Society Rooms, Denver High School Building.

The President, Richard Pearce, in the Chair.

COMMUNICATIONS.—The following named paper was read:

By Chas. S. Palmer, "A Preliminary Paper on the Eruptive Rocks of Boulder County and Adjacent Counties, Colorado."

INFORMAL COMMUNICATIONS.—By P. H. van Diest, "On Slickensides."

ABSTRACT OF MINUTES

—OF THE—

COLORADO SCIENTIFIC SOCIETY,

FOR THE YEAR 1890.

OFFICIAL PART.

SIXTY-EIGHTH REGULAR MEETING.

FEBRUARY 3RD, 1890.

In the Society Rooms, High School Building.

The President, Richard Pearce, in the Chair.

Mr. Arthur S. Dwight, of Pueblo, was elected a member of the Society.

BUSINESS OF THE ANNUAL MEETING.

The following officers were elected for the year 1890 :

President, ...	R. C. HILLS.
Vice-President, ...	GEO. L. CANNON, JR.
Secretary, ...	P. H. VAN DIEST.
Treasurer, ...	O. J. FROST.

EXECUTIVE COMMITTEE.

RICHARD PEARCE, HERMANN BEEGER,
GEO. MUNSON, F. GUITERMAN,
J. T. KEBLER.

Report of the Secretary of the Colorado Scientific Society for the year 1889.

MEMBERSHIP.

The Society has lost six members during the year, one by resignation and five by suspension for non-payment of dues. As an offset to this loss fourteen new members and two associates were elected,—a net gain of ten which increases the total number of members and associates to seventy.

MEETINGS.

There were nine regular meetings held during the year, the average attendance being ten and the largest at any one meeting fourteen. Notwithstanding an increase in the number of resident members, the average attendance was less than in the preceding year.

COMMUNICATIONS.

Exclusive of the address of the retiring President there were ten papers on original subjects presented to the Society, the number of contributors being seven. This is a considerable decrease as compared with previous years, and more so when the large increase in membership is considered.

It is very desirable that all new or important facts coming under the observation of members should be communicated to the Society even though made in an informal way, since information thus brought forward may pave the way to more extended investigations.

MUSEUM.

The chief additions to the collections consist of eight cases of palæontological specimens deposited by R. C. Hills. With this exception the accessions were few as compared with previous years.

LIBRARY.

The additions embrace exchanges from eighty different scientific societies and institutions, and donations of United States publications by the Department of the Interior.

NEW QUARTERS.

Owing to the demands of the rapid growth of the city and county, the rooms formerly occupied by the Society in the Court House had to be surrendered to the county officers. Under the circumstances it was deemed best to accept the considerate offer already made by the Board of Education to furnish space for museum and meeting purposes in the Denver High School Building. Accordingly, in June, the effects of the Society were removed to the quarters now occupied. The change has been in some respects beneficial, since the museum is more accessible than hitherto to the members and to the public.

On the whole the past year has not developed among the members that active interest in the affairs of the Society which the records of previous years and an increased membership might lead one to expect. It is to be hoped, however, that the year before us will witness a return of the vitality and enthusiasm so necessary to the full realization of the aims of the Society.

Report of the Treasurer of the Colorado Scientific Society for the year 1889.

Dr. 1889.		Cr. 1889.	
Jan. 7. Balance on hand,	$156 15	Miscellaneous printing, . .	$ 66 05
Membership dues collected,		Printing Proceedings, . . .	300 43
for '88, $ 30.00		Minerals, ...	47 00
" '89, 550.00		Stamps, postals, etc., ...	41 20
" '90, 10.00	590 00	Janitors, ...	45 00
		Periodicals, ...	3 50
Meteorite fund, ...	25 00	Express and drayage, . . .	39 82
Museum fund, ...	10 00	Show cases, furniture, etc.,	308 41
Proceedings sold, ...	14 10	Balance in hands Secretary,	3 70
Sale Court House furniture,	13 85	Balance in bank, ...	3 99
Due R. C. Hills, curator, .	50 00		
	$859 10		$859 10

O. J. Frost, Treasurer.

ABSTRACT OF MINUTES

—OF THE—

COLORADO SCIENTIFIC SOCIETY,

FOR THE YEAR 1890.

OFFICIAL PART.

SIXTY-SEVENTH REGULAR MEETING.

JANUARY 6TH, 1890.

In the Society Rooms, High School Building.

The President, Richard Pearce in the Chair.

Nominations were made of officers for the ensuing year, to be elected at the next regular meeting of the Society.

COMMUNICATIONS.—By E. Le Neve Foster, "Production of Carbonate of Soda from the Alkali Waters of Owen's Lake."

By Geo. L. Cannon, Jr., "Identification of a Dinosaur from the Denver Group."

SIXTY-EIGHTH REGULAR MEETING.

FEBRUARY 3RD, 1890.

In the Society Rooms, High School Building.

The President, Richard Pearce, in the Chair.

Mr. Arthur S. Dwight of Pueblo, Colo., was elected a member of the Society.

In the absence of the newly elected President, the Vice-President, Geo. L. Cannon, Jr., took the Chair.

COMMUNICATIONS.—By Richard Pearce, "On a Remarkable Crystalline Compound of Arsenious and Sulphuric Acids."

SIXTY-NINTH REGULAR MEETING.

MARCH 3RD, 1890.

In the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—By R. C. Hills, "The Coal Fields of Colorado" (First Paper).

INFORMAL COMMUNICATIONS.—The President introduced "Mining Geology" as a subject for discussion at future meetings.

SEVENTIETH REGULAR MEETING.

APRIL 7TH, 1890.

In the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

Mr. F. K. Mixer of Denver, was elected a member of the Society.

INFORMAL COMMUNICATIONS.—By R. C. Hills, "Crate-Shaped Vanadinite Crystals from Silver District, Arizona."

By Richard Pearce, "Tellurium in the Sulphide Ores of Leadville."

The advisability of undertaking two or more Excursions to Mining towns in the vicinity during the Summer was considered, and the chair appointed Messrs. Pearce, Munson, Guiterman and Wynkoop a Committee to ascertain to what extent Members would coöperate in carrying out a practicable plan to that end.

SEVENTY-FIRST REGULAR MEETING.

MAY 5TH, 1890.

In the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—By R. C. Hills, "The Raton Coal Field of Colorado" (Second Paper).

INFORMAL COMMUNICATIONS.—By R. C. Hills, "Pseudomorphs of Malachite after Azurite."

SEVENTY-SECOND REGULAR MEETING.

JUNE 2ND, 1890.

In the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—By F. F. Chisholm, "Iron-ore Beds in the Province of Santiago, Cuba."

By F. Guiterman, "The Gold Deposits in the Quartzite Formation of Battle Mountain, Colorado."

INFORMAL COMMUNICATIONS.—By J. B. Farish, "Suite of Rocks from Weatherow, Nova Scotia."

SEVENTY-THIRD REGULAR MEETING.

JULY 7TH, 1890.

In the Office of The Dunderberg Mining Company at Georgetown, Colo.

The President, R. C. Hills, in the Chair.

Mr. Henry R. Wagner of Denver, Colo., was elected an associate member of the Society.

COMMUNICATIONS.—By Whitman Cross, "Geology of the Roseta Hills, Custer Co., Colorado."

By R. C. Hills, "On the Fulgerite of the Spanish Peaks."

A vote of thanks was tendered the Georgetown members of the Society and other citizens of the place, for courtesies extended.

SEVENTY-FOURTH REGULAR MEETING.

AUGUST 4TH, 1890.

In the County Court House at Boulder, Colo.

The President, R. C. Hills, in the Chair.

Messrs. Ernest Craig and Samuel James of Denver, Colo., and B. B. Lawrence of Idaho Springs, Colo., were elected members and Mr. J. N. Hughes an associate member of the Society.

COMMUNICATIONS.—By Prof. Charles S. Palmer, "On the Nature of the Chemical Elements."

By Geo. L. Cannon, Jr., "The Geology of Perry Park, Colo."

By Jno. B. Farish, "A Boulder County Mine."

By Dr. W. P. Headden, "The Columbites and Tantalites of the Black Hills, South Dakota."

A vote of thanks was tendered the Boulder members of the Society and other citizens for courtesies extended.

SEVENTY-FIFTH REGULAR MEETING.

SEPTEMBER 1ST, 1890.

In the Society Rooms, High School Building.

The President and Vice-President being absent, Mr. Hermann Beeger was invited to the Chair.

Mr. Thos. Charlton of West Cliff, Colo., was elected a member of the Society.

There being no communications, P. H. van Diest introduced "Mining Geology" for discussion.

SEVENTY-SIXTH REGULAR MEETING.

OCTOBER 6TH, 1890.

In the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—By R. C. Hills, "The Grand River Coal Field" (Third Paper).

SEVENTY-SEVENTH REGULAR MEETING.

NOVEMBER 3RD, 1890.

In the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

Mr. L. S. Storrs was elected a member of the Society.

COMMUNICATIONS.—By Dr. W. P. Headden, "Notes on the Discovery and Occurrence of Tin Ores in the Black Hills, South Dakota."

By R. C. Hills, "The Yampa Coal Field" (Fourth Paper).

SEVENTY-EIGHTH REGULAR MEETING.

DECEMBER 1ST, 1890.

In the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

COMMUNICATIONS.—By Prof. Charles S. Palmer, "On the Quartz Porphyry of Flagstaff Hill, Boulder County."

ANNUAL MEETING.

DECEMBER 15TH, 1890.

Held in the Society Rooms, High School Building.

The President, R. C. Hills, in the Chair.

The following officers were elected for the year 1891:

President, ... DR. W. P. HEADDEN.
Vice-President, . . . GEO. L. CANNON, JR.
Secretary, ... F. GUITERMAN.
Treasurer, ... O. J. FROST.

EXECUTIVE COMMITTEE.

RICHARD PEARCE. T. E. SCHWARZ.
J. F. MAIN. R. M. HOSEA.
W. P. HEADDEN. F. GUITERMAN.
P. H. VAN DIEST.

Mr. R. C. Hills, as retiring President, delivered his address, "Orographic and Structural Features of Rocky Mountain Geology."

Report of the Secretary of the Colorado Scientific Society for the year 1890.

MEMBERSHIP.

During the past year the Society has lost eight members, three by resignation and five by suspension for non-payment of dues. As an offset seven new members and one associate were elected, so that the total membership remains the same as at the beginning of the year.

MEETINGS.

There were twelve regular meetings, exclusive of the annual meeting. The average attendance was eleven—a slight increase over the average of previous years. The average number of visitors present was greater than ever before, principally owing to the interest manifested at the provincial meetings.

The latter were productive of highly satisfactory results. The July meeting at Georgetown was well attended and thanks to the efforts of the local members and associates the excursion was to the visiting members a most enjoyable affair. The successful outcome to the Georgetown meeting was the means of developing additional interest at the August meeting, held at Boulder, which was marked by the presence of more than the average number of members and visitors, and the presentation of no less than four original and important communications. Here also, the local members exerted themselves to make the excursion to the neighboring mines as enjoyable as it was eminently successful and satisfactory.

COMMUNICATIONS.

Exclusive of the address of the retiring President, there were sixteen communications on original subjects presented to the Society—the number of contributors being ten. A series of papers on the Coal fields of the State were presented in addition, and will be published as an independent part of Vol. IV. The increase in number of papers and in number of contributors is very gratifying, being in excess of any previous year.

LIBRARY.

The additions were mainly scientific publications from various domestic and foreign societies and institutions, about eighty in number, the Smithsonian reports, and scientific papers and monographs donated by the Department of the Interior.

P. H. VAN DIEST, *Secretary.*

Report of the Treasurer of the Colorado Scientific Society for the year 1890.

Dr.			Cr.	
Jan. 7. Balance in bank, .		$ 3 99	Miscellaneous printing, . .	$105 90
Bal. in hands Sec.,		3 70	Printing Proceedings, . . .	103 58
Membership dues collected,			R. C. Hills, curator, balance,	50
for '89,	$ 50.00		Janitor, ...	30
" '90,	560.00	610	Periodicals and Books, . .	11 78
			Express and drayage, . . .	15 87
Proceedings sold, ...		6 10	Stamps, postals, etc., ...	39 95
			Balance in bank, ...	266 71
		$623 79		$623 79

O. J. FROST, *Treasurer.*

Report of the Curator.

During the past year several important additions have been made to the collections of the Society. Among these the magnificent suite of tin-bearing rocks presented by Prof. W. P. Headden, and a suite of Cornish tin specimens presented by Mr. Richard Pearce are worthy of special mention.

From the Georgetown members and associates we are also indebted for a series of representative ores from that district which, supplemented by rock specimens gathered by other members in the same district, enables us to make a display of its characteristic products.

Other small collections made in Boulder County at the time of our visit last summer have made possible a limited display of the characteristic ores from that part of the State. It is the intention that the representative suites of ores and enclosing rocks now on exhibition shall constitute the nucleus of collections which will rapidly expand to proportions commensurate with the interests they represent. It is much to be desired that members who have the opportunity will assist in making these collections as complete as possible for the purpose intended, viz: to exhibit clearly the mineralogical character of the ores and nature of the enclosing rocks. The specimens should be sufficiently rich to illustrate the prevailing composition, and if two or more minerals are present they should be distinguishable in the mass. Rock specimens should be sufficiently large to admit of being chipped or hammered down to a size 3 x 4.

The districts of Central City, Leadville, Silver Cliff, Aspen, Breckenridge and Red Cliff are not yet represented in the collections; nor are the San Juan districts outside of Marshall Basin and Red Mountain.

During the month of December the collections were transferred to the gallery on the upper floor of the building and eight new cases were added.

No attempt has yet been made to classify the fossils except in a rough way, and until we are assured of permanent quarters and the services of a salaried assistant, I do not think the Society is warranted in making a larger display of specimens. At the same time this need be no obstacle to the continued collection of specimens, since we have reason to believe that the time will come when space will be available for their proper exhibition, and the more good material we possess, the easier will it become to induce the State authorities to afford the necessary permanent space.

R. C. HILLS, *Curator.*

COMMUNICATIONS

AND

ADDRESSES.

MEETING OF JANUARY 2nd, 1888.

NOTES ON CERTAIN RARE COPPER MINERALS FROM UTAH.

BY W. F. HILLEBRAND AND H. S. WASHINGTON.

Some time since analyses and partial descriptions of several rare copper minerals, from the American Eagle Mine, Tintic District, Utah, were published* by one of us. These minerals had been found by Mr. Richard Pearce in ore shipments from that mine to the Boston & Colorado Smelting Works, near Denver, Colorado. Later, in shipments from the neighboring Mammoth Mine, in the same district, Mr. Pearce discovered a second series of minerals of similar character, most of the species, however, being distinct from those of the former occurrence. In recent papers† he has given the results of his examinations and enumerated the following species: enargite, olivenite, conichalcite, clinoclasite, brochantite, pharmacosiderite, tyrolite (?), erinite, chalcophyllite, malachite, azurite, and one or two others of doubtful identity, of most of which "enargite is the mother mineral."

In order that this interesting series, in part new to America, might receive fuller study than he was able to devote to it, Mr. Pearce, with the assistance of Mr. Whitman Cross, kindly selected a set of specimens for examination in the laboratory of the U. S. Geological Survey at Washington. The chemical work of this paper was there

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* Proc. Colorado Sci. Soc., i, 112, and Bull. U. S. Geol. Survey, No. 20, p. 83.

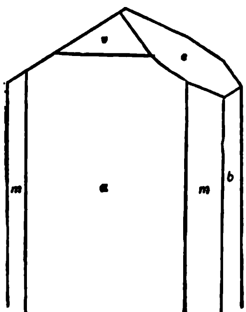
† Proc. Colorado Sci. Soc., ii, 134, 150.

carried out by one* of us, while the crystallographical and optical study was undertaken by the other † at New Haven under the guidance of Prof. E. S. Dana. The results of our work, both chemical and physical, failed to meet all the hopes induced by a first view of the material at disposal, although this was the best that could be found. They are of sufficient interest, however, to make public, especially in view of the meager state of our knowledge regarding a majority of the species herein mentioned.

1. Olivenite.

This mineral occurs well crystallized; its habit is prismatic and tabular parallel to *a* (100, *i-ī*) and the crystals are, as usual, very simple, as shown in the figure. The planes *b* (010, *i-ĭ*) and *v* (101, *i-ī*) as a rule are either absent or very small. Measurements were made for the purpose of obtaining a more exact axial ratio than we have at present, the old values of Phillips dating back to 1823.

Upon examination and measurement with a Fuess horizontal goniometer it was found that $e \wedge e'$ (011 ∧ 01̄1) was the only angle sufficiently accurate for the purpose, *a* and *m* being a little rough and uneven. The angle mentioned furnished a good value for *c*, but to obtain the value for *ă*, use had to be made of a specimen of olivenite from the American Eagle Mine (No. 5684 in the Yale University collection). This olivenite was acicular in habit, the prism *m* (110,*i*) predominating. From these crystals good measurements were



(Fig. 1.)

* W. F. Hillebrand. † H. S. Washington.

obtained of $m \wedge m'''$ ($110 \wedge 1\bar{1}0$) and a satisfactory axial ratio deduced. The measured angles are as follows:

$$e \wedge e', 011 \wedge 0\bar{1}1 = 67^\circ\ 51'$$
$$m \wedge m''', 110 \wedge 1\bar{1}0 = 86^\circ\ 26'$$

From these angles we obtain the following axial ratio:

$$\breve{a} : \bar{b} : \acute{c} = 0.93961 : 1 : 0.672606$$

The measurements above differ considerably from the fundamental angles of Phillips, which are,

$$e \wedge e', 011 \wedge 0\bar{1}1 = 69^\circ\ 10' \text{ and } m \wedge m''', 110 \wedge 1\bar{1}0 = 87^\circ\ 30'$$

giving the axial ratio,

$$\breve{a} : b : \acute{c} = 0.9573 : 1 : 0.6894$$

Measurements were made with the view of determining whether the species is really orthorhombic or not. The following are the angles obtained:

$$a \wedge e, 100 \wedge 011 = 89^\circ\ 4', a' \wedge e, \bar{1}00 \wedge 011 = 89^\circ\ 59'$$
$$a \wedge e', 100 \wedge 0\bar{1}1 = 39^\circ\ 9', a' \wedge e', \bar{1}00 \wedge 0\bar{1}1 = 90^\circ\ 1'$$

It is seen that the front angles are in each case a trifle less than the rear angles, but not much reliance can be placed on these results, owing to the poor surface of both a (100) and a' ($\bar{1}00$).

Under the microscope the tabular crystals showed parallel extinction and a slight pleochroism, the vibrations || $\acute{c}$ being pale olive green, while those || $\bar{b}$ were of a brownish yellow, with the absorption $b > c$.

The mineral was not analyzed because of the small quantity available, and because its identity was otherwise clearly established.

2. *Erinite.*

Erinite occurs as a dark green crystalline lining of cavities, associated with and generally upon enargite, azurite, barite, or clinoclasite. Crystals of olivenite are frequently scattered over its surface, which shows often a somewhat satiny sheen, due to minute crystal facets.

Hardness 4.5. Sp. gr. undetermined. Because of its intimate association with azurite and olivenite, it was very difficult to obtain pure material for analysis. Sample I contained 3.90 per cent. of insoluble matter, not included in the analysis. Sample II was composed of a small lot of vitreous crusts, the only ones of the kind observed, which had been collected before shipment of the specimens, and were thought to be erinite by Mr. Pearce, whose partial analyses of material similar to sample I are added, for comparison, under III.

	I.	II.	III.	
	Hillebrand.		Pearce.	
			a	b
CuO	57.67*	57.51	56.56	57.43
ZnO	1.06	0.59	....	....
CaO	0.32	0.51	0.43	....
MgO	tr.	tr.	....	....
As_2O_5	33.53	31.91	32.07	32.54
P_2O_5	0.10	....	....	....
H_2O	7.22	9.15	6.86	7.67
Fe_2O_3	0.14	0.20	0.85	....
SO_3	....	....	tr.	....
	100.04	99.87	96.77	97.64

Analyses I and II, and presumably those of Pearce, show the composition of air-dried powder. Sample I lost 0.67 per cent. H_2O over sulphuric acid, and a total of 0.78 per cent. at 100° C. At 280° C. the total loss was 1.14 per cent., leaving 6.08 per cent. firmly combined. Sample II lost 2.06 per cent. over sulphuric acid, and a total of 3.22 per cent. at 280° C., leaving 5.93 per cent. firmly combined. The molecular ratios, including all the water, are:

	CuO (CaO, ZnO)		As_2O_5 (P_2O_5)		H_2O
I.	5.08	:	1.00	:	2.74
II.	5.34	:	1.00	:	3.66
III. (mean)	5.13	:	1.00	:	2.87

* Mean of 57.61 and 57.74.

If the weakly combined water be excluded from both I and II the ratio is brought considerably nearer to that derived from Turner's approximative analysis,* i. e. 5 : 1 : 2.

It is uncertain whether Turner's sample was air-dried or heated to 100° C.

3. *Tyrolite.* (?)

Regarding the identity of this species some doubt exists, as the analytical results obtained do not agree with those given by von Kobell† and Church‡. In general appearance it seems to resemble tyrolite. It occurs in thin scales on quartz, but more often in radiating scaly masses, somewhat like the pyrophyllite from Graves Mt., Georgia. It has a bright, apple green color, sometimes with a tinge of blue; a somewhat pearly luster; a hardness of 2.5 (1.5–2 for tyrolite in the text books), and perfect cleavage. Under the microscope it showed little or no pleochroism and extinction parallel and perpendicular to the radial line. In convergent light the cleavage flake showed the ordinary biaxial figure with the dispersion $\rho > v$. Its double refraction is negative, the acute bisectrix being perpendicular to the cleavage face, and coinciding with the crystallographic $\dot{c}$. The obtuse bisectrix lies parallel to the radial direction of the crystal, but whether it corresponds with $\breve{a}$ or $\bar{b}$ cannot be determined. It was unfortunate that a crystallographic investigation was impossible, as our knowledge of tyrolite in this respect is of the most meager description.

On heating it flies into fine fragments, which, by gentle tapping of the tube, collect into spongy masses. The mineral melts in the flame of a Bunsen burner.

The sp. grav. of sample I (containing 2.25 per cent. of insoluble gangue) was 3.27 at 20½°C. From sample II,

* Edin. Journ. Sci., ix, 95, 1828. Phil. Mag., iv, 154, 1828.

† Pogg. Ann., xviii., 253. ‡ Journ. Chem. Soc. [2], xi, 108.

which was the purest and best crystallized to be found, 1.25 per cent. of gangue has been deducted.

	I.			II.	III.
	a	*b*	Hillebrand. Mean.		Pearce.
CuO	45.20	45.23	45.22	46.38	42.60
ZnO	....	0.04	0.04	tr.	0.97(Fe_2O_3,Al_2O_3)
CaO	6.86	6.82	6.84	6.69	9.10
MgO	0.05	....	0.05	0.04	....
As_2O_5	28.84	28.73	28.78	26.22	27.87
P_2O_5	tr.	....	tr.	tr.	....
H_2O	17.26	....	17.26	17.57	16.23
SO_3	?	?	?	2.27	2.45
	98.21		98.19	99.17	99.22

SO_3 was unfortunately not tested for in I. It may, however, reasonably be assumed to be present in about the same amount as in II, and if it be considered to be present as gypsum ($CaSO_4$, $2H_2O$), the following molecular ratios are obtained:

	CuO (CaO)		As_2O_5		H_2O				
I.	5.00	:	0.94	:	6.80 or 11	:	2.07	:	14.96
II.	5.00	:	0.84	:	6.81 or 11	:	1.85	:	14.98
III.	5.00	:	0.90	:	6.29 or 11	:	1.98	:	13.84

It appears herefrom that the As_2O_5 is somewhat less, and the H_2O much less than required to satisfy the formula $5CuO$, As_2O_5, $9H_2O$, derived from von Kobell's (l. c.) analysis on the supposition that the $CaCO_3$ found by him and later by Frenzel* and Church (l. c.) is not an essential constituent of tyrolite.

It is improbable that more than a very small quantity, if any, chalcophyllite was mixed with the material analyzed under I and II, although both appeared on some of the specimens marked tyrolite received from Mr. Pearce, and are not always easy to distinguish. In any mixture of tyro-

* Naumann-Zirkel, Elemente der Mineralogie, p. 540.

lite and chalcophyllite the water found must exceed its percentage in the former mineral. This is here not the case, whence it is to be inferred either that the present mineral is not tyrolite or that the older analyses do not represent its true composition.

A large portion of the water is very loosely combined. Of that in analysis I, 4.69 per cent. escaped at 100° C., the most of it over sulphuric acid; and in analysis II, 4.15 per cent. was removed by sulphuric acid, and further 0.91 per cent. escaped at 100° C., making a total of 5.06 per cent. These amounts, subtracted from the total percentage found, leave 12.57 and 12.51 per cent. respectively, or about five molecules (assuming five molecules (CuO(CaO))). At 280° C. the loss on sample II. was 10.34 per cent., in which is presumably included the water of the gypsum supposed to be present, leaving three molecules firmly combined. Church (l. c.) likewise noticed a great loss of water in vacuo and at 100° C., but assumed that it was hygroscopic water included between the plates of the mineral. The second of his analyses, with data for calculating the percentage composition, is as follows:

Substance	0.4585	CuO	50.06
H_2O in vacuo.	0.024	As_2O_5	29.29
H_2O at 100°	0.011	H_2O	[8.73]
$CaCO_3$	0.0505	$CaCO_3$	11.92
CuO	0.212		
$Mg_2P_2O_7$	0.205		100.00

whence he deduces the formula $5CuO, As_2O_5, 4H_2O$. Assuming that $Mg_2P_2O_7$ is an error for $Mg_2As_2O_7$, or for As_2S_3, in which latter form it appears that arsenic was usually estimated by him in minerals of a similar character, it is impossible to deduce the above given percentage for As_2O_5. But considering the latter correct, and including the water lost in vacuo and at 100°, the composition is:

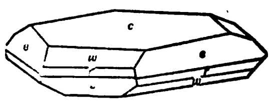
CuO	46.24
As_2O_5	27.05
H_2O	15.70
$CaCo_3$	11.01
	100.00

which furnishes the molecular ratio CuO : As_2O_5 : H_2O as 5.00 : 1.01 : 7.43, not greatly differing from those derived from analyses I and II above.

4. *Chalcophyllite.*

This mineral occurs in the form of small hexagonal plates arranged in rosettes, differing from the radial arrangement of the supposed tyrolite. It showed the same bright apple green color, pearly luster, and perfect basal cleavage. An optical examination proved it to be uniaxial with negative double refraction.

These crystals showed several planes replacing the edges, and measurements were made of them as far as possible. The angles did not agree very closely, owing to the imperfection of all the surfaces, but they were sufficiently exact to prove the presence of r ($10\bar{1}1, R$), e ($01\bar{1}2, -\frac{1}{2}R$), and two other rhombohedrons, new to the species, having the symbols w ($10\bar{1}6, -\frac{1}{6}R$), and d ($01\bar{1}3, -\frac{1}{3}R$). The figure shows the habit of the crystals, but, with d absent, this plane being only observed in one instance. The very rough angles obtained are given below:



(Fig. 2.)

	Observed.	Calculated.
$c \wedge r$,	$0001 \wedge 10\bar{1}1$ = 71° 27′	71° 16′
$c \wedge w$,	$0001 \wedge 10\bar{1}6$ = 26° 10′	26° 10′ 20″
$c \wedge e$,	$0001 \wedge 01\bar{1}2$ = 56° 51′	55° 51′ 10″
$c \wedge d$,	$0001 \wedge 01\bar{1}3$ = 41° 50′	44° 30′ 30″

The above observed angles are the means of several measurements which vary among themselves from one to three degrees. The fair agreement in the first two results, therefore, is merely accidental, and no value can be attached to these measurements, which are inserted because the measurements of this species are extremely few.

The mineral was not analyzed for want of sufficient material. On heating, it decrepitated as violently as the last mentioned mineral, and in the flame of the burner fused, though not with the same readiness.

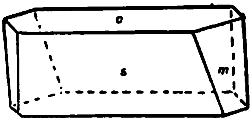
5. *Clinoclasite.*

The clinoclasite occurs in two distinct habits, one distinctly crystallized and the other in barred shaped or globular forms. It is of a dark bluish green color, almost black by reflected light, bright green by transmitted light. Streak and powder, bluish green. Specific gravity at 19° C., 4.38. (4.36 Pearce.) Hardness, 2.5–3.

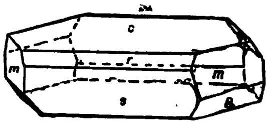
At first sight these crystals seemed to be very promising and likely to afford good fundamental measurements for the species. But on further examination they did not come up to our expectations, *c* (001, *O*) and *s* ($\bar{3}02$, $\frac{3}{2}$-*i*) being the only two planes giving even fairly good measurements. *m* (110, *I*), *r* (101, –1-*i*), *t* ($\bar{1}11$, 1) and *p* ($\bar{1}13$, ⅓), the other planes observed, were all dull or rounded, and only capable of giving angles accurate enough to identify the forms. Of the planes above, *t* and *p* are new to the species. Most of the crystals were apparently made up of two or more individuals in nearly parallel position, but inclined slightly in the zone *c*|*b*. A measurement in one case gave the angle 4° 10′, but as it is not the result of twinning, this angle, of course, is not constant, and only shows the very slight inclination of the individual crystals.

A consequence of this method of growth will be described later.

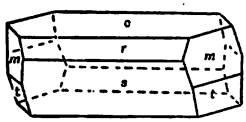
The crystals were all simple; Fig. 3, or a combination of that with *r*, being the most usual. Occasionally the



(Fig. 3.)



(Fig. 4.)



(Fig. 5.)

lower half of *m* is replaced by *t*, as shown in Fig. 5, giving the angle 13° 20′ (calculated 13° 17′) for $m \wedge t$. The new plane *p* ($\bar{1}13$) was observed in several crystals and is shown in Fig. 4. The following angles were obtained for it:

	Observed.	Calculated.
$c \wedge p$,	$001 \wedge \bar{1}13$—61° 6′	61° 26′ 30″
$s \wedge p$,	$\bar{3}02 \wedge \bar{1}13$—50° 14′	51° 19′ 10″
$p \wedge p'$,	$\bar{1}13 \wedge \bar{1}\bar{1}3$—82°	85° 48′

The angles are merely approximate, but sufficient to establish the form. The crystals are for the most part elongated in the direction of the *b* axis, with a length of from 2 to 3mm, and show easy cleavage parallel to *c*.

The other type of clinoclasite is interesting, as showing the consequence of the nearly parallel growth of the crystals mentioned above. In some of the specimens the crystals are grouped about the *b* axis, with *c* exposed. They are inclined a trifle in the zone *c*|*b* and also in the zone *a*|*b*, thus rounding off the group in two directions, but decidedly more in the latter zone, forming, with the elongation in the direction of *b*, distinctly barrel-shaped forms. Occasionally the curvature in the zone *c*|*b* is carried still further, producing globular forms. In all cases *c* forms the outer surface and the crystals are closely crowded together, producing a bright and coarsely rough surface.

The material analyzed consisted of the globular masses mentioned above, and was probably not as pure as the crystals and barrel-shaped forms. A trifling amount of insoluble matter (0.05 per cent.) has been deducted. For comparison Mr. Pearce's partial analyses are also quoted:

	I. Hillebrand. *a.*	I. Hillebrand. *b.*	Mean.	II. Pearce. *a.*	II. Pearce. *b.*	Theoretical Composition.
CuO	62.34	62.54	62.44	61.68	61.22	62.65
ZnO	0.06	0.04	0.05	....	....	....
As_2O_5	29.59	29.60	29.59	29.36	28.85	30.25
P_2O_5	0.05	0.05*	0.05	....	....	....
H_2O	7.73	7.72	7.72	7.31	7.27	7.10
Fe_2O_3	0.12	0.12	0.12	....	....	....
SiO_2	0.06	0.06*	0.06	....	....	....
	99.95	100.13	100.03	98.35	97.34	100.00

These results reveal nothing worthy of remark, except that the water, as in most earlier analyses, is found uniformly higher than that required by the formula 6CuO, As_2O_5, $3H_2O$, or $Cu_3[AsO_4]_2+3Cu[OH]_2$.

6. *Mixite.* (?)

On some specimens of ore, but apparently not in close association with the other minerals mentioned, was a mineral occurring in delicate tufts of silky needles of a whitish to pale greenish color, as described by Mr. Pearce (l. c., p. 151, under the title of "New Mineral"). It was impossible to procure enough of the needles free from an underlying non-crystallized greenish coating of cavities for a satisfactory analysis. A good deal of the latter was necessarily included in the sample tested, but qualitative tests showed that both needles and coatings contained the same constituents. It is hardly to be doubted that both have the same centesimal composition.

* Assumed the same as in *a*.

	I. Hillebrand. *a.*	*b.*	Mean.	II. Pearce.
CuO	43.89	43.88	43.89	50.50
ZnO	2.79	2.62	2.70	....
CaO	0.26	0.26	0.26	3.19
Bi_2O_3	11.14	11.22	11.18	...
As_2O_5	27.78	28.79	28.79*	27.50
P_2O_5	0.06	....	0.06	....
H_2O	11.04	11.04	11.04	12.55
SiO_2	0.36	0.48	0.42	....
Fe_2O_3	0.97	....	0.97	....
	98.29		99.31	93.74

That an error as to the CuO occurs in Pearce's analysis is beyond question. The above results agree fairly well with Schrauf's analysis of mixite, † which contained 43.21 CuO, 13.07 Bi_2O_3, 30.45 As_2O_5, and 11.07 H_2O, besides a little CaO and FeO, but the form of this mineral as given by Schrauf differs from that of the present one, and its color is given as emerald to bluish green. Schrauf's number for the sp. grav. (2.66)‡ is unquestionably much too low. That of the material now analyzed was 3.79 at 23½° C. When treated with dilute nitric acid it becomes at once covered with the brilliant white coating of bismuth arseniate so characteristic of mixite. The latter mineral is stated to belong to the monoclinic or the triclinic system, while the observations of Mr. Whitman Cross would indicate that the present one can belong to neither of those systems. He says: § "The needles are very slender, with a length of more than 1^{mm} in some cases by a thickness of less than 0.05^{mm}. They are deeply striated vertically, and the crystal

* The higher value was undoubtedly nearer the truth than the lower.

† Zeit. f. Kryst., iv, 277.

‡ Since this paper was presented to the Society, Professor Schrauf has informed us that this number is erroneous; it should be 3.753. He further adds, "You certainly have mixite."

§ Proc. Colorado Sci. Soc., ii., 153.

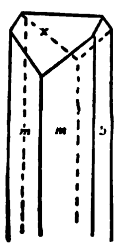
system could not be determined, although the extinction in polarized light makes reference to the tetragonal, the hexagonal, or the rhombic system necessary. The index of refraction is high. Pleochroism distinct, the colors observed being for the thicker crystals, *a* (and *b*) sea green, *c* sky blue."

7. *Pharmacosiderite.*

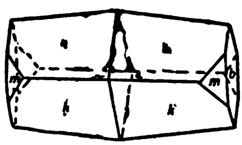
No analyses were made for want of sufficient material.

8. *Brochantite.*

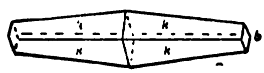
This hydrous sulphate of copper occurs in two distinct types in the specimens examined. The first, or ordinary brochantite, is of a prismatic habit, as is shown in Fig. 6, The crystals are dark green and transparent, but do not give good measurements, owing to the imperfection of the surface. The cleavage parallel to b (010, i-$\breve{i}$) is perfect. The measured angle of $m \wedge b$, $110 \wedge 010 = 51° 46'$, is only



(Fig. 6.)



(Fig. 7.)



(Fig. 8.)

approximate, and differs considerably from Miller, who gives 52° 5′, and Schrauf, who gives 52°.

The second type is like warringtonite from Cornwall, described by Maskelyne.* This variety was suspected by Mr. Pearce (loc. cit., p. 135). It is of a light green color

*Chem. News, X, 263, 1864, and Phil. Mag., [4], XXIX, 475.

and has a curved double wedge-shaped habit. The forms observed are shown in Figs. 7 and 8. The crystals were poor for measuring, all the planes, with the exception of *b*, being curved to a great degree. The crystals were none of them more than 2 or 3mm long, with the relative proportions of the figures. They were implanted by *b*; *m*, in Fig. 7, was identified with certainty, the angle for $b \wedge m$ being 52° approximately. The plane lettered *k* was very much curved in all cases, and its symbol, consequently, is not known with exactness. It corresponds in its angles very roughly, it is true, to the *k*, 12 . 1 . 4, of Schrauf; some of the angles obtained from these crystals and the corresponding ones of Schrauf's warringtonite being given here:

		Washington.	Schrauf.
$b \wedge k$, 010 $\wedge$ 12 . 1 . 4	=	80°–82°	86° 43′
$m \wedge k$, 110 $\wedge$ 12 . 1 . 4	=	45°	43° 11′
$k \wedge k'$, 12 . 1 . 4 $\wedge$ 12 . 1 . $\bar{4}$	=	75°–80°	

In most of the crystals of this type *b* was undulating parallel to *c*.

Want of material forbade an analysis of this mineral, but blow-pipe tests and the crystallographic examination establish its identity beyond doubt.

A MODIFIED METHOD OF DETERMINING ZINC.

BY WM. P. HEADDEN.

If the ore be sulphide, as is usually the case in ores containing lead, copper and zinc, one-half gram of it, finely pulverized, is treated with from 3–5 C.C. of concentrated nitric acid, a few drops of concentrated sulphuric acid added and the whole evaporated to dryness.

If examination of the residue should show that undecomposed ore still remains, it is to be moistened with nitric acid and again evaporated; if the ore has been properly pulverized, this will be found unnecessary. The residue, consisting of sulphates and usually containing nitric acid, is treated with a few C.C. of concentrated hydrochloric acid, and gently heated until the effervescence ceases and all the nitric acid has been destroyed. A failure at this point may lead to incorrect results.

The solution, without being filtered, is now precipitated, with ammonia, or ammonia and ammonic carbonate, after the addition of ammonic chloride in relatively large quantities. I prefer to add it in the solid state.

The partially washed precipitate is dissolved in hydrochloric acid and reprecipitated by ammonic hydrate. The united filtrates, including wash water, should not exceed fifty C.C. and will contain the whole of the zinc and copper. This solution is slightly acidulated with hydrochloric acid, strips of aluminium added and boiled for a few minutes, when the whole of the copper will be precipitated. Granulated lead may be used instead of the aluminium; it is, however, doubtful whether it has even the advantage of greater cheapness. If a large amount of copper is present it necessitates the addition of a great deal of lead and the exercise of considerable care to insure its complete precipitation.

The solution, which may be either decanted or filtered from the precipitated copper and excessive aluminium, is to be diluted—after the addition of 8–10 C.C. concentrated hydrochloric acid—to a quarter of a litre, and titrated with a standardized solution of potassic ferrocyanide.

The results agree very well.

The method may be so modified that sodic acetate may be used to precipitate the ferric oxide, but I have not found it preferable to the method as given, either in time consumed in its execution or in agreement of the results.

MEETING OF FEBRUARY 6th, 1888.

COLORADO VOLCANIC CRATERS.

BY P. H. VAN DIEST.

It was my original intention to give you to-night a verbal communication descriptive of craters in Colorado found in the field-notes on file in the Surveyor General's office. But since I saw in the notice for this meeting that our esteemed Secretary had booked me for a paper, I came to the conclusion that I could as well write my communication, with some introduction about volcanoes in general.

Several lines of weakness of the earth's crust are observed. Volcanoes occur along such lines, either as isolated cones, or in groups, as for instance at Iceland, or in long ranges as in the Andes, at Java, the Antilles. Three hundred volcanoes marked by craters are known to exist on this earth. One hundred and sixty-five of these are active volcanoes, and of this number ninety-six are situated on islands, and the others, except two in Middle Asia, are situated at less than forty miles distant from the sea.

The most plausible and generally accepted theory about volcanoes is, that they are wide and extremely deep chimneys or shafts. At the bottom exists a smelting heat, water gets access from the sides, the shaft is filled with volcanic sand. The whole mechanism reposes on an alternate play of fluids. Although a molten mass, water and steam cannot be in harmony, and must create ultimate action of the one element on the other, hundreds, even thousands of years may go by before enough steam is raised under great pressure, to create a paroxysm, which makes itself known on the surface by more or less violent eruptions. The height of the smelting zone in the shaft depends not only on the temperature, but also on the kind and amount of material on hand in the shaft. The action of the steam zone depends on the height of the smelting zone, and also on the depth of lateral infiltration of water, and on the quantity and distribution of the influx of such water. For the so-called period of rest or quietness of a volcano, these functions are equalized or balanced. From the smelting zone downwards a mechanical combination of the masses takes place by smelting. Upwards no smelting occurs, but a molecular combination, and with it crystallization. All solids which are in the shaft and all fluids which come in from the sides play a part in this synthetically working laboratory. When this occurs, only locally, concretions are formed by accumulations of crystals like the sanidin and olivine bombs of the tufa. But if the mass-cakes or sinters together the shaft becomes closed, and an obstacle is created to the outlet of evolving gases and steam, and when the smelting zone lies too high to allow a condensation of these gases and steam, they will with increasing pressure force their way out. The force of the escape creates heat and a vacuum, which elevate temporarily the smelting zone, and allows the influx of water through side cracks.

The mechanical fight between the steam and molten lava at depth will in the beginning form solidified eruptive products, until the lava in some cases gets the upper hand, displaces the water influx, and in reaching the orifice carries it along either chemically or mechanically to the surface. Lava is thus a partly or entirely remolten tufa or any other material existing in the shaft. The deeper the source the more molten the mass will be. The elevation of the steam zone in the shaft appears to be dependant on the nearness and depth of the sea, and the nearer the sea the higher appears to be located the smelting zone of active volcanoes.

The alternate action of volcanoes depends on a connection with water currents percolating from the bottom of the sea. A volcano becomes extinct when one or more of the following conditions are fulfilled: Lowering of the smelting zone, modification and diminishing of the water influx and a crystalline metamorphosis of the tufa column. The more evenly these conditions act together the more lasting is the rest, the smelting zone sinks, water-flows, raised to higher points, become weaker or cease altogether; the upper-laying tufa sinters and thereby crystallizes to a solid mass, while the still overabundant steam and gases at depth find an outlet in springs, geysers, etc.; so dies the once active volcano and the tufa column in the crater becomes a solid volcanic rock.

We find in these conditions the reason why nearly all volcanoes located inland are extinct. They were once active enough when bordering prehistoric seas along tertiary, cretaceous or jurassic shores. We find plenty of data of such action even of much more extensive volcanic flows than we observe along the present sea coasts. At many places where we observe basaltic and rhyolitic flows, erosion has since taken away the outlines of many a crater which existed inland in early times. No doubt some were active craters of a magnitude exceeding, for instance, the present Raon crater at the Island of Java, which has a diameter of 5,000 feet, and permits one from its edge to see at least 2,250 feet down its dark throat.

Only at a few places can the outlines of a well-defined inland crater be found. This is the case in the Auvergne, the Eifel and also in Colorado. Near the town of Cornwall, in Rio Grande county, at the slope of the Pentada Del Norte Peak, in section 34 of township 38 north, range 5 east, and section 3, township 37 north, range 5 east, of N. M. P. M., are observed craters of a diameter of about 800 feet and a few hundred feet in depth. They are surrounded by small lakes. The notes of the surveyor who ran the section lines alongside these craters are very meager. Surveyor Snell, who last fall ran lines in township 4 south, range 86 west, near the town of Dotsero, at the junction of the Eagle and Grand Rivers, came across a crater which he measured at the top to have a diameter of 1,320 feet and at the bottom 856 feet. The distance between the top and bottom being 800 feet. The walls are bare of vegetation, but the bottom is covered with a rank growth of grass and sage. On the southwest slope of the cone a few spruces were observed. The crater is located in section 23, township 4 south, range 86 west, and from there south, lava beds extend into sections 4 and 5 of township 5 south, of same range. These beds of lava extend from the mouth of Lava gulch in a fan shape to the very edge of Eagle river, covering the entire bottom lands in the northwest quarter of section 4 and a small part of the northeast quarter of section 5. Their average elevation above the river is fifty feet. The upper edge adjoining the foothills is rather smooth, but as the beds approach the river their surfaces become more uneven and broken, until the lava is heaped up in rough, ragged and contorted masses with deep pits, alternating with jagged hillocks, making a passage over the lava at the lower end almost impossible. The Eagle river creeps close to the south edge of the beds, which face it, with a ragged, broken front of from ten to forty feet high. There are slight traces of magnetic iron in and about the lava beds.

Dr. Peale, of Hayden's staff, describes this lava flow, although not mentioning the existence of the crater. He presumes that the flow has its sources in the hills on the north of the Eagle river; that it came down the ravines and spread out on the valley covering a space of three or four miles. It forms a bluff edge ten to twenty feet above the Eagle. The rock is, according to Dr. Peale, a black vesicular basalt, containing free quartz and olivine. From the pulverized black mass, some magnetite could be separated. He considers this rock of a comparatively recent date; First. Because the flow took place since the carving out of the valley. It occupies the bottom of the valley bordering the river like the slag poured out from a furnace. The river being the limit of the flow, none of the rock occurring on the south side of the river. Second, Because the erosion has been very slight; and Third, Because the rock is destitute of vegetation and comparatively free from any soil. The period during which it was poured out is, according to Dr. Peale, to be measured by hundreds not thousands of years, rather less. There are, no doubt, other places in Colorado where extinct craters can be found. I was informed that a crater is observed near Chambers Lake and Mount Richthofen in township 7 north, range 75 west. I looked up the notes of said township, but found no special mention made of a crater, the occurrence having no doubt escaped the notice of the surveyor. I expect that the existence of small crators, or at least remnants of them, will be found in Costilla County.

PRELIMINARY NOTES ON THE ERUPTIONS OF THE SPANISH PEAKS REGION.

BY R. C. HILLS.

The complicated systems of dykes and associated eruptive occurrences developed in the region of the Spanish Peaks are among the most remarkable of the results brought about by the disturbances of Tertiary times in the Rocky Mountains, and a short description of the most noteworthy features may be of interest to the student of structural geology, while serving as an introduction to a more detailed description in the near future.

The district to be described extends from the southern extremity of the Greenhorn Mountains, or Wet Mountain Range, to the northern line of New Mexico, with an average width of thirty miles, embracing a large part of the counties of Huerfano and Las Animas and the greater part of the Raton coal field.

The prominent topographical features of the district include the Raton Hills, culminating in Fisher's Peak, to the southward; Veta, Silver and Sheep Mountains and the isolated Black Buttes to the northwestward; and centrally the high saddle-shaped mountain known as the Spanish Peaks. The intervening country is rolling table-land, elevated from 200 feet to 1,500 feet above the level of the plains, bounded on the east by a long irregular line of sandstone bluffs facing the prairie, and on the west by the great Sangre de Cristo Range.*

*The northern half of this district is shown on the map (page ——). The dykes are too numerous to be properly represented on so small a scale; hence they were omitted.

The surface geology of the country may be described as consisting mainly of Laramie beds, largely sandstones, flanked by exposures of Colorado shales, the latter being continuously developed over the prairie region bounding the district to the eastward.* Protruding though these beds are the eruptive rocks, represented by the masses of the Spanish Peaks, Veta, Silver and Sheep Mountains, and the isolated buttes in their vicinity, together with the numerous dykes everywhere traversing the district. Well-defined intrusive sheets, conformable along planes of contact, outcrop in the sandstone bluffs which mark the eastern border of the Laramie; while other similar sheets make their appearance in the shale exposures of the Colorado and are always prominent in the latter along the base of the Sangre de Cristo. To these forms of eruptive occurrences must still be added the great overflow of Fisher's Peak, the most easterly of all the Colorado eruptions.

The dykes are of general distribution throughout the district, but more numerous than elsewhere near the Spanish Peaks, from which they radiate in every direction. Silver Mountain likewise has a system of diverging dykes, but they are fewer in number and less regular than those of the Spanish Peaks. The latter are exceptionally persistent, extending with a fairly uniform course even for a distance of eight to ten miles; in several instances they protrude through the shale-beds far out on the plains, forming what are known as *crestones* or hogbacks. The thickness ranges from a few inches up to 50 feet with great regularity in nearly all cases.

The structure of the Spanish Peaks and of Silver Mountain is similar and directly related to the great sys-

*At the time the above was written the existence of the Huerfano Tertiaries, elsewhere described, had not been recognized.

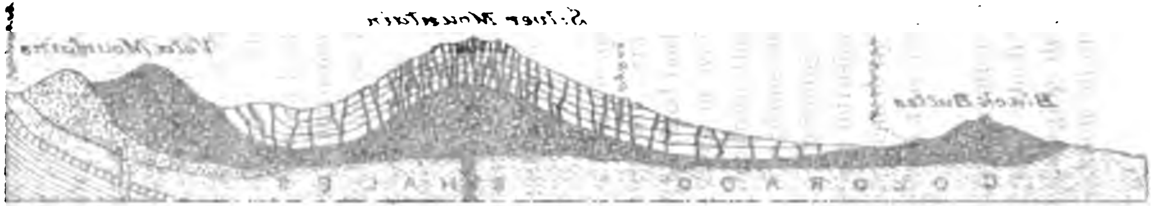
tems of diverging dykes. In both cases the upheaval was due to the intrusion of a laccolite-like mass not less than 2,000 feet thick, extending laterally along the Colorado shales a distance of from eight to twelve miles. The superincumbent sedimentary rocks being fissured by the upheaval allowed the lava to ascend through these vents; thus giving rise to the two systems of dykes which, with but few exceptions, do not extend below the horizon of the intrusions; that is, they terminate in the Colorado. This fact is very noticeable a few miles west of the Spanish Peaks where the Colorado containing the Three Buttes intrusion is comparatively close to the mountain. The dykes radiating from the West Peak are most numerous on the west side and trend directly towards the upturned sedimentary beds. The Dakota sandstone, being continuously exposed on that side of the field, would hardly fail to disclose any intersecting dykes; nevertheless, only two could be found west of, or lower than, the Colorado.

.The laccolitic mass of the Spanish Peaks is apparently compounded of a succession of intrusions arranged in stratigraphical order, owing to which the tilted body of the East Peak exposes a series of eruptives in which each variety is macroscopically distinguishable from those adjacent and from which it is separated by planes of contact conformable with the bedding of the overlying upturned sedimentaries. No doubt each of these intrusions corresponds to an upheaval and may be represented by a minor system of dykes, although the relation in this respect remains to be studied.

At Silver Mountain the upheaval was greatest immediately under the present culminating point, which is therefore the focus of the intersecting and diverging dykes, and where they are so numerous as to exclude all other rock

Section Showing the Structure of Silver Mountain.

Section Showing the Structure of Spanish Peaks.



Section Showing the Structure of Silver Mountain.

Section Showing the Structure of Spanish Peaks.

matter. Here also the dykes of the system do not extend downward below the horizon of the laccolite—that is, they terminate in the upper part of the Colorado. In this part of the field intrusive sheets are found outcropping as low as the soft beds of the Jurassic; but dykes are of rare occurrence at this horizon, only two having been noted cutting rocks lower than the Colorado, and these were foreign to the Silver Mountain system.

The material of North Veta Mountain, of the Black Buttes and of the Silver Mountain dykes is identical and clearly derived contemporaneously from one and the same magma; hence the dykes are petrographically and physically referable to one system or group. With the Spanish Peaks system, so called with reference to radial arrangement and mode of occurrence, it may be possible, subsequently, to effect a separation into groups of contemporaneous origin based on petrographical characters possessed in common with one or the other of the intrusions or laccolites.

In addition to the two prominent systems just described, there exists a third, apparently not connected with the laccolitic masses of either Silver Mountain or the Spanish Peaks, but with some one of the many intrusive sheets elsewhere present in the Colorado. These sheets probably extend with varying continuity through the Colorado rocks of the entire district. In the western part of the field they are a continuous and prominent feature of the Colorado exposures from the State line north to the Huerfano, a distance of fully fifty miles. The intrusion of this material into the shales underlying such a broad area of country produced in the overlying coal-measures a system of cracks or fissures through which the lava exuded under the displacing weight of the superincumbent strata, in accordance with the law of hydrostatic equilibrium, somewhat modified by attending circumstances. This explanation of the formation of dyke systems by laccolitic intrusions is embodied in the theory advanced by G. K. Gilbert in discussing the origin of the Henry Mountain laccolites.* The remarkable type of structure there so fully developed is found as strongly expressed in the Spanish Peaks and Silver Mountain occurrences; and not only are these among the most typical examples of the kind, but the entire district here considered is an exemplification, on an extensive scale, of the same structure in a modified form. As compared with the Henry Mountains eruption, however, there is this noticeable difference, that in the vicinity of the former the sedimentary beds were already highly inclined, consequently the conditions for the development of this structure in its most typical form were less favorable. Of the several geologists who have written regarding the Spanish Peaks region, Dr. Peale alone seems to have recognized the true character of the eruptions,† while, so far as the writer's observations extend, the opinion expressed by Hayden, and assented to by Endlich, that the Spanish Peaks occurrence "is a gigantic dyke," appears to be without foundation.‡

In the case of South Veta and Sheep Mountains we have a second group of laccolitic intrusions not directly connected with any corresponding system of dykes, although a few thin sheets in the sedimentary strata of the East Peak consist of the same material and are probably of contemporaneous origin. There are five intrusive masses of mountain dimensions belonging to this group, all of which occur in the Colorado of the northwestern part of the district between the Cuchara and Huerfano. All the laccolitic

*Geology of the Henry Mountains, page 73.
†Bul. U. S. Geol. Sur., Vol. III., No. 3.
‡Hayden's Report, 1876, pages 233-241.

occurrences found in that part of the field west of the Laramie outcrop, except North Veta Mountain, really belong to this group. The Veta Mountains consist of two distinct eruptive masses of about equal size, forming the elevations called respectively North Veta and South Veta Mountains. The adjacent extremities of the two masses overlap each other slightly at the contact. North Veta Mountain is the most easterly of the overlapping parts, and as already stated, belongs to the Silver Mountain and Black Buttes system. The material of the South Veta Mountain group consists solely of finely-granular hard white porphyry, easily distinguished in the field from the more coarsely-crystalline hornblendic material of the Silver Mountain and Spanish Peaks systems. The relative age of the Veta Mountain porphyry has not yet been satisfactorily determined. In all probability it is more recent that the material of the Silver Mountain eruption, for sheets of this material, with accompanying dykes, are present west of the white porphyry intrusions, and in a lower geological horizon yet the porphyry is nowhere cut by dykes.

In the southwestern part of the district, while the intrusive sheets outcropping in the Colorado are quite prominent, they do not possess the proportions observed in the northwestern part. Occasionally they show a local thickening; for instance, one near Stonewall has a thickness of about 200 feet.

The only important eruption that remains to be noted is that of Fisher's Peak in the Raton Hills. This is an overflow, or succession of overflows, on a large scale, similar in most respects to the other great overflows of Colorado. There are no points in connection with the Fishers' Peak eruption requiring consideration here, it being merely mentioned for the reason that it falls within the limits of a district characterized throughout by the same structural peculiarities.

The nature of the displacements observed in the Raton coal field is entirely in accordance with the structure we find developed. Outside of the general inclination and tilting of the strata, due solely to regular orogenetic movement, the prominent flexures are confined to the vicinity of the great intrusions of the northwestern part of the field. Elsewhere irregularities of dip, though frequent, are not serious. Fault displacements of a few inches are common, but those of ten or more feet are comparatively rare, only a few having been noted along the entire length of the eastern Laramie outcrop. Even dykes, situated within a few hundred feet of each other, have rarely caused sufficient displacement to prevent the regular working of the adjacent parts of an intersected coal-seam. Considering the enormous amount of fissuring the country has undergone, the limited amount of deformation may seem remarkable, yet a little reflection will show that it is quite in keeping with the observed facts. Such deformations would naturally result from the upheaval accompanying the injection of thin sheets of lava horizontally into the strata. In this case the upheaval was followed by subsidence owing to the displacement, on the hydrostatic principal, of a certain amount of viscous lava which, ascending into the fissures produced by the upheaval, solidified in the form of dykes. The amount of subsidence, measured by the relative quantities of material contained in the dykes and sheets, corresponded to about one-half the amount of upheaval. The tendency of the subsiding movement was strongly toward a readjustment of the faulted parts, especially when the fault-planes coincided with dyke-planes, and the supporting lava sheet became reduced, as in the majority of cases, to a thickness of only a few feet.

One would naturally suppose that a succeeding upheaval would reopen the first-formed fissures, and in many instances increase the amount of faulting, but this does not appear to have taken place, for double-dykes are more rare than those intersecting at acute angles. Furthermore, masses of sandstone or conglomerate are frequently observed adhering to the sides of protruding dykes high above the surrounding country, indicating a strong union between the dyke matter and the partly-metamorphosed or indurated walls.

Apparently then each injection of lava corresponded to a pulsating movement which gave rise to an independent system of dykes and fault-displacements without, as a rule, increasing the amount of pre-existing displacements. Consequently while faults may be quite numerous the amount of displacement in any given case will rarely exceed the maximum thickness of the sheet which produced it. The intrusions in the Colorado along the eastern border of the field are generally of extreme tenuity; the large intrusions, or such as might have produced a great amount of faulting during the period of injection, lie above the horizon of the workable coal-seams. It is safe to assert that there are no great faults traversing the country east and west, or parallel to the trend of the dykes, in the eastern part of the field. The few of importance that are known, so far as they have been followed, trend northeast and southwest, and may be due to dynamic manifestations primarily connected with the eruptions rather than to the simple upheaval attending the lateral injections.

The description of the various types of eruptive rocks found in the Spanish Peaks region must be reserved until their characters, and the many interesting points bearing on their relationship, have been worked out.* It might, however, be interesting to note here a peculiarity connected with the composition of many of these eruptives and that is the exhibition of very decided magnetic polarity. This does not manifest itself as a property of the entire mass, but is strongly developed at certain points along the outcrop of each dyke, the rock between these points exercising no appreciable influence on the magnet-needle, although one cannot detect any apparent difference in structure or appearance between magnetic and non-magnetic material from the same dyke. Generally, when the rock acts strongly on the needle it will be found to possess, also, polarity to a nearly equal degree, which again is not exhibited as a current of a definite direction, depending, as in the case of an ordinary magnet, upon the form of the fragment, which may, or may not, develop opposite poles at the two extremities. An ordinary hand specimen will often present opposite poles within 2 inches of each other along one side or border, and the poles may alternate at irregular intervals around the entire margin or show themselves on opposite flat sides. The poles presented by fragments of this size when brought close to a case containing a common compass are capable of deflecting the needle from 10° to 70° from the normal direction, and in masses weighing several hundredweight polarity is sometimes so strongly developed that a complete revolution of the needle can be effected by moving the compass in a circle around, and within 6 inches of, a particular point on the surface of the mass.

*The limited number of thin-sections that have been glanced at since this paper was read indicate the predominence of porphyries, diorites, porphyrites, basalts and probably dolerites, with varieties intermediate in composition, andensitic and trachytic types not being represented. However, the sections referred to are but a small fractional part of the whole number to be examined.

Seemingly, the grains of magnetite abundantly disseminated through the rock, and to which the magnetism is attributable, are so many independent magnets which, in their relation to each other, are not free to arrange themselves with reference to their polar affinities; but such arrangements probably exist accidentally at different points through the mass and are capable in each case of producing a more or less intense positive or negative effect upon the magnet-needle.

The changes brought about by the injection of so much igneous material into the sedimentary beds are in some particulars quite important. While the coal-measures of the Raton field are of the same age as the measures of northern Colorado, and were probably at one time continuous with them, the coals of the two fields show a marked difference in their composition; for instance northern Colorado coal shows not the slightest tendency to cake when heated, and is capable of holding in its pores a high percentage of moisture; the coal from the Raton field on the other hand carries but little moisture and is either a slightly-caking or else, as at Trinidad, a coking-coal. This difference is apparently due to the fact that the comparatively few, and widely separated, eruptions of northern Colorado were incapable of producing an appreciable general alteration of the coals.

The difference between slightly-caking and coking-coal in the Raton field evidently bears a direct relation to the magnitude of the neighboring eruptive masses, the coking-coal occurring in that part of the measure underlying the Fisher's Peak overflow.

Other changes of a more striking character have resulted from the injection of the lava along a coal-seam, producing either a dense natural coke or an impure powdery graphite. The coal of one or more of the large seams is frequently found to have been thus altered. The outcrop of natural coke near Trinidad is probably two miles long, that of the Chicosa and Road cañons over four miles long; north of the Apishapa there is an outcrop of very dense coke of about the same length, and between Bear Creek and the Santa Clara there is probably five miles of outcrop containing these alteration products.

In places beds of coal, separated 50 feet or more from the horizontal intrusions, have undergone a slower alteration, producing limited quantities of semi-anthracite. Coarse sandstones are often found metamorphosed to quartzites near one of these lava sheets, almost a sure sign that the coal in the measures has also been altered at that point.

The alteration of the originally dry coal to a slightly-caking or coking variety was probably brought about by radiation of heat through the medium of water; other and more pronounced alterations were due either to direct contact with molten lava or to the action of steam or very hot water. In the case of the shales the effect of direct contact with the lava has been to produce a few feet in thickness of hard, light-colored slaty rock.

About one and one-half miles north of the Huerfano, near Badito, there are several small dykes traversing the Colorado shales. The rock of one of these when broken is found to contain vesicular cavities filled with petroleum of characteristic odor. On investigation it was ascertained that a bed of highly-bituminous limestone, such as often occurs in the Colorado, was cut by this dyke a short distance below the surface, indicating that the petroleum may have originated by a natural process of destructive distillation incident to the passage of the fluid lava through the bituminous stratum.

FURNACE PRODUCTS.

Mr. Richard Pearce exhibited some red lead containing metallic (crystalline) silver, taken from the hearth of an old furnace.

The probable method of the formation of this product is as follows:

In smelting for argentiferous copper matte, a very fusible compound of sulphur, copper and lead is formed, a portion of which is absorbed by the hearth of the furnace. This compound undergoes a series of liquations in its passage to a cooler zone until a final product is obtained, consisting of argentiferous and auriferous lead which, from its great fusibility, finds its way into the joints of the brick work of the furnace.

In all probability the auriferous silver separates, or crystallizes out from its solution in lead by a process of very slow cooling, and by a subsequent process the lead becomes changed into red oxide of lead.

An assay of the crystals gave silver, 92.083 per cent.; gold, 3.587 per cent.

MEETING OF MARCH 5th, 1888.

NOTES ON SOME UNUSUAL OCCURRENCES OF GALENA CRYSTALS.

BY F. F. CHISOLM.

Near the town of Hermosa, in Sierra County, N. M., some large bodies of lead ore are found in veins or seams crossing the bedding planes of the limestones at right angles. The limestone is said to belong to the lower carboniferous measures. The lead occurs in massive beds of " hard and soft carbonates " which carry but little silver, and in smaller masses of galena which are rich in silver.

As a rule, where the galena crystallizes coarsely, the grade in silver is high. The manner of deposition of the ore is evident everywhere, the traces of thermal action being very plain.

There are numerous small caves in the ore bearing seams, the surfaces of which are sometimes lined with ore. Occasionally small crystals of molybdate of lead occur in these caves. In two of the numerous veins the crystals of galena are distorted and abnormal. It is a characteristic fact that the distortion of the galena is most marked when the crystals are found loosely imbedded in a clayey talc, which is found abundantly in connection with the ore. The larger specimens have been cleaned with a brush. The single and twin galena crystals can be beautifully seen, and also the distortion, which, in some cases, occurs on opposite sides of the crystalline masses. A very singular feature of the galena is the frequent occurrence of "etched" faces, seeming as though the deposition of the galena had been suddenly arrested; whether only certain faces are etched or not, I am unable to say. On some of the specimens the "building up" of the crystals is very readily and easily seen. I am unable to state whether there is anything unusual about the form of the crystals beyond the well marked development of the octahedral and dodecahedral planes or not. I have never seen such excellent or well marked specimens of the kind.

MINERALOGICAL NOTES.

BY W. F. HILLEBRAND.

Although the results of analysis of the herein mentioned minerals, unsupported, as they are, by any crystallographic evidence, do not lead to complete identification of species, they are deemed of sufficient importance to place on record, together with such information regarding their physical properties as could be gathered from the material at hand, which was in some cases rather scanty.

A few years ago, in granitic debris on Devil's Head Mountain, Douglas County, Colorado, in the Pike's Peak region, Mr. W. B. Smith found a number of minerals which appeared worthy of examination. Two of these, allanite and gadolinite, have already been analyzed by Mr. L. G. Eakins.* Analyses I–VI below represent the composition of the others, of which all but No. III were made in the laboratory of the U. S. Geological Survey in Denver over two years ago.

1. Samarskite. (?)

The mineral first to be mentioned occurred in fragments of all sizes up to that of a chestnut, without any evidence of crystal form except on a small portion of one piece, where a structure resembling that shown in Fig. 1 was apparent. The color was pitch black, with brilliant vitreous luster, but pale brown in thin splinters. Streak dirty brown. The pieces were very brittle, and when heated flew into fine sharp fragments. Fracture subconchoidal. These characteristics agree very closely with those given by

(Fig. 1.)

*Proc. Colorado Sci. Soc., ii, 32.

J. Lawrence Smith* for the purest North Carolina samarskite, but the density is much greater, being 6.18 at 22° C. for I., as might be expected from the percentage of Ta_2O_5, which is much higher than that as yet found in any recognized samarskite. Hardness 5.5-6. Slight solubility in HCl was shown on prolonged boiling, and a somewhat greater in H_2SO_4. Before the blow-pipe a splinter became dull, but did not fuse. Analysis I shows the composition.

A single piece of but a few grammes weight, while in its general behavior and appearance resembling those just described, presented two points of difference. The streak was salmon colored, and the rather thin piece was bounded on two opposed sides by flat surfaces which might possibly be the result of cleavage. These observed differences led to analysis II. The density at 25° C. was 6.12 and the hardness 5.5. As the analysis reveals a remarkable agreement in composition with the first described specimens, there is no reason to suspect the presence of distinct species.

Analysis III gives the composition of the specimen shown in Fig. 1, which it was thought might be an altered state of the above described mineral. It was evidently in an advanced stage of alteration, being very easily broken and so much stained (brown) that scarcely any evidence of its original color and luster could be observed, though what little of these features remained indicated agreement with those above mentioned. As some water escaped at 100° C., and still more for each further slight increase in temperature, air-dried material was taken for the analysis. This shows in most respects so close an agreement with I and II that the assumption of original identity with the brilliant black mineral does not

*Am. Journ. Sci., [3], xiii, 359, 1877; Ann. Chim., xii, 253, 1877; Original Researches in Mineralogy and Chemistry, p. 197.

seem far fetched. The chief differences lie in the much lower percentage of Ta_2O_5 in III, and the presence of UO_3 instead of UO_2. The density at 16° C. was 5.45.

	I.	II.	II.
Ta_2O_5	27.03	28.11	19.34
Cb_2O_5	27.77	26.16	27.56
WO_3	2.25	2.08	5.51
SnO_2	0.95	1.09	0.82
ZrO_2	2.29*	2.60*	3.10 (with TiO_2)
UO_2	4.02	4.22	6.20 (UO_3)
ThO_2	3.64	3.60	3.19
Ce_2O_3	0.54	0.49	0.41
$(Di, La)_2O_3$	1.80	2.12	1.44
Er_2O_3	10.71†	10.70†	9.82†
Y_2O_3	6.41†	5.96†	5.64†
Fe_2O_3	8.77	8.72	8.90
FeO	0.32	0.35	0.39 (or 0.74 UO_2)
MnO	0.78	0.75	} 0.77
ZnO	0.05	0.07	
PbO	0.72	0.80	1.07
CaO	0.27	0.33	1.61
MgO	....	....	0.11
K_2O	0.17	0.13	} 0.36
$(Na,Li)_2O$	0.24	0.17	
H_2O	1.58	1.30	3.94
Fl	?	?	?
	100.31	99.75	100.18

The method of analysis followed was, with certain modifications, that devised by J. Lawrence Smith.‡ Two instead of five grammes of material were taken for greater convenience in manipulation.

*Probably containing some TiO_2.

†Calculated from the molecular weight of the mixed oxides of this group on the unsupported assumption that only Er_2O_3 and Y_2O_3 were present. The molecular weight in the case of I was 304.9, in that of II 307.7.

‡Am. Chem. Journ., V., 44, 73; Chem. News, xlviii, 13, 29; Original Researches in Mineralogy and Chemistry, p. 350.

A few remarks in regard to certain points in the course of analysis may prove of service to those having similar analyses to make. By the method of Smith the constituents of the mineral are divided at once into two portions, those soluble in HFl, and those insoluble. The former portion includes Ta, Cb, Sn, W, U (if present as UO_3), Fe, *Ti, Zr in part, Zn, Mn, Mg, K and Na, while the latter contains the earths of the cerium and yttrium groups, Th,U (if present as UO_2), part of the Zr when other earths are present, a small part of the Fe, and the Pb and Ca.

It was found after converting the insoluble fluorides into sulphates and dissolving in water that a white insoluble residue remained, which, according to Smith, in the case of samarskite, should be Cb_2O_5 and Ta_2O_5. Neither of these could be found in it, however, the whole being lead sulphate. After filtering, the remainder of the lead was thrown down by H_2S. The uranium then having been oxidized by nitric acid the earths (except ZrO_2 and some CaO) were thrown down by oxalic acid (not ammonium oxalate) in excess. The use of oxalic acid was rendered necessary by the observed solubility of the earths of the yttrium group in ammonium oxalate. These, when freed from bases of the cerium group, were not precipitated by this reagent, or more properly, the precipitate at first formed dissolved *completely* in excess of the precipitant on very gentle warming and was not again precipitated on cooling. This behavior indicates the presence of erbium in quantity, which may influence the yttrium present, for the latter by itself is stated to be only partially soluble in concentrated

*Treatment with HFl at once reveals whether the iron is present as admixed hematite or limonite (as in analyses III, where it remained suspended in the liquid in an extremely fine state of division) or is chemically combined with the acids of the mineral. In the first case it resists the solvent action of HFl for some time after the tantalates and columbates are thoroughly decomposed.

boiling ammonium oxalate and to be again thrown out on cooling. It should be remarked, however, that the solubility above mentioned was very much greater than when to a hot solution of erbium and yttrium sulphates,* prepared according to the data furnished by the above analyses, ammonium oxalate was added in excess.

The filtrate from the insoluble fluorides was evaporated to dryness, dissolved in water and a few drops of hydrofluoric acid, and the tin was thrown down by H_2S as done by Marignac.† The filtrate was then evaporated with large excess of H_2SO_4, heated till all HFl was certainly removed, then, without driving off the excess of H_2SO_4, diluted and boiled (stirring constantly to prevent bumping) in a very large platinum dish for ten or fifteen minutes. The precipitate, collected on a filter, was then dissolved in HFl, the filtrate evaporated with excess of H_2SO_4 and treated in every way as above described till after the third precipitation by boiling. The combined filtrates were then evaporated, most of the H_2SO_4 was driven off, the residue taken up with water and boiled for some time. The remainder of the metallic acids, except some TiO_2 if present, is now entirely precipitated, but to free altogether from ZrO_2, Fe_2O_3, and from most of the TiO_2 the precipitate was again dissolved in HFl, the filtrate evaporated with H_2SO_4, the excess of the latter partly driven off and the acids were again thrown down by boiling.

This process is somewhat tedious, but seemed to possess the advantage of entirely separating Ta, Cb, and W from Fe and Zr, and in great measure from Ti, unless the latter is present in quantity. The point to be observed is that the

*From T. Schuchhardt. Though marked *chem. pure* it is not at all probable that they were so.

†Ann. Ch. Phys., [4] xiii, 5.

first precipitations shall be made in strongly acid solutions, the latter in solutions less strong. The procedure of Smith—driving off nearly all H_2SO_4 at first and then boiling with HCl—is objectionable; the metallic acids become strongly caked during removal of the H_2SO_4 and retain much iron, which no amount of boiling with HCl can remove.

The further treatment of the combined filtrates requires no special mention.

For the separation of WO_3 the ignited and weighed oxides were fused with Na_2CO_3 and S and separated as recommended by Rose. The method, however, leaves much to be desired, for a considerable quantity of the R_2O_5 acids goes into solution with the tungsten. Cb_2O_5 and Ta_2O_5 were separated by Marignac's method.

FeO was estimated by titration with $KMnO_4$ after solution of the very finely powdered mineral in H_2SO_4 by heating for two or three days in sealed tubes, a blank experiment being made with H_2SO_4 alone in another tube. The excess of $KMnO_4$ above that required for the conversion of all uranium (when assumed present as UO_2) to UO_3 was considered to be equivalent to the FeO. The accuracy of the determination is of course not affected by the fact that uranous salts reduce ferric salts in solution.

Fluorine could not be found quantitatively, but from the slightly acid reaction of the water evolved on heating the mineral its presence is rendered probable.

From the two first analyses it is impossible to identify the mineral with any known species beyond doubt, although it appears to be more nearly allied to samarskite than to any other. The presence of iron as Fe_2O_3 distinguishes it from most other columbates and tantalates containing much iron. That the greater part of the iron exists in the ferric condition is certain, for if the uranium existed as UO_3 instead of UO_2 as assumed, the amount of $KMnO_4$ required to oxidize 4.02 per cent. of UO_2 (analysis I) would indicate but 2.13 per cent. of FeO.

2. *An Ill-Defined Zirconium Mineral.*

With the mineral just described occurred peculiar growths, from an inch to an inch and three-quarters long, of a brown color and having the form shown in Figs. 2 and 3, of which analyses IV–VI represent the composition.


(Fig. 2.)


(Fig. 3.)

Evidences of crystal faces were observed on the upper terminations of some specimens. It seemed not at all probable from its appearance that the substance was homogeneous, and a thin section showed plainly a mixture of two or more minerals. One of these is probably limonite, and the action of HFl supports this view, for, while the powder as a whole was instantly decomposed, brown oxide of iron remained for some time suspended in the liquid. The specimen represented by analysis VI differed much in appearance in places from the others, fractured surfaces being coarsely granular and showing clear reddish grains of some size which could easily be detached. The sp. gravities were 3.70 (IV), 3.60 (V), 3.64 (VI). The analyses give the composition of air-dried material, for it was found that at 100°C. and with each further increase of temperature water was lost. They are only of value as showing the composition of these characteristic forms, which are mixtures of perhaps cyrtolite, or some allied alteration product of zircon, with limonite and a phosphate.

	IV	V	VI
Ta_2O_5		0.71	
SnO_2	47.99	0.03	51.00
ZrO_2		47.81	
SiO_2	20.06	20.64	19.21
ThO_2	1.16		
Ce_2O_3	0.06	1.20	0.60
$(Di, La)_2O_3$	0.19		
Er_2O_3	4.77	4.76	4.55
Y_2O_3	2.27	2.48	3.13
Fe_2O_3	5.53	5.97	4.86
MnO	0.47	0.57	0.33
CaO	1.99	1.93	2.15
MgO	0.13	0.11	....
K_2O	0.20	0.10	0.17
Na_2O	0.46	0.50	0.42
H_2O	12.87	12.00	12.97
P_2O_5	1.64	1.75	0.93
Fl	0.25	0.42	0.42
	100.04	100.98	100.74

3. A Sulphide of Copper, Silver, and Zinc.

Mr. Richard Pearce gives an analysis* of a mineral from the Gagnon Mine, Butte, Montana, which he describes as massive and in appearance much like bornite, with density 4.95 and hardness 3.5–4. A specimen received from Mr. Pearce, and analyzed at his request, had a density of 5.407 at 20°C. It was rather brittle, but flattened out in part under the pestle. From the analysis (VII) 0.12 per

*Proc. Colorado Sci. Soc., ii, 70.

cent. of gangue has been deducted. Pearce's analysis is given under VIII.

	VII.	VIII.
Cu	40.24	41.10
Ag	21.80	24.66
Pb	1.46	....
Zn	12.83	9.80
Fe	1.98	2.09
S	20.88	20.51
Insoluble	....	1.02
	99.19	99.18

The general formula deduced from both analyses is RS, with the different constituents apparently in varying proportions. It is impossible from the specimens examined to decide whether the mineral is new or only a mixture.

4. An Argentiferous Arsenide of Nickel and Cobalt.

From Mr. W. George Waring, through Mr. Whitman Cross, a mineral from the Rose mine, Grant County, New Mexico, was received, which has the composition given under IX. It is said to occur also in the Black Hawk mine in the same county. It has a steel gray color, and the particles abraded by a sharp blow of the hammer "take fire, and the pathway of each particle thus ignited as it falls to the ground is marked very distinctly by a trail of dense white smoke," according to Waring. In a closed tube a heavy sublimate of arsenic is formed on very moderate heating. The gangue of the mineral is mainly carbonate of lime and iron with quartz. The carbonates may be extracted with HCl, when the arsenide is left entirely unaffected and showing evidences of crystalline structure ("pyritohedral," Waring). The Sp. Grav., after correcting for 4.80 per cent. of quartz, was 6.644 at 20°C.

	IX.
As	74.04
S	0.13
Ag	4.78
Cu	0.04
Pb	0.03
Fe	0.44
Ni, Co	19.52*
CaO	0.09
MgO	0.05
	99.12

The atomic ratio of Ni, Co, Ag, Fe to As is much above 1:2.5, showing either that the substance is a mixture of two minerals with the general formulas RAs_2 and RAs_3, or of arsenic with one of the formula RAs_2.

Laboratory of the U. S. Geological Survey,
Washington, D. C., Feb., 1888.

*The separation of Ni and Co miscarried. According to a blowpipe analysis by Waring the proportion of Ni to Co is 3 to 1.

MEETING OF MAY 7th, 1888.

THE QUATERNARY OF THE DENVER BASIN.

BY GEO L. CANNON, JR.

The Quaternary areas of the West constitute no exception to the general rule that the superficial deposits are the last to receive serious consideration. Only a small portion of the vast territory west of the Missouri river has received systematic study, and large areas remain without description if not wholly without an examination. The country lying along the eastern base of the Rocky mountain system is a notable example of the latter class. In a region possessing so many attractions in other fields of geological research, few have cared to devote time to the study of the comparatively uninteresting feature of the local Quaternary. Fewer still have cared to record their observations, and to the extent of the writer's information, the literature on the subject of the superficial geology of this region consists of a few isolated allusions of but little value except in confirming the results of individual study.

During the past three years, in intervals of his professional duties, the writer has examined the country included in the map of the Denver Basin, and has spent a portion of the recent season in making, in behalf of the United States Geological Survey, a series of reconnoissances in various portions of Southern Wyoming, and of Southern and Eastern Colorado, for the purpose of ascertaining the limits of the formation represented in this district.

TOPOGRAPHY.

The territory embraced within the limits of the map accompanying this report is naturally divisible into three regions, the foot-hills, the Hogback region and the Western border of the Great Plains; the last two regions constituting the "Valley," *i. e.*, of the Platte, of the early settlers.

The foot-hills consist of a mass of crowded colossal ridges emanating from the main mass of the Colorado or Front Range, pursuing an average due easterly direction, Narrow cañons, often with vertical mural faces, 500 to 1,000 feet high, separate the mountains within the district under consideration. Beyond the limits of the map the cañon walls occasionally diverge, permitting the existence of beautiful park-like valleys, as at Idaho Springs. The bottoms of these gorges are filled with foaming torrents; and a passage to the mining communities beyond has been effected only by the construction, at great cost, of roadways along the cañon walls. Among these cañons may be named the world-renowned Clear Creek, Boulder and Platte Cañons. The mountains present angular outlines, and are, wherever the slope will permit the formation of a talus, covered with considerable masses of angular debris, the product of forest erosion. From this mantle of shattered rock the system has received its graphic title, the Rocky Mountains. The foot-hills attain an average elevation of 7,500 feet, rising abruptly from a mean level of 6,000 feet and occasionally reaching in isolated peaks, an altitude over 9,500 feet.

The Hogback region is a belt about one mile wide, of a series of highly inclined Mesozoic strata, paralleling the base of the foot-hills. Erosion valleys, varying in width and depth with the variations of stratal inequalities of thickness, or resistance to atmospheric degradation, separate the ridges. The great Dakota hogback, protected by its massive capping of quartzitic sandstone, towers, in places, 800 or 900 feet above its intersecting valleys.

As a rule, however, the other ridges are low, few exceeding a direct height of over 100 feet above the general level of the undulating surface of the valleys. The mountain streams issue from this region through narrow gorges worn through the ridges. The erosion of the softer beds beneath the harder strata has given crenulated outlines to the inner faces of the ridges in sharp contrast with the rigid outlines of the face toward the plains.

A broad shallow valley some 25 miles wide, drained by the South Platte river and its main tributaries, Plum, Cherry, Sand, Dry, Clear, Bear, and Deer creeks, forms the remaining region. The form of the valley, partly the product of a shallow synclinal fold, is mainly due to Post-Tertiary erosion. The eastern edge of the Hogback region may be estimated as having an average elevation of 6,000 feet, and the eastern rim of the valley, the divide between Coal and Box Elder creeks, an altitude of 5,500. The bed of the Platte, near the center of the map at Denver, is somewhat below 5,200 feet and before crossing the boundaries of the map has sunk below the 5,000 feet level. From both sides of the depression a gently undulating plain, slopes almost imperceptibly to the main drainage channel. Broad plateaus are common and typical mesa forms and sharp water-sheds are correspondingly rare.

FORMATIONS.

From the present inadequate data it is impossible to form a satisfactory correlation between the glacial districts of the mountains and the non-glacial areas of the foot-hills and the plains, and until a general knowledge of the Quaternary of the New West has been obtained, anything but the broadest possible outlines of a scheme of synchronization between our local deposits and those of adjoining or more distant regions would be presumptuous. It has, therefore, been deemed best to treat of the Quaternary features of this vicinity independently of their relations to those of other districts.

Three prominent events form a natural basis for the division of the Post-Tertiary history of this country, two epochs of elevation and degradation separated by an interval of subsidence and extensive sedimentation. The epochs may be named the Erosion Epoch, the Loessial Epoch and the modern Terrace Epoch.

The Erosian Epoch dates from the cessation of the latest Tertiary sedimentation to the commencement of the deposition of stratified drift in the drainage channels formed during the preceding epoch. The Loessial Epoch includes the time subsequent to this event until the beginning of the modern Erosion period, and is characterized by the formation of two prominent deposits: a deposit of river drift succeeded by the disposition of a thick mantle of loessoid silt over the surface of the entire plain country. The Terrace Epoch has effected the completion of the sculpturing of the lines of relief and was inaugurated by the re-elevation of the country causing the recession of the water of the preceding times.

THE GLACIATION OF THE ROCKY MOUNTAINS.

A brief sketch of the formerly glaciated areas adjoining our district should precede an account of the non-glaciated territory.

The glacialists are practically unanimous in pronouncing the glaciation of the western portion of the United States as the product of the action of local

Alpine glaciers. The border of the continental ice-sheet of the Eastern States parallels the western bank of the Missouri River, and terminates at no great distance from the river, the southwestern depression of the mass being arrested by the increase of elevation and by a northward projection of the zone of ice waste due to a coinciding upward curve of isotherms approximating to the present lines of mean annual temperature. Traces of a southward moving ice mass are conspicuously absent from the territory to the west.

Any of the higher mountain masses of the Cordilleran system will afford, in the latitude of Colorado, abundant evidence of former powerful glacial action. Such glaciation does not, however, extend into lower altitudes nor were the ice rivers of any great length. The glaciated areas of the high mountain ranges in Colorado were islands in a sea of sub-ærial degradation. Typical glacial phenomena are rarely found below the level of 8,000 feet and the lower foot-hills are conspicuously free from such features. In the narrow cañons of the main range the greatest difficulties attend the tracing of the succession of climatic changes. A few lacustrine formations in the broader valleys develop the fact that the Rocky Mountains have experienced the typical alterations of climate common to the Quaternary period in the northern hemisphere. The cañon walls of the foot-hills are free from polished, striated or grooved surfaces. Even if the improper assumption be granted that the rock is ill-adapted to preserve such records, certainly the passage of a glacier would have left a permanent memorial in the rounded edges of the slopes facing up the cañons. The careful search of many trained observers has failed to reveal even microscopic striations on the rounded and sub-angular rock masses composing the so-called morainal accumulations at the cañon mouths. This, together with the absence of that variety of rock material that would reasonably be expected in morainal deposits of glaciers having so large tributary areas, argues strongly against the morainal character of these accumulations. The foot-hill erosion is therefore of subærial character, and the product of a limitless period of meteoric degradation. The edges of the mountains, however, having been covered by the uplifted abutting edges of Mesozoic strata and the lava sheets, from which the material composing the Denver beds has been derived, have a definite limit to the time of the evolution of their surface features. The box-like cañons owe their origin to the rapid vertical corrosion of the streams and the tortuous character of their serpentine courses to a possible genesis of a stream carving through softer material than that through which they are now deepening their troughs.

THE EROSION EPOCH.

At the present time the date of the inauguration of this period cannot be accurately determined. The materials composing the beds of our latest known Tertiary formations—the summit of the Arkansas-Platte Divide and the top of Green Mountain—are poorly adapted for the preservation of organic remains, and our knowledge of the fauna and flora of these times is very limited. The conflicting testimony of the paleontologists concerning the age of the first subjacent formation containing any amount of organic remains and the uncertainty to what extent the deposits have been covered by easily-eroded strata, renders the solution of the problem a matter of difficulty, and it has not been found possible to synchronize them with late Tertiary formations in the neighboring States and Territories.

Green Mountain is crowned with a remnant of a remarkable boulder-conglomerate, composed of rounded cobbles and boulders, principally of the red feldspathic granite of Mt. Morrison and containing in its lower layers some andesite, large trunks of silicified wood from some older Tertiary beds, some fragments of the harder Mesozoic rocks and trunks of trees turned into lignite. This conglomerate has been considered as a product of glacial action, or as contemporaneous with the formation of the aqueo-glacial deposits of the Loessial Epoch, but is more probably a heavy Pliocene conglomerate similar in character to others of that age found along the Rocky Mountain system.

From the top of this mountain (6,993 feet) to the bed of the Platte (5,197 feet) there is a difference of nearly 1,800 feet elevation. After making proper allowance for the curvature of the synclinal folds, the progressive diminution of the thickness of beds, due to the distance from the orgin of the sediment and the decreasing altitude to the east, at least 1,200 feet of practically horizontal strata must have been removed during this epoch from this center of the Platte Valley. This is but one example of the scarcely conceivable degredation of the time, a degredation that can only be measured by the cubic mile. Were it not for the admirable adaptability of many of the feebly indurated beds for rapid chemical and mechanical decomposition, we would be tempted to place the date of the commencement of this denudation in the middle of the Tertiary period in order to gain the time necessary to effect some of the more remarkable erosion products. The reductions of the former plateau covering the Arkansas-Platte Divide into a number of radiating mesa tongues and isolated buttes, *e.g.*, Dawson's and Raspberry Buttes; the separation of Green and the Table Mountains from the Archæan and Hogback formations, the carving of numerous rifts through which the mountain creeks debouch from the Hogback region; the formation of the gorge separating the formerly continuous Table Mountains; the evolution of all the weird features of Monument and Perry's Parks, of the Garden of the Titans at Morrison, and the renowned Garden of the Gods have received all but the finishing touches of sculpture during this epoch.

The erosion of the Platte Valley kept pace with the corrosion of the river, producing a series of low reliefs of broad shallow valleys and of slopes rarely exceeding 5°. The sharp reliefs in the plains district are principally the result of modern erosion on the deposits of the Loessial Epoch. The gentle slopes are certainly not the product of a semi-arid climate like the present, and the main support of the theory of the extreme dessication of the plains at this time is the singular absence of residuary products between the loess and the undecomposed sandstones on which it rests. A prolonged period of aridity would have produced angular outlines, cliffs and mesa forms. A temporary aridity, by destroying the conservative influences of vegetable growths, may have permitted the removal of the residuary product of a previous moister climate, and the removal of the soil as fast as the sandstones decomposed. If the proof of a period of aridity corresponding with the Inter-Lahotan and Inter-Bonneville interval of aridity could be established the close of this epoch would be marked by an approximately accurate date.

THE LOESSAL EPOCH.

The wide drainage channels of the previous epoch now became filled to a maximum depth of 25 feet, with a series of stratified drift and gravels. The size of the stones in the drift varies inversely with the distance from their source, and the drift of a smaller stream will therefore show at times near the point of union a coarser detritus than that of the stream into which it empties. Near Denver, the stones are rarely as large as one foot in their longest axis, although a few large boulders probably transported by floating ice are sometimes met with. Near Sterling the comminution of the particles has reached the condition of coarse sand. The deposits present all of the characteristic features of typical fluviatile deposits. The material composing the river drift varies in nature, with the character of the formations drained by the stream; and the thickness and breadth of the deposits, with the size of the areas drained by the streams and with the slopes of the land over which it passes. The northern bank of the old channel of the Platte may be seen in several places in North Denver where the loess is separated from the sandstones by only a few inches of gravel. The southern bank is everywhere buried under heavy deposits of loess as on Capitol Hill. The extent of the beds in this direction may be estimated by the presence or absence of river drift between the loess and sandstone in the wells in this vicinity. The greater portion of the Platte River drift seems to have been derived directly from Platte Cañon. Large amounts of material have also been contributed by its southern tributaries, Cherry, Plum, and Sand Creeks—the rhyolites, the characteristic silicified woods, and portions of Monument Creek sandstone are derivations from the Divide region. Nodules of drab chert and dolomite derived from the Lower Carboniferous measures at Perry's Park often contain poorly preserved casts of brachiopods, minute crinoids and corals, and the tubes of tubicoloid annelids. Smoky quartz crystals are not uncommon in both the ancient and modern beds of the Platte, both of which have the same composition and are with difficulty distinguished from each other. Amateurs will always find something of interest to reward a search in these beds. Material from the north of the Platte is less commonly observable, possibly owing to an absence of distinctive material on that side of the stream, rather than to a diminution of the transported material. The abundant red orthoclase affords a ready means of distinguishing the gravel of this river from the gravels of both the old and the recent beds of its affluents from the south, the latter being composed of the whitish debris from the decomposition of the Monument Creek group.

The Platte River drift may also be detected by layers of horizontally arranged flattened pebbles more or less covered by a stain of limonite from the hydration of the the magnetic sands that usually accompany auriferous gravels and by a similar carbonaceous stain, the possible remaining trace of fresh water algae once covering the stones in the stream. All of the streams contain appreciable quantities of gold dust, often in sufficient quantity to pay moderate returns to economical working. The cellars of the business portion of Denver are dug in a gravel that pans well, and would yield fair results under the modern hydraulic methods. Some of the first discoveries of gold in Colorado were made in these deposits, and resulted in the development of a crop of mushroom towns. Denver's position as the metropolis of the Rocky Mountain region was largely determined by the start given to it by the discovery of gold in the river drift of the Platte close to the Larimer street bridge over Cherry Creek. The meager returns from the crude and expensive methods of the early time, and the more promising developments in the lode and placer mines of the mountains prevented the continuous working and exhaustion of the deposits. A few hundred dollars are still annually obtained from the surreptitious washings of the people near the Rio Grande shops, an industry frowned upon by the vendors of town lots in that neighborhood. The gold of Cherry and Sand Creeks is too fine to be economically saved. Near Elizabeth and Golden, placers of some value are being worked. The source of the gold in the southern streams is the concentration of the infinitesimal amounts of the precious metal contained in the sandstones and lavas of the Divide, and that of streams coming from the mountains, from the concentration of the auriferous constituents of the country rock and the lode gold.

Being quite porous, the river-drift absorbs and retains a considerable portion of the water from rains and from the irrigated fields that would otherwise be rapidly drained into the streams. The same quality obviates, in the smaller towns, the necessity of sewers, but it is a detriment to farms on the surface of the deposit by permitting the leaching of valuable elements of plant-food, and also in requiring more water for the proper irrigation of a field than is necessary on a farm on a loess deposit. To a farmer not owning an early priority to the use of the water from a ditch, this difference in the percolating capacity of the soil may mean, especially in a dry season, whether he can cultivate his farm or not.

In Denver the gravel is of considerable value for various building purposes and for grading, the earth in a cellar often paying a large part of the cost of the excavation. Wells sunk through a thickness of this deposit to the sandstone, when not contaminated by organic seepage, yield excellent water, but the shallower wells are often too highly charged with alkali to be of use for any purpose.

A large molar of an elephant was found near the corner of Sixteenth and Larimer streets, and with the vertebræ of a bison, are the only fossils known to have been obtained from this deposit. There are some reasons for considering some portions of the deposit as being of older age than the remainder, but the characteristic uncertainty of the permanency of a river's bank makes the demonstration of this fact a matter of difficulty. The coloring of the Quaternary measures on the Denver Basin map is in accordance with a probable difference in the age of the beds.

THE LOESS FORMATION.

The eastern portion of the State, below an elevation of 5,800 feet, unless denuded by recent erosion, is covered by a mantle of fine earth, varying in thickness from a few feet near the mountains to over 200 feet near the Kansas line. Throughout this area the deposit is practically homogeneous, and bears no relation to the formations beneath it. Although presenting some differences from the typical loess of the Rhine or of the Mississippi River, the points of resemblance so far exceed the differences that it is safe to apply to it the same designation. Certainly it is neither a sand, a clay, nor a marl, but partakes of all their various qualities. It is quite homogeneous in color, composition and structure, and weathers into the same peculiar erosion products. The writer would describe the color as an ash-like brown, but to others it might appear as neutral shades of yellow, buff, drab, or even dirty white. Near the foothills it becomes a dark brown, and on going east gradually becomes lighter until near the State line, where it is nearly white. Sometimes in this vicinity it assumes a reddish brown tint. A similar progressive change is noticed in the diminution of argillaceous and ferruginous constituents. The surface of the loess, colored by the infiltration of small amounts of carbonaceous matter from the scanty vegetation of the prairies, is darker than the rest of the formation.

The lower portions of the loess are often stained with calcareous matter leached from the silt above. Sometimes the lime forms into pulverulent spots and at others forms the loess-mannschen concretionary forms of the Rhine. The homogenity of the loess becomes less apparant upon a close examination. A vertical surface exposed to wind and rain will so develop a horizontally stratified surface owing to slight differences in composition or in induration. Soil presenting no differences to the eye will at first yield readily to the shovel and in a few inches will require vigorous work with a pickax and a few inches deeper perhaps will return to its former condition. These slight differences have a considerable importance in the conservation of water; a porous layer of a few feet in thickness resting on an indurate stratum will form the ideal conditions for irrigating. Deep plowing by penetrating such a layer would materially alter the amount of water absorbed by that field. In some cases an artificially indurated layer is formed by the action of the percolation of surface water from the ditches.

No layer of the silt is sufficiently impervious to resist the passage of water and it therefore becomes necessary to penetrate the entire thickness of the deposit before reaching a permanent supply of water. Unless diverted by subterranean drainage, there is usually a current of water flowing through the lower portion of the loess, being that portion of the water from the surface that is in excess of the absorbing powers of the sandstone surface over which it flows. The height of the saturated loess depends directly on the amount of water received from the surface and at the close of the irrigating season wells sunk in this formation generally lower the water several feet below the summer level of the water. Below irrigating ditches the depth of wells afford good criteria in estimating the depth of the formation, but are of little value outside of irrigating districts, as it is often necessary to bore a considerable distance into the sandstone before a permanent supply of water can be obtained. The passage of the percolating waters robs the upper portions of the loess of much of the soluble elements of a fertile soil, concentrating the same in the lower layers of the deposit. A surface of loess stripped of its upper portion affords a soil of extra fertility. Trees and deep root crops can also take advantage of the water of the lower portions of the loess, dispensing with a good portion of surface irrigation. The depth of the loess near the State line is a serious impediment to the settlement of the country in compelling the homesteaders to sink wells often over 200 feet before water is reached.

The loess affords the greater portion of the brick-earth used in this State, and although somewhat deficient in argillaceous matter, makes a brick that answers the requirements of the climate. The alluvium of the streams is also used for the same purpose.

The small portions of gold in the silt have become concentrated on the surface of the sandstone bed-rock beneath the loess, but are in no case sufficiently abundant for economic extraction.

The silt is not adapted for the preservation of vegetable remains and nothing is known of its flora. Molluscan fossils are also absent. The bones of two species of elephant, one with affinities to the mastodon, are not uncommon, and the same is true of the bones of the ancestors of the modern bison. Portions of six skeletons of an ancient horse differing only in slight respects from the living

E. caballus have been found within the city limits. Bones of small rodents of the genera Cynomys, Geomys, etc., are common and are probably modern intrusions, although many have the same desiccated appearance as the bones of the extinct ungulates with which they are associated. A possible metapodial bone of a camel, a skeleton of a snake and of a frog have also been secured near Denver.

Thos. Belt, of London, England, records, on page 298 of the Proceedings of the American Association for the Advancement of Science for the Year 1887, the discovery of a portion of a human skull in the loess near Argo. An examination of the locality of the discovery would seem to confirm his conclusion relative to the loessial age of the relic.

The fragmentary observations of numerous observers throughout the Mississippi Valley bear evidence to the general prevalence of formations of a loessoid character. A systematic correlation of these beds may demonstrate the existence of similar deposits belonging to different periods, but the tendency of the data is toward the conclusion that they form portions of one enormous fresh water sea deposit covering the Mississippi Valley and extending northward lower into the British possessions for an indefinite length.

The horizontally stratified structure of our local loess and the rock fragments suspended in the silt forbid the application of the Æolian hypothesis of loėss formation to this locality. The theory of the formation of loess by the deposition of silt from a muddy lake is the only theory consistent with the phenomena of this district. The postulation of a sub-aqueous origin of a formation of this extent, at an elevation of a mile above the sea level, necessitated a fruitless search in eastern Colorado for the boundaries of the lake, but not only did the lines of relief diminish as we went east but the amount of sedimentation increased. A similar vain search was made for traces of the shore phenomena of the lake, an absence which is partially explainable by the severity of the recent erosion along the foot-hills and the marking of the shore features by accumulations of torrential drift. Possibly the fluctuations of the level of the lake did not permit sufficient time for the effecting of any considerable amount of shore erosion.

The history of the Rocky Mountain region being a record of nearly continuous alterations of elevation and subsidence, it seems more probable that a depression of this chain in modern times permitted the formation of an extensive lake or series of lakes, than that a tract of country in the Gulf States, at least a mile long, should have been elevated to the height of many hundred feet so rapidly that the corrosion of the Mississippi was not sufficient to cause the drainage of the mid-continental valley.

From the present imperfect data for correlation purposes it would appear that the melting of the ice in the second glacial epoch in adjoining states afforded the supply of water to fill the valley, and was indirectly the cause of the excessive precipitation of the time. Microscopical and chemical studies in progress will show whether the silt has had an origin from the muddy streams which issued from the former glaciers of the mountains.

A most remarkable feature of the loessial deposits is the large amounts of rounded stones, often of considerable size, found suspended in the basal strata of the loess or resting on the surface of the subjacent sandstone. In many places the lower portion of the loess bears a marked resemblance to a sub-glacial hill, but the absence of residuary matter of the easily eroded underlying shales, and the absence of glacial phenomena in the mountains near these accumulations soon dispel the illusion.

The stones occur at all elevations of the highly eroded and uneven surface of the sandstone, and show a strange tendency to congregate in masses on the summit of any little eminence raised above the general surface of the land, to the deprivation of the surrounding country of similar material. This dispersion of the drift prevents the assumption of a transportation by currents of water, and forbids the belief that the boulders are the remnants of a former boulder conglomerate covering the plains. The agencies of transportation that could have carried these stones from their source in the foot-hills are therefore reduced to the agency of glacial transportation, which, for reasons before stated, cannot be invoked in this case; and to the least improbable agency of glacio-natantice. It therefore seems probable that the stones were gathered by shore ice along the borders of the lake, and dropped by the melting ice through the yielding mud of the lake to their present position. Where the lake was shallow the ice cakes would naturally become stranded on any little projection of the bottom of the lake, or in a very quiet lake the mass of a submerged hill would exert an attractive influence sufficient to prevent the passage of the ice over its surface. The stones in the loess of the Denver basin have traveled from their sources along the base of the mountains and of the Divide toward the center of the Platte Valley in straight lines, often at right angles with the course of the river, and rarely, if ever, cross a line coinciding with the course of the existing stream. Characteristic material from the Divide and from the country south of the Platte, although very common on the exposed summits of the hills within a mile or two of the south bank of the Platte, cannot be found on the hills just north of the stream, while the distinctive foothill debris so common on the North Denver hills is unknown on the other side of the river. The material of the ice drift on the north side of the Platte bears a close correspondence to the rock formations of the country along the edge of the mountains immediately back of the spot where the observation is being made. The small grains of sand in the loess show a like diversity of origin with the larger stones. A current sufficiently strong to prevent the crossing of floating material, in a lake depositing such fine sediment, appears anomalous, but its existence is demonstrated by the occurrence as the river is approached of a coarser sediment in the loess and by the occurrence in the loess of lines of small pebbles that have the appearance of having been rolled over the surface of the submerged loess. The loess resting on the surface of the old river drift channels is also filled in a similar manner, affording an excellent means of tracing the buried courses of the ancient streams. The stones in the glacio-natant drift are generally covered by the lixiviated alkaline constituents of the superincumbent loess. Sometimes this coating is an inch thick and serves as a cement to bind adjoining stones.

Above the level of the highest known deposit of the loess along the mountains, wherever the slope will permit, there may be found a heavy drift from the mountains containing boulders, more or less rounded, of several tons weight. This drift occurs on plateaus near the mountains at as high an altitude as 7,500 feet, and under circumstances that forbid the assignment of the agency that brought them to their present position to any other cause than that of floating ice. The relation of this drift to the glacio-natant deposit in the loess has not been satisfactorily determined. The elevated positions where the former drift is formed may account for the removal of a former layer of loess by the increased power given to the erosive forces by the increased acclivity. It may be barely possible that if the loess is glacier-formed silt, that the continued subsidence of the mountains brought them at last to an altitude that would not permit of glacial formation, yet would still allow the freezing of the borders of the lake.

In a few places along the Platte, near Denver, are small local patches of loessoid formation resting between the ordinary loess and the Platte River drift, and which differs from the loess proper by exhibiting a more apparant stratification, a greater proportion of argillaceous material, a greater resistance to atmospheric erosion, and to the passage of stones dropped from melting ice. It also contains considerable residuary material of the Denver sandstone and a number of small shells of the genera Physa, Planorbis, Limnea, Pupa and Succinea.

THE TERRACE EPOCH.

The subsidence of the continent having ceased, a re-elevation of at least 6,000 feet took place and may be still in progress. Data for the assumption of the existence of a different altitude at the close of the Erosion Epoch have not been secured, but it is probable from the occurrence of faults in the loess and the river drift that some changes in level have taken place in recent times.

With the recession of the water and the commencement of the drainage of the Mississippi Valley, the erosive forces attacked the accumulations of the previous epoch. The denuding agencies have effected the removal of the loess from the river valleys and of large portions of the river drift, leaving the remainder of the latter deposit in continuous terraces along the sides of the flood plains.

They have also deepened the grooves through which the old streams ran for an average distance of 50 feet below their former bed rocks. The course of the main channels do not coincide with those of the channels of former times. Some difficulty has been experienced in removing the gravel, and as a rule the excavation commenced on the sides of the stream where the gravel was less thick than in the center. Lateral corrosion has also made incursions into the sandstone banks, and near the mouths of the smaller streams, new channels, diverging from the course of the stream, have been formed. The old channel of Cherry Creek separates from its modern course, and forms the side of Capitol Hill as far as Seventeenth street, where it turns toward the Platte, the characteristic gravel being found in the cellars on Seventeenth and Eighteenth streets. The same gravel was found in the excavation for the State Capitol beneath a thickness of 20 feet of loess. The diminished size of the flood plains is commensurate with the diminished precipitation. The presence in the smaller creeks of material from formations outside of the present drainage area of these streams has been derived from the river drift of the old streams which extended into the region from which the erratic material was obtained. Small amounts of glacio-natant drift are sometimes carried into the stream from overhanging bluffs, *e.g.*, the bluffs on Cherry Creek near Shackleton Place. The changed conditions of the streams afford no indubitable evidence of a different altitude from the close of the Erosion Epoch. Large amounts of loess have been removed from the higher elevations and in the area bounded by the foothills, the Platte and Clear Creek, often nothing remains but the glacio-natant boulders with their white incrustations to point to a former considerable thickness of superincumbent

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soil. North and south of this area the amount of denudation has been less, only the high ridges and knolls protruding above the general surface exhibit the basal portion of the loess, and a sandstone exposure is quite rare.

The loess having been deposited in layers of uniform thickness corresponding with the inequalities of the eroded sandstone surface beneath, present surface features in the greater outlines, rudely sympathizing with the reliefs of the buried surface. The minor details of sculpture, owing to the different materials in which the carving is effected and the diminished force of the degrading agencies, necessarily present different features. The characteristic resistance of loessial material to lateral erosion, and its readiness to submit to vertical corrosion are admirably adapted to produce vertical lines of relief. On Sand Creek, cliffs of this material show vertical faces 30 to 40 feet high, and oppose a resistance of weathering and the lateral corrosion of the stream that would do credit to an indurated sandstone.

The surface of the loess, except near the streams where the edges are drained by finished drainage systems, is covered by a series of low ridges and knolls, and of shallow troughs and circular basins varying greatly in diameter and depth. No apparent system can be noticed in the arrangements of these forms, nor do any of the ordinary agencies of erosion appear to explain their peculiar formation. Something of a similar nature has recently been noticed in the æolian loess of Asia, where it seems to have been formed by subsidence due the removal of the lower layers by the action of underground streams. Where the bottom of a basin is formed in semi-indurated loess, the fine silt brought down from the surrounding slopes will form a sufficiently impervious layer to permit in dry areas the existence of small playa ponds, and in the rain-belt country and in irrigated districts permanent ponds. The playas are of great value to stockmen in lessening the distance that animals must travel for water and thereby extending the amount of available range. The poor homesteader is saved the considerable expense of sinking a well for the purpose of watering his stock by a proximity to a playa, being only obliged to bring a few barrels of water for household purposes from some more fortunate neighbor's well.

Æolian agencies have accomplished important work in finishing the minutia of the surface features. The patches of cactus (Opuntia) and the mats of the moss-like buffalo grass afford a poor protection to the violent winds of the region. The loosened silt, resembling the surface on which it is deposited, cannot be readily detected after a storm has moistened the soil. How far it assimilates with the surface and to what extent it is washed into the streams is a problem for future solution. At the foot of a slope of loess considerable accumulations of the coarser portions of the formation will be found, the result of checking the carrying capacity of the water flowing over the surface by the lessening of the slope on reaching level ground. East of Box Elder or Running Creek, sand dunes formed by sand blown in from the east, make their appearance and increase in magnitude as we go east. In eastern Colorado, in many places, the loess is concealed for miles by a deposit of whitish sand.

Cloud bursts, *i. e.*, the precipitation of a large body of water in a limited space, within the space of a few minutes, produce some extraordinary effects. On a plain, some distance from a stream-bed and a mile from the mountain from which the boulders traveled, have been found trains of stones weighing twenty-five pounds or over, resting directly on tufts of water-swept grass. Contrary to the proverbial inability of traveling stones to acquire accumulations, some of these boulders in passing over a surface of argillaceous soil acted as a nucleus for the formation of a ball of earth over a yard in diameter. Deposits of alluvium of small extent occupy the river beds below the level of the river drift terraces.

When the material transported by a local storm reaches some of the dry stream-beds of the plains, it is arrested by the absorption of its transporting force-water, and, in this way, considerable beds of sand are left in the stream-bed that when moistened occasionally form extensive quicksands, one, on the neighboring Kiowa Creek, having successfully swallowed a locomotive that in spite of diligent searches has never been found. The disappearance of the safe of the City Hall in the great Cherry Creek flood may or may not be an example of the same kind.

CONCLUSION.

The writer is sensible of the imperfections of the data on which some of the conclusions are based, and of the probability that further systematic study will develop facts that may seriously modify the statements herein contained; and while he regrets that his limited time has not permitted a more thorough study of the field, he trusts that this paper will be regarded as only a provisional study and will serve as a provocation for other and more complete studies by men who have devoted a lifetime to the study of superficial geology.

THE GENESIS OF ORE DEPOSITS.

BY RICHARD PEARCE.

At a discussion following a paper read by Mr. Emmons at one of the meetings of the Society, I spoke on experiences of my own in regard to the genesis of ore deposits, among a number of localities giving well marked examples of lodes having been formed by metamorphic action; I referred to the silver veins of Georgetown which occur in the granite.

I have received from Mr. H. M. Griffin, the owner of the Seven-Thirty Mine, near Georgetown, a very interesting communication, together with some rock and vein specimens, which I have taken some pains to examine.

A careful study of the rock in which the silver veins or bands occur shows, I think, that there is a very close relation between the lodes themselves and the main joints of the granite, and many years ago, when I had frequent opportunities of studying the peculiar features of those deposits, I came to the conclusion that the veins or lodes were in many cases merely joints, and that the thickness of the fissure proper was limited frequently from an inch to a few inches. It must not be understood, however, that this represents the usual size of the band of mineralized rock, which is usually called by miners the lode.

A specimen sent by Mr. Griffin is an excellent example of such a vein to which I referred. The material comprising the vein consists of sphalerite, pyrite, galenite and quartz; no well defined silver minerals are visible except in one case, and this is at the point of junction with the adjoining rock. However, on examining the rock, which is a typical porphyry or rhyolite, we find dark sooty stains which are rich in silver; a microscopic examination showed this black substance to be argentite, and in one instance I found a well marked piece of pyrargyrite. A sample of the vein taken in section assayed 358 oz. of silver per ton, and a sample of the rock without any attempt at selection assayed 326 oz. per ton.

MEETING OF JUNE 4th, 1888.

TWO SULPHANTIMONITES FROM COLORADO.

BY L. G. EAKINS.

The mineral first to be described was sent to the Denver laboratory of the U. S. Geological Survey in the latter part of 1885, by Mr. E. R. Warren, of Crested Butte, Colorado.

At that time a hasty qualitative examination was made, establishing the fact that it was a sulphantimonite of lead, and since then nothing more has been done with it until the present analysis was made.

This mineral comes from the "Domingo" Mine, on the ridge between Cañon and Baxter Basin, Gunnison County, Colorado, in which locality it is known as "mineral wool."

It consists of aggregates of small acicular crystals, forming matted wooly-like masses in the cavities of a highly decomposed gangue rock of siliceous material mixed with some calcite. It is dull, grayish-black in color, with occasional spots of iridescence, due undoubtedly to a slight superficial oxidation.

In procuring material for analysis, a lot of loose material sent by Mr. Warren was slightly crushed and rubbed with water in a mortar and poured off, the fine, needle-like crystals floating off readily; this was afterwards purified by a re-treatment in the same manner, and then subjected for a short time to the action of dilute hydrochloric acid, to remove the slight amount of attached calcite. The material obtained in this manner appeared under the microscope to be perfectly pure and homogeneous, with the exception of a slight amount of gangue still remaining.

No crystalline form could be made out, and on account of its peculiar nature no attempt has been made to determine either specific gravity or hardness. Heated before the blow-pipe it fuses readily without decrepitation; in the closed tube it gives a slight sublimate of sulphur only; in the open tube it gives off sulphurous acid and dense white fumes of oxide of antimony. Heated strongly the antimony all volatilizes, leaving a fused residue of sulphate of lead, slightly colored by the iron present; on charcoal it gives the lead and antimony coatings, and in the reducing flame with soda, a lead button. It is soluble in hot, strong hydrochloric acid with evolution of hydrogen sulphide.

The analysis is as follows:

		Atomic Ratios.
Ag	trace	
Cu	trace	
Pb	39.33÷207=.190	.222 (Pb, Fe)
Fe	1.77÷ 56=.032	
Mn	trace	
Sb	36.34÷120=	.303
S	21.19÷ 32=	.662
Insol. Gangue.	.52	
	99.15	

Dividing these atomic ratios through by .222, we get:

Pb, Fe = 1 = 3
Sb. = 1.36 = 4.08
S. = 2.98 = 8.94

giving the formula: $(Pb., Fe)_3 Sb_4 S_9$, or $3 (Pb., Fe) S. 2Sb_2 S_3$.

This mineral, it is seen, fills a place in the group: $3RS, (As, Bi, Sb,)_2 S_3$ of which there are but few good examples, and which until now has not had an antimony representative.

The somewhat low summation of the analysis is probably due to two causes; first, a small amount of soluble gangue which was present and undetermined; second, the sulphur is about four-tenths of one per cent less than required, due to the slight natural oxidation of the mineral, together with an additional amount induced by the treatment with dilute hydrochloric acid for the removal of calcite.

In addition to the complete analysis given, there were additional determinations made of lead, antimony and sulphur, the results obtained being in strict agreement with those given above.

The second of these sulphantimonites was collected in the summer of 1887 by Mr. Whitman Cross. It comes from a mine on Augusta Mountain, Gunnison Co., Colorado, this locality being about one mile east of the "Domingo" mine.

Locally this mineral is also known as "mineral wool," and although differing considerably in appearance from the one first described, they were, on account of the similarity of occurrence, considered as probably indentical.

It occurs in a siliceous gangue together with pyrite and sphalerite, and forms groups of acicular crystals which are elongated prisms, deeply striated, but whose form could not be determined.

The individual crystals of this mineral are considerably larger than those of the one previously descibed, and in consequence they do not tend so much to form matted aggregates.

Its color is a bright, steely, grayish-black with no tendency toward tarnish or iridescence.

The separation of this mineral from the accompanying ones and the gangue was a matter of considerable difficulty; on account of their size the crystals could not be successfully washed out from the other material, but by the use of a rapid current of water and the Thoulet method a small quantity was finally procured perfectly free from everything except some pyrite, and that had no effect upon the analysis, as the mineral was dissolved in a mixture of hydrochloric and tartaric acids, leaving the pyrite unattacked. It was then filtered through a Gooch crucible, and the amount of pyrite determined and deducted from the amount of material taken.

The fact that but a trace of iron was found in the analysis is conclusive proof that the pyrite was practically unattacked.

Blowpipe characteristics are the same as in the one before described.

The analysis is as follows:

	Atomic Ratios.
Ag	trace
Pb	55.52÷207=.268
Fe	trace
Sb	25.99÷120=.217
S (calculated).	18.98÷ 32=.593
	100.49

Dividing these atomic ratios by .217, we get:

$$Pb = 1.24 = 4.96$$
$$Sb = 1 \quad = 4$$
$$S = 2.74 = 10.96$$

giving the formula: $Pb_5 Sb_4 S_{11}$ or $5PbS, 2Sb_2 S_3$.

We have here, in formula, a Freieslebenite in which, instead of lead and silver, the silver has been completely replaced by lead, and although the crystallographic agreement of this mineral with Freieslebenite has not been established, there seems to be no good reason for not referring it to that species.

NOTES ON THE ORE OCCURRENCE OF THE RED MOUNTAIN DISTRICT.

BY T. E. SCHWARZ.

Some four years ago, when the writer first visited the Red Mountain mining district of Ouray County, he was shown on the lowest level of the Yankee Girl Mine, then some 90 feet below the surface, an approximately round chimney of ore occurring on a nearly vertical wall of a hard, fine-grained bluish rock, with the remark that the latter was "the foot-wall of the lode." The character of this wall, together with the peculiar ore formation, led the writer to venture the opinion that the wall did not bound a fissure vein, in the ordinary acceptance of the term.

Subsequent experience in the development of the Yankee Girl Mine to a depth of 800 feet, as well as with other Red Mountain properties, has to a certain extent confirmed the opinion then hazarded, that the district was the scene of ancient mineral spring activity, and that its ores now filled such water channels, forming a section abounding in ore chimneys of irregular occurrence, probable great vertical depth, and of small horizontal section.

The Red Mountain district proper may be said to occupy the basin at the head waters of Red Creek, from Ironton Park to the Divide, a distance of six miles. I believe, however, these notes apply as well to the entire ore occurrence of Red Mountain in its extent from Silverton on the south to Ironton on the north.

The practical mining man rarely has time to more than note facts that operations in his limited field force upon him, whilst the study of the district as a whole, aided by chemical and microscopical analysis, must be left to the able corps of which Prof. Emmons is chief. It will therefore be the scope of this article to briefly note the features of the section and formation.

The formation on the two sides of Red Creek at once strikes an observer as very dissimilar.

On the east side, upon which are the mines of the section, the Red Mountain presents a very rough exterior with its jagged cavernous cliffs, its long stretches of slide rock, and its characteristic bright red colors. No vegetation shows above timber line. A series of benches are a noticeable feature on this side. These for considerable distances are very well defined, and at other points are covered by slide or cut away by erosion. They form the base of the mountain to a height of 400 to 800 feet, and are generally characterized by quartz outcrops. At the south end of the district two small parks occur nearly surrounded by these massive outcroppings, which are the distinctive surface feature of the district, and mark the location of many of the producing mines. These outcroppings occur as knolls rising from twenty-five feet to 200 feet above the surrounding surface, and varying in size and shape from twenty-five feet in diameter to 150 feet by 500 feet. Many present a pyramidical or conical appearance, with sloping base of detached rock, and a cliff of hard blackened cavernous quartz for the apex.

The west side of Red Mountain Creek, being the east slope of the range which divides the Uncompahgre drainage system from that of the San Miguel, shows different surface features, with its slaty colored cliffs, abundance of verdure and grassy slopes, and entire absence of bright red colors and heavy outcroppings. On this side good spring water abounds, whilst on Red Mountain all the streams and springs are strongly impregnated with mineral. A change of formation, therefore, is indicated along the course of Red Creek.

This formation is in the heart of an area of some fifteen miles square, which embraces the most productive portion of the San Juan country, and is entirely covered by an overflow of eruptive rocks, principally varieties of trachyte, andesites and andesitic breccias, in which most of the ore deposits occur as fissure veins of strength and persistence. Among such of note are the Sheridan, Mendota, Old Lout, Virginius, San Juan Chief, North Star on King Solomon Mountain, North Star on Sultan Mountain and others. These properties show few points of similarity either of ores or ore formation with those of Red Mountain. The latter district has been the scene of intense matamorphism, as evidenced in the large areas of soft bleached andesite, which changes sometimes gradually and sometimes at once on some cleavage plane to the hard, fine-grained bluish green and unaltered rock, provisionally diorite, or at other points to a fine or coarse breccia full of kaolin and pyrite. The white softer rock of a rather fine granular structure, and gray quartzy lustre, with kaolin faces, encloses most of the Red Mountain ore bodies. Another marked result of metamorphic action is seen in the massive knolls of quartz, or, more strictly speaking, silicified andesite. They are in many instances, as in the National Belle and Enterprise Mines, penetrated by caves and irregular passages, sometimes as large as forty feet by sixty feet, filled more or less with iron oxides, white kaolinite and ores of secondary deposition. These caves branch out extensively toward the surface, form large chambers and come together and diminish in size in depth. Evidences of their formation along certain cleavage and fracture planes, affording passage for surface waters, is not wanting in most instances. They extend in depth to the water level, which is rarely over 200 feet below the outcrop, but varies greatly in different properties, in some cases within distances of 1,000 feet. Their walls are smooth and rounded, sometimes hard, but generally of porous siliceous soft rock.

The ores of the district may be divided into two classes, viz.:

1. The surface ores or those of a secondary formation.

2. The sulphide ores, or those occurring below the former water level.

1. The ores of the first-class are found in the caves described above, either adhering to the walls in masses of stalactitic, roughly crystalline or botryoidal form, or else as loose sand carbonates, or a clayey mixture with kaolin, heavy spar and detached masses of ore and rock filling the caves to a greater or less extent.

The ores of the National Belle, Vanderbilt and Grand Prize carry a heavy per cent. of lead, varying from 30 per cent. to 50 per cent. in carload lots. They occur as sulphide in coarse crystalline masses attached to cave walls, or altered to massive sulphate and carbonate. Many of these masses show the sulphide only as a central core. Associated with these are lead arsenates, limonite and sphalerite or zinc blende, with considerable kaolinite. The latter occurs snow white, each particle, as determined, I believe, by Mr. Whitman Cross, being a perfect crystal. The zinc blende in the National Belle is in a rare form, as botryoidal masses, consisting of nearly concentric fibrous layers, and is usually found detached from cave walls and lying in a mass of kaolin on the bottom or side of caves. They are as large as twelve inches in diameter, and emit phosphorescent light on scratching with steel. I have observed that adjoining caves vary considerably in the gold and silver contained in their ores, whilst the coarse cube galena is usually lowest, and the dark carbonates the highest grade ore.

To the east of the National Belle lie a group of mines very similar to it in character, but differing in the presence of considerable sulphide and oxide of bismuth in the cave ores. Such a property is the Enterprise, from which several tons of bismuth ore have recently been reduced by Mr. A. H. Keller, of Silverton. He informs me that this ore carries 25 per cent. to 50 per cent. of bismuth in assorted lots, from which he has reduced several hundred pounds of metal 98 per cent. fine. I believe this to be the first large lot of metallic bismuth reduced on the continent.

2. The ores of the second-class have naturally made up the bulk of the Red Mountain production. In the properties producing the oxidized ores peculiar to the caves, the unoxidized ores begin at the water level, where the cave ores cease. In many other properties, in which the cave formation is not present through erosion or never existed, the latter class of ores outcrop on the surface. In such cases the quartz knolls do not occur.

These ores are sulphides and sulph-arsenides of the metals, producing the following minerals in quantity, viz.: galena, chalcopyrite, pyrite, erubescite, bismuthinite, enargite, stromeyerite, tennantite, tetrahedrite. Among the metallic minerals of rarer occurence are silver glance, stephanite, and zinkenite and zunyite, noted by Mr. Franklin Guiterman in ores from the Zuni Mine, and I apprehend others not yet determined. Associated with these ores are rhodonite (manganese spar), gypsum and heavy spar.

In the National Belle, Enterprise, Hudson, and contiguous properties, in the upper and southern portion of the district, enargite occurs massive and as the prevailing mineral below the horizon of oxidation. It varies greatly in silver contents, from 15 oz. to 150 oz. per ton, in different properties, and is associated generally with low grade iron pyrite and zinc blende, and with either the lead or bismuth sulphide. The relation of these ores to the oxidized ores will be referred to below.

In the northern or lower portion of the district are the two heaviest producing properties, the Yankee Girl and Silver Bell, near which are the Genesee, Paymaster, Guston and others. They all present the same type of formation, varying only in the character of the ores. The high grade ores of the Silver Bell, are characterized by bismuth, whilst in those of the Yankee Girl, stromeyerite (sulphide of copper and silver), is the distinguishing mineral. The surface ores of the chimneys in this portion of the district are either galena, or pyrite and chalcopyrite. The changes in character and grade of ore are often rapid and the section is one of surprises. Particularly is this the experience in following the ore chimneys in depth, owing to their sudden and irregular changes of pitch. To describe in detail their apparent eccentricities would extend this article unnecessarily, and I would therefore briefly mention the prominent features of their occurence.

1. The ores occur in chimneys, so called, having small horizontal section, more or less circular, and rarely showing, in present developments, more than 60 feet in largest diameter.

2. These chimneys consist of ore and its matrix, usually a hard, fine-grained brown, or grayish quartz, frequently very porous. Generally the ore is concentrated in one portion of the chimney or embraces the whole of it,

occurring massive and quite free from gangue for considerable distances.

3. The rock, surrounding or enclosing the chimneys, is the soft whitish andesite, referred to above. It occupies large areas, separated from each other by the hard, fine-grained, blue green, "blocky" diorite. The latter is absolutely barren of ore.

4. Individual chimneys, occurring in one area of what we may term for brevity "white rock," show no relation to each other beyond sometimes a similarity of ores, or a gradual drawing together in depth, or at some horizon a seeming arrangement along a certain course.

5. Chimneys, separated by areas of diorite, are foreign to each other, and generally show dissimilar ores.

6. The line of change from "white rock" to diorite has no regular direction or course, but is undulatory both in horizontal and vertical directions.

7. The ore chimneys frequently change their pitch, sometimes quite suddenly. Any one chimney may recede from a given vertical line for several hundred feet of depth and then approach it again. It is also rare for one to continue in the same plane for any considerable depth.

8. Every chimney is connected with one and sometimes two cleavage or fracture planes, approximately vertical, but not of great individual strength laterally. Horizontal planes exercise the greatest influence on the ore bodies, changes in character and pitch occurring at such horizons.

9. Changes in direction or pitch frequently accompany an enlargement of the chimney.

10. The alteration of the enclosing rock increases as the ore chimney is approached. This is shown by the increase in proportion of silica in the composition and by the

occurrence of cleavage faces and large or small masses of kaolin near the ore bodies.

There are in this section some notable instances of marked increase in grade of ore from the surface to considerable depth. There are also, in the case of the cave properties, many instances of the reverse experience. The ores occurring in the caves are richer than the unoxidized ores extending immediately below them. That the mines of this district have uniformly grown richer with depth, and that such improvements may be fairly expected in developing, is a popular fallacy, not supported by experience. As a general rule, the copper and bismuth minerals are the enriching elements, and the iron and lead sulphides the poorer ores. Car-load lots have been shipped from the Yankee Girl Mine, returning as high as 3,500 ounces and 5,000 ounces silver per ton and 30 per cent. to 33 per cent. copper. The Silver Belle has produced in large lots bismuth ore, milling 500 ounces to 1,000 ounces in silver per ton. The bulk of Red Mountain ores, at present coming from a depth of 200 feet or over, carry from 5 per cent. to 20 per cent. of copper.

The geology of the district is not easily given in detail. In a recent paper before this Society, Mr. S. F. Emmons has briefly referred to this formation, and advanced an explanation in accordance with most of the facts cited above.

It is evident the district has been one of great activity of heated mineral solutions, which have deposited their contents along nearly vertical channels, and that such channels have been formed along planes produced by cooling of heated rock masses, or by some near dynamic movement. The small lateral extent of these planes would indicate, probably, the former theory. Owing to the structure of the rock, with its network of planes, the circulation of these solutions must have been comparatively rapid. The strong horizontal planes, which formed drainage courses for large areas collecting their mineral contents in solution, might be expected to play an important part in determining the character of the ores in the chimneys with which they connected. It seems that the alteration of the country rock and the deposition of the ores was a simultaneous process. The general merging of ore into rock on one or more sides of the chimneys, and gradual change of the hard quartz into the soft andesite, together with the presence of kaolin in and adjoining the ore, would indicate this. The absence of extended fractures of the formation, having considerable lateral persistence, accounts for the non-formation of fissure veins. On the other hand, the nature of the rock, and the forces governing the subterranean circulation of mineral solutions, favored their concentration at points of least resistance along vertical planes. In their passage upwards, a gradual deposition of mineral contents, and a replacement of portions of the adjoining rock took place, forming chimney-shaped deposits, lacking in the confining walls and resulting regularity of fissure veins.

The carbonate ores are the result of the action of surface waters upon the original sulphide ores, the enargite, pyrite, galena, etc., found below. This has been a process of natural concentration of the silver and lead, whilst portions of the other original constituents have been carried off in solution. The oxidizing and dissolving properties of these surface waters account for the formation of the caves along cleavage and fracture planes, and the redeposition of ores upon their walls.

MEETING OF JULY 2nd, 1888.

ON SOME STRATIGRAPHICAL AND STRUCTURAL FEATURES OF THE COUNTRY ABOUT DENVER, COLORADO.

BY GEORGE H. ELDRIDGE.

The region about Denver, within a radius of twenty-five miles, a study of which has recently been completed, presents several stratigraphical, structural and economic features which are of sufficient interest to warrant a brief notice in advance of the publication of the Monograph of which they are about to form the subject matter. To this end the present paper is offered to the Society, in company with that of Mr. Cross, which deals with the eruptive geology of the region, and the formation known as the "Denver Beds," a sedimentary formation composed chiefly of eruptive material, and forming the highest beds in the immediate vicinity of Denver, and in the prairies to the west, between it and the foot-hills.

The points to be touched upon in what follows, are: The interdependence of topography and geology as illustrated in this field; the general and distinguishing characters of the formations met with, together with the evidences as to their age furnished by lithological comparison and by the fossils contained; the stratigraphical relations of the Tertiary groups to each other, and to the Cretaceous, as instanced by numerous unconformabilities; certain regions of most remarkable nonconformity, as at Golden and

Boulder; the systems of faults met with; and, finally, the general features of the coal fields and of their coals.

Of the interdependency of topography and geology, the usual excellent examples so obvious in all mountain regions, as the results of upheaval, folding, difference in the texture of successive formations, or the association of rock masses of different composition, are all again repeated in this locality, together with one or two peculiarities of structure which, by reason of the union of prairie and mountain, become especially evident in a foot-hill country like the present.

The first of these is what is designated as structure "en echelon," the result of folding on an axis which extends diagonally across the general trend of the mountains, in Colorado in a direction 10° or 20° nearer northwest than that held by the range itself, by which an anticlinal is formed, the northern end of which disappears in the range, while the southern end extends out into the prairie, and, from the southeastern dip which the axis invariably has, gradually disappears beneath its surface. Between the diverging southern end of this fold and the range proper lies a complementary synclinical with its axis rising to the northwest. The effect of this structure is to produce a series of offsets from east to west, in passing along the foothills in a southerly direction, a marked feature in the topography, the type locality of which lies in the vicinity of the Big and Little Thompson Creeks, a few miles north of this field. Good examples are, however, met with at several points in the Denver field, notably on Ralston and South Boulder Creeks, where the peculiarity is brought out especially well in the sandstones of the Dakota and Trias, and in the intermediate Jurassic shales.

A second peculiarity of structure, causing rather odd topographical detail, is the occurrence here and there along the higher foot-hills of Archæan and Triassic rocks, of benches of the red sandstones and conglomerates of this age, jutting horizontally outward from a point well up on the side of the mountain mass to which they are attached, and, from their excellent state of preservation, resembling at a distance the remains of an ancient lava flow. An especially good illustration of this occurs a mile and a half north of Morrison, but the key to the solution of the peculiar structure is found at a second locality just south of North Boulder Creek, where the formation of a bench was stopped in a transition state, by which it appears probable that its origin may be due to the overcoming of cohesive force along the planes of stratification of the more highly inclined strata, and a resulting slip downward, or the crumbling of the upper members until, stopped by the resistance opposed at the portion now forming the base of the hills, they bowed out, as it were, into an arch, the upper part of the curve assuming a horizontal position and forming the flat bench noted, and enhanced in its boldness by the subsequent erosion of the lower half of the arch to the general level of the surface along the base of the foot-hills.

Equally, and perhaps more, interesting from their hidden nature and the closer research necessary for their exposure, are the examples of topographical and geological interdependence afforded in the prairie region, where the forms taken on by the hills, the location of stream-courses, the erosion of valleys, and the terraces of ancient Quaternary lakes, which are to be seen at many points lying immediately against the foot-hills, are directly referable to structural phenomena of composition, texture, or faulting.

The latter phenomenon has played a most important part in the determination of stream-courses, and nowhere more so than in the northwestern portion of the field, where stream after stream may be crossed whose present valley, even to its turns, has long ago been defined by fractures and cross-fractures of the crust, resulting in the opposition of rocks of different composition and texture, and the results of attendant dislocation. Coal and South Boulder Creeks, and the intermediate gulch north of Louisville, are throughout their entire prairie course excellent illustrations of this class of interdependence examples.

A good illustration of hill topography, attributable to underlying geology, is found in the mesa-like elevation lying between Marshall, Louisville, and South Boulder Creek, where faulting, folding and the texture of the subjacent rocks have all entered into the final outline of the present day. Again, regarding the terraces, their distinct outlines are even yet visible against the foot-hills, enduring evidences of the intermittent subsidence of the waters of those great lakes of ancient times, which occupied such vast areas of the now prairie region, still further supplemented by the later river terraces, quite as prominent as the first, and telling an almost equally interesting history.

From oft-repeated examples similar to those just cited, the Denver field may be regarded as one of the most prolific of western areas in excellent illustrations of the interdependence of topographical features and geological structure.

ROCK FORMATIONS.

Of the great geological divisions, the representatives in the present area are the Archæan, the Trias and Jura, the Cretaceous and the Tertiary.

Archæan.—The Archæan is well exposed along the western border of the field, and consists of gneissoid granites, fine to coarse banded gneisses, and mica and amphibole schists, often having for several miles an uninterrupted approximate east and west strike, with a dip now north, now south, and an estimated thickness, barring unrecognizable faults, of at least 25,000 feet. From the general disposition of the strata, the granitoid gneisses seem to occupy the underlying position geologically, and at times, when almost entirely devoid of gneissoid structure through broad zones and very coarsely crystalline, they quite resemble the true granites forming the core of the range.

Associated with the Archæan on South Boulder Creek, and in the hills just north of Coal Creek, are some white quartzites and coarse quartz conglomerates, which have undergone extensive metamorphosis. From their obscure relations to the crystalline rocks it is impossible to assign them to any age, beyond the statement that they are very ancient, and may or may not antedate the Cambrian.

Trias.—Resting immediately upon the Archæan, with an easterly dip, varying between 30° and 45°, rarely greater, occurs that important western formation, rather broadly designated as the "Red Beds," which, in the present field, is regarded as comprising all the strata lying between the Archæan and the well-known Atlantosaurus clays of the Jura. It is commonly referred to the Trias, and is divisible into two equally important sub-groups. The lower, owing to the uneven surface of the old Archæan floor upon which it was laid down, has a variable thickness, in general approximating to 1,500 feet, and is composed of massive beds of red or pinkish-red sandstones and conglomerates, with very little argillaceous matter, the whole capped by an ever present bed of creamy white, quartzose sandstone, with now and then gritty layers, and characterized near the top by great quantities of small, brown ferruginous balls, which at first weather out into wart-like protuberances, and finally upon further disintegration of the surrounding rock-mass, fall out altogether, leaving corresponding cavities in the bed, which give it a remarkable, pitted appearance.

The upper member of an average thickness of 600 feet is for two-thirds its distance, from base to summit, a group of very fine-grained, brick-red sandstones and shales, with narrow intercalations of limestone peculiar to the formation near its base; the remaining upper third being a succession of brightly variegated clays, with layers of gypsum and limestone, and capped by a bed of pinkish sandstone of fine material, mostly quartz, about 20 feet in thickness. The entire Triassic formation, by reason of its comparative softness, has undergone more rapid erosion than either the Archæan or the Dakota, and is therefore found underlying the longitudinal valley, within the ridges of the "hog-backs" of the latter formation.

As to the Triassic age of these beds the existing evidence may briefly be summed up as follows: First, there exists in the West an enormous thickness of strata, which by their lithological and palæontological characteristics resemble the new red sandstone of Europe; second, as in Europe, so in this country, they are separable into two great broadly dissimilar formations, the Permian and the Trias. The former does not occur in the Denver field, but may be seen in the Gunnison country and the region of the Arkansas Cañon below Salida, where it is recognizable by typical Permian plants with, as yet, no conflicting evidence in favor of a more recent age for it, but on the contrary, if with affiliations for any age other than the Permian, certainly in favor of the Carboniferous, both by its fauna and lithological constitution. The presence of the Permian has also been recognized by Mr. C. D. Walcott in the Kanab Valley, Arizona. The evidence in this case, however, is based both on the Permian character of its mollusca and on the stratigraphy, and is regarded as decisive.* The Trias, on the other hand, is believed to exist in this field, since it has been recognized by its fauna, without conflict, in southeast-eastern Idaho,† where a heavy thickness of red beds of precisely similar constitution and habit to those in the present field comes above the horizon of the fossils found, but below the Jura. Still further: The red beds of Fairplay, in the South Park, which also closely resemble those along the eastern base of the Rocky Mountains, have likewise been found to contain a number of unmistakable Mesozoic fossils belonging to the Cockroach family, and referred by Prof. S. H. Scudder to the Trias; but here, it must be admitted, there does occur certain conflicting evidence in favor of the Permian, based on the flora contained; nevertheless, without too great assertion, it may be remarked that evidence from the fauna is regarded the world over as rather more reliable than that from plants, and especially where, as in this case, the horizon marks the advent of a new life, which would more than counterbalance the continuance of an old flora. Finally, the upper of the two series of beds has a distinct lithological resemblance in its sandstones, limestones and gypsums, and in the relative distribution of those rocks, to the Triassic beds of Germany.

Jura.—The Jura for two-thirds its distance from base to summit, or about 130 feet, consists of the drab marly

*Am. Jour. of Sci. Third Series, Vol. XX, 1880, page 221.

†Twelfth Annual Report of the United States Geological and Geographical Survey, F. V. Hayden, U. S. Geologist-in-Charge. Bulletin of the U. S. Geol. and Geog. Survey, Vol. V, No. 1.—Contributions to Invertebrate Palæontology No. 5: Triassic Fossils of Southeastern Idaho—By C. A. White, M. D.

clays known as the "Atlantosaurus Clays" from the remains of enormous Jurassic dinosaurs found near their top. These are overlaid by the "Saurian Sandstone" twenty feet thick, which also furnishes saurian remains, and is furthermore everywhere easily recognizable from its peculiar markings of small, circular, brown polka-dots and by its stratigraphical relations; this, finally, is overlaid by more clays of variegated hue, broken by several narrow bands of sandstone, which extend to the base of the Dakota. The entire formation is of fresh water origin, and is one of remarkable lithological persistence, for its equivalent is found far to the north in Wyoming, to the south at Cañon City and on the western slopes of the Divide in the vicinity of Crested Butte. In the latter locality the narrow bands of limestone in the lower body of clays furnish several forms of fresh water molluscs, traces of which it is thought have been seen in the similarly occurring limestones of the present field.

Cretaceous.—The cretaceous of the Denver Basin consists of the members usually present in the Northwest, that is, of the Dakota, Fort Benton, Niobrara, Fort Pierre, Fox Hills and Laramie. In the arrangement of these formations that given on the maps of the Hayden survey will be followed here, by which the Fort Benton and Niobrara are grouped together as the Colorado, and the Fort Pierre and Fox Hills as the Fox Hills, the name Fort Pierre being discarded altogether, the other groups retaining their full rank as such.* This manner of grouping is given the preference

*Since first writing the above, careful consideration has led to the belief that it would be better to adopt, instead of the nomenclature of the maps of the Hayden survey—by which confusion and inconvenience is likely to arise from the fact that one of the old established names, "Ft. Pierre," is entirely discarded, and another of them, "Fox Hills," is elevated in rank and made to include the former—a nomenclature which contains an entirely new term and by which the old formation names of Fort Pierre and Fox Hills may still be retained in their early signification. The name since suggested for this group is "Montana," a notice of over that of the Fortieth Parallel survey as being the more rational, both from a palæontological and from a lithological point of view of the beds. The Fort Benton and Niobrara, while perfectly distinguishable from each other in a general way, have a broad transitional zone, comprising fully a third of the total thickness of the two groups, and moreover blend in a similar manner as to their fossils. The same is true in regard to the Fort Pierre and Fox Hills, their relations being, if anything, even a little closer. Acknowledging then this intimate relation between the subordinate members of the Colorado and Fox Hills respectively, the argument for the preference expressed above is completed by the fact that a natural gap exists between these two groups, both in their mineralogical constitution and in their fossil life.

A rapid glance at the composition of the several members of the Cretaceous will bring out the foregoing remarks in a clearer light.

Dakota.—The Dakota, the basal member, is essentially a sandstone formation between 200 and 300 feet thick, divided midway by a band of fire-clay into two prominent benches, the lower of which has a bed of conglomerate at its base. The conglomerate is a very well marked horizon characterized by its abundance of well rounded quartzose pebbles, among which gray jasper and chert are abundant, and by its strong silicious cement, which appears to have silicified to a certain extent the pebbles themselves. In this field rolled limestone pebbles, in some of which undoubted

which will be published in a forthcoming number of the Am. Jour. of Science. Briefly, it is to be understood as replacing the group name "Fox Hill" as used in this article and on the Hayden maps, and to include the formations Fort Pierre and Fox Hills as originally understood in the Upper Missouri Section of Messrs. Meek and Hayden.

This suggestion is made with the approval of Dr. C. A. White, whom the change most closely affects, *vide* the volume for 1876 of the U. S. Geological and Geographical Survey of Territories. Hayden, p. 22. White's Classification.

Silurian fossils occur, are also found in the conglomerate. Owing to its hardness these beds generally stand in sharp serrated ridges fringing the main range, which are locally known as "hog-backs."

Colorado.—The Dakota is immediately overlaid by 400 or 500 feet of black clays, the Fort Benton division of the Colorado, the upper third of which has frequent intercalations of limestones carrying the fossils already referred to as blending in their life with those of the Niobrara which immediately succeeds it. This latter formation consists of a prominent forty-foot band of a drab-white limestone of great local economic value, overlaid by a series of siliceo-calcareous shales carrying quantities of the integuments of fish remains, the entire sub-group averaging in thickness about 300 feet.

*Fox Hills.**—The Fox Hills, henceforth to be understood as embracing both the Fort Pierre and the original Fox Hills of the early surveys of Hayden, varies somewhat in thickness in the several parts of the field, but maintains a pretty constant average of about 8,700 feet. It forms a belt just without the little limestone ridges of the Niobrara of a width of between 1½ and 2 miles, marked at its eastern edge by small rocky combs of the frequently outcropping Laramie sandstones. The formation is, to within 700 or 800 feet of the top, a series of drab shaly clays, containing numerous concretions of highly fossiliferous drab limestone, and interrupted only once, about midway, by a band of quartzose sandstone, which rarely shows except in natural or artificial cuts. On approaching the top, however, the clays become perceptibly arenaceous, though still maintaining their shaly character, and it is only within the upper 100 feet that the sedimentation has become sufficiently

* See preceding foot note.

altered to form a solid outcrop of sandstone. This sandstone is very persistent over the entire field, and is perfectly recognizable upon thorough acquaintance by its even grain, which is very fine, by its mixed composition of quartz and mica, by its yellow or greenish yellow color, by its stratigraphical relation to the Laramie sandstone, which immediately overlies, and by a remarkable development of fossils at its very summit, typical of this horizon over the entire West. Among the forms here found are *Cardium* [*Ethmocardium*] *speciosum*, *Mactra alta*, *Tellina scitula*, *Tanacredia americana*, *Vaniella humilis*, *Solemya subplicata*, *Calista deweyi*, *Anchura americana*, *Crenella elegantula*, *Nucula cancellata*, *Sphaeriola cordata*, *Callista* [*Dosinopsis*] *owenana*, *Liopistha* [*Cymella*] *undata*, *Mytilus subarcuatus*, *Turritella*, etc.

No other horizon in the entire group shows such a distinct life as the above, the nearest approach to it being the occurrence of two or three zones in which certain fossils predominate, and which serve the purpose of indicating in a general way in what part of the group one may be working. But, as if to prevent a division of the group, even these forms are found to have a wide range on either side of the zone in which they predominate, some of them indeed occurring almost from base to summit. The stratigraphical position of the zones referred to is, for one, midway the group, for another, three-fourths the distance from base to summit, while the third may be regarded as embracing the probable equivalent of the old Fox Hills group, the upper 800 of the present one.

Laramie.—The closing member of the Cretaceous, the Laramie, occurs with great regularity over the entire Denver field, and embraces between 150 and 250 feet of heavy bedded sandstone, composed almost entirely of clear, glassy quartz, which form the base of the group, overlaid by 400 or 500 feet of drab, white, red or green clays, with nodular ironstones invariably containing plant remains, often well preserved. Along the foot-hills, and in the Louisville, Baker and Erie fields, it is the basal sandstones that carry the coal, but at Scranton, twenty miles northeast of Denver, the bed there worked occurs well up toward the summit of the formation. Its age is determined by its fossils, which are few but characteristic.

*Tertiary: Willow Creek Beds.**—The formation next succeeding the Laramie in geological order, and unconformably resting upon it, is the lower of the three Tertiaries that occur in the Denver field, for which the name "Willow Creek" is here suggested, from the locality in the southern part of the field, from one to three miles southeast of the mouth of Platte Cañon, where it has its greatest and most typical development. It is composed of a basal member of conglomerate, or gritty sandstone, according to its distance from the foot-hills, with an overlying zone of gray, argillaceous or arenaceous shales, containing lenticular masses of hard, quartzose sandstone, with an occasional ironstone; where, confined between under and over-lying groups, it has a thickness varying between 600 and 1,200 feet.

The conglomerate at its base has a thickness, over the greater portion of the field, of about 200 feet, though this may become the bulk of the formation, as in its type locality, or may decrease to the merest edge, as at its northern limit along the Platte river near Brighton. It is extremely characteristic, containing, as it does, pebbles derived not only from

*Instead of the term "Willow Creek," used here provisionally, and which, it is recalled, has already gone into literature as a division of the Canadian Laramie, the name "Arapahoe" is finally proposed, as being both more appropriate when applied to this formation, and also free from the objection of bringing confusion into Cretaceous geology, as the term "Willow Creek" would very likely do.

every formation that lies below it in the Denver field, but also from others far beyond, especially the Carboniferous, of which the debris affords some excellent specimens of Beaumontia, a case parallel to that of the occurrence of Silurian pebbles already mentioned as found in the Dakota. Like the pebbles of the Dakota, too, only in a far greater degree, those of this formation have undergone extreme silification. Jaspers, agates, flints and silicified wood abound, and the debris of the older groups, including the fossiliferous limestone just noted, has often undergone the most complete alteration in this manner. This feature, however, is especially noticeable only in that portion of the formation which, from having been laid down within a comparatively short distance of what was probably the ancient shore line, contains a very large amount of pebbles of the older rocks, and is thus best calculated to show any changes of this kind that may have occurred. Farther out, the conglomerates are replaced by sandstones, still carrying pebbles, indeed, but unaltered ones and chiefly derived from the clays and ironstones of the subjacent group. Between these two points, under favorable circumstances, a complete transition from one class to the other is to be noticed.

Still another characteristic of this group, but one more notably peculiar to that portion of it which is exposed on the prairies, is the frequent occurrence of the remains of Jurassic Dinosaurs, mingled in a most remarkable manner with the horn-cores and other parts of *Bison alticornis*, a new form which, according to Prof. O. C. Marsh, from its relations, may indicate for these beds a late Pleiocene age.

Regarding the presence of the Dinosaurs, the remains of which consist of different, or adjoining, parts of vertebral columns, spines, etc., it is quite possible that they may have been transferred from their original beds in the mountains to the present formation by the ice of that period. Prof. Marsh regards it as quite impossible that their life should have been continued from the older to the more recent age.

The above forms have again been found in the Denver beds overlying the Willow Creek, and are noticed in the accompanying paper by Mr. Cross, but the Dinosaurs have not as yet been found in as great abundance as in the lower group, while the Bison has been found in a much more satisfactory state.

Denver Beds.—As the Denver Group forms the leading topic of Mr. Cross' paper it will not be touched here.

Monument Creek Beds.—The third and most recent of the Tertiaries, embracing the true Monument Creek Group of the Hayden survey, extends but a short distance into the southeastern corner of the region under discussion, but occupies an immense area beyond, forming the great mesas or buttes at the head of Cherry and East Plum Creeks, and extending southward beyond the Arkansas Divide.

Its thickness generally approaches 1,500 feet, and its manner of occurrence shows a break in the continuity of its disposition sufficient in point of time for the formation of a bed of rhyolitic tufa of an average thickness of forty feet.

The material for both portions has been derived from all the older sediments down to the Archæan, but that prior to the period of interruption is distinguished from the portions subsequent to it by the absence of the eruptive material which forms so prominent a constituent of the younger member, and which includes both fragments derived from the rhyolitic bed, and from other igneous rocks, the sources of which have not as yet been ascertained. The dividing band of rhyolite does not extend into the Denver field, but is well exposed in the vicinity of Castle

Rock, where it furnishes one of the finest building stones in the United States.

Though the group is perfectly divisible into two distinct formations it is, for the present, better to retain the name first given, more particularly to its lower member, as a designation for the entire group, especially in view of the very meagre existing information.

The age of this group is undetermined, but Cope,* somewhat contrary to Prof. Marsh's views, regards it as probably Miocene, from certain forms gathered at a point some distance south of the Denver field.

Stratigraphical Relations of the Tertiaries.—The stratigraphical relations of the three divisions of the Tertiary just described bring to light some remarkable facts as to their history. In the first place, by reason of the nearly uniform thickness which the Laramie maintains along the foot-hills, and from the equal angle of dip which this, together with the beds of the Willow Creek formation has assumed, it is impossible to detect any actual evidence of non-conformity between the two groups beyond the presence in the younger of small fragments of the ironstones which are so characteristic of the older or Laramie. In the region of Brighton, however, near the northern limits of the Willow Creek beds, where the strata of both formations are approximately horizontal, it is not uncommon to meet with the younger formation resting in the eroded hollows of the older, and containing rolled clays, ironstones, and pieces of sandstone evidently derived from the underlying beds. Again, a similar relation between the Denver formation and the Willow Creek beds is found to exist at the northern limits of the former where, in addition, repeated evidence

*U. S. Geological and Geographical Survey of Colorado, 1873.—F. C. Hayden, Geologist-in-Charge. Page 430.

also exists of the deposition of the Denver Group in a natural basin of the older rocks, well brought out in the manner in which the Denver beds are found lying upon or against the hills composed of the older formation. Still further east of the Platte River, at several points along Sand Creek, and to the north of it the Denver formation is found resting directly on the Laramie, showing the entire disappearance in certain directions of the intermediate group. These features for the third time appear in the relations of the Monument Creek Group to each of the older ones, for this, according to locality, rests either on the Willow Creek beds, as in the southwestern part of the field, or on the unevenly eroded surface of the Denver beds, as in the southern or southeastern parts, or directly on the Laramie, as on Coal Creek (Upper Sand Creek), near the eastern border of the field. Where it rests on the Willow Creek beds, however, as it does a little south of the Denver field, the evidence of either non-conformity, or even a break in the continuity of the beds, is extremely slight, consisting in but the single doubtful fact that the younger group may possibly have derived a little of its material from the older. All the ordinary evidences of interruption in sedimentation have been completely obscured by the exceptional fact that the composition of the two groups for a long distance on either side of the supposed line of interruption is apparently the same, and by the occurrence of this line in the vicinity of the foot-hills at the very point where the beds change from a horizontal to an inclined position.

In certain portions of the field, as for instance at Golden, where all the formations are present in regular succession except the Monument Creek, the non-conformities thus described may be represented only by a change of sediment, but a change so distinct and sharp that, taken in connection with the general movements of the crust which must have been necessary to bring about the conditions existing in the relations of these groups to each other at other points, it is a strong argument for at least a fairly long break in the geological continuity between the several groups even though lying one upon another in an apparently regular manner.

In the foregoing pages all evidence from plant remains has been neglected on account of the general untrustworthiness of the results thus far obtained.

STRUCTURAL PHENOMENA.

The Golden Non-Conformities.—As the simplest way of discussing the non-conformities in the region around Golden a comparison between the topography of the affected region with that normal for the country in general will first be given, to be followed by an enumeration of the non-conformities with the horizons at which they occur, and finally each non-conformity and the event which led up to it will be taken up in brief detail.

The normal foot hill topography, as may have been gathered from what has already been said, consists of a mountain mass of Archæan rocks, fringed at an average distance of a half mile by a sharp serrated ridge of Dakota sandstone, in the valley between which and the former lies the Trias and Jura, and above which in their geological succession come the Fort Benton; the Niobrara generally constituting a second smaller reef outside the Dakota; the Fox Hills, now including the Fort Pierre; the Laramie, the basal sandstones of which form either a low roll in the ground, or an actual comb of rock slightly projecting above the surface of the surrounding prairie; and finally to the east of the Laramie clays, at a distance of between 600 and 1,200 feet from its basal sandstone, a second comb, of the conglomerates of the Willow Creek Group, followed at about the same distance by either an outcrop, or a peculiar ribbing of the prairie due to the lower members of the Denver formation.

For mile after mile along the mountains the above features may be traced with unswerving regularity, but in the vicinity of Golden these surface features become entirely changed; the Dakota hog-backs have disappeared for over a mile north of the town and for two or three south of it, the Laramie sandstone with its coal has gradually approached to within 500 feet of the Archæan, and opposite this wide topographical gap and resulting valley there appear the two great basalt masses of North and South Table Mountain, Clear Creek debouching from the main range midway their length, flowing through Golden, and cutting the basalt-capped plateau, originally single, into two nearly equal parts.

Excluding the non-conformities of general occurrence throughout the entire field, that is, those between the Archæan and the Trias, the Laramie and Willow Creek, and the latter formation and the Denver beds, there are still to be found three which are peculiar to this locality alone—one at or near the close of the Trias, a second at the close of the Jura, and a third in the Cretaceous, at the top of the Colorado.

Their appearance in the field is rather remarkable, and, before taking them up in detail, an observation had best be made upon the manner in which it has been effected. Entering most prominently into the history of these non-conformities are as many folds, all of which occurred prior to the general uplift of the Rocky Mountains, and hence with the erosion going on at the time represented a completely different topography for the region from that of the present day. When therefore the great uplift of the Rocky Mountains brought the beds into the position they now have, all hills, the result of previous folding, were changed in their individual positions from one in which the plane of their bases was horizontal to one in which it became vertical or at least inclined at a high angle, and parallel to the direction of the mountains. In the subsequent erosion of the region, therefore, what would originally have been a profile section of the strata constituting these folds, now appears as a plan of the same beds on the present surface, all originally north and south dips becoming present north and south strikes, in some cases very slightly altered in character by incidental variations in the amount of folding in the general uplift.

Entering now into the more important details of the geological history of this region, the following succession of events will be found to have transpired since the close of the period in which the Triassic beds were laid down.

The opening incident was the appearance of a comparatively gentle fold, the shape and extent of which it is impossible to estimate beyond that shown by the present cross-section of the beds entering into it. It had a north and south extent, however, of a little over two miles, with the crown of the arch about a half-mile north of the present bed of Clear Creek, and it was of sufficient height to bring nearly all of the upper member of the Trias under the influence of subsequent erosive action.

This movement must be regarded as synchronous with at least a portion of that more prolonged and extensive one by which the sea was sooner or later shut out from certain areas in the Rocky Mountain region of Colorado, causing either a partial or an entire absence of marine beds, according to circumstances, with a succeeding deposition of freshwater strata, in which a lucustrine life appeared. In the area under discussion, the fresh-water Jurassic alone was laid down.

General subsidence continuing against and upon the eroded and uneroded portions of the Triassic beds entering into this fold, or at least upon that part of them which became submerged, were deposited the fresh-water beds of the Jura just mentioned. Whether or not they extended entirely over the pre-existing hill it is, on account of subsequent complications, impossible to say. They are at least wanting at the present time in a wide gap exactly coincident with the upper part of the ancient arch.

At the close of the Jura the same area was subjected to a second uplift less pronounced than the first, but of slightly greater horizontal extent. As in the former case, general subsidence continued, followed without interruption by the deposition of the Dakota, Fort Benton and Niobrara.

While a certain degree of doubt exists as to the Jura having extended entirely across the pre-existing fold, it is very probable that the Dakota never did, though the conditions of subsidence must have been such as to have permitted at least a half of the Fort Benton and the entire Niobrara to have done so.

The deposition of the Colorado having been completed, the rocks underlying this region now for the third time underwent upheaval, the disturbed area in this case covering a far greater scope of country than in either of the foregoing ones, the north and south extent of it, the only direction attainable, embracing a distance of thirteen miles, from a point a little south of Bear Creek to one ½ or ¾ of a mile north of Van Bibber. The profile of this hill, in the direction mentioned, shows a long, gradual slope to the southward, and a short, steep one to the north, with an elevation of at least 4,600 feet above the undisturbed portions of the strata, and somewhat less above the surface of the surrounding sea. Its period of emergence was sufficient for extensive denudation, both from slopes and summit, the entire sedimentary cap, down to within 500 feet of the Archæan, having disappeared from the latter, and a large part of the Niobrara and often much of the Fort Benton from the former. Upon being again submerged, the fine clays, etc., of the Fox Hills were deposited horizontally against its sides, now in contact with one formation, now with another, submergence and sedimentation keeping pace so closely that the entire disappearance of the hill was accomplished only a short period before the close of the Fox Hills period, at most but 200 feet of the upper portion of this formation finally covering the top of the hill.

Sedimentation now continued on through the Laramie, Willow Creek, and a portion of the Denver formations, without any further disturbance from local dynamic movements. Such movements as did occur in this area were parts of the more general ones taking place over the entire field, and, so far as the geological history peculiar to this immediate locality is concerned, it was, for the time being, brought to a close.

It was resumed, however, during the Tertiary age, when the final folding which gave the Colorado Range approximately its present shape took place, and with it the beds of the Denver field assumed the position they now hold. This, together with the outpouring of the lavas of Table Mountain, midway the period of deposition of the Denver formation, must be regarded as the closing feature in the geological development of the area under discussion.

The Boulder Non-Conformity.—The second area of non-conformity lies in the foot-hills in the vicinity of Boulder, extending southward from North Boulder Creek, for a distance of about three miles, but reaching to the north of it not over a mile.

With the exception of the usual one between the Archæan and Trias, there is here but a single break in the continuity of the strata, this occurring at the close of either the Dakota or Fort Benton, probably the former, though the rocks are not sufficiently well exposed to determine it positively.

In this case the beds were continuously deposited to the summit of the Dakota, when after suffering a fold similar in character to those at Golden, the arch became eroded to within 200 or 300 feet of the Archæan, and upon subsequent submergence of the region permitted the deposition upon what remained of the fold of the Fort Benton and Niobrara, the latter alone probably extending completely across the arch, though it would be possible for the upper part of the Fort Benton also to have been laid down in certain hollows on the old sea floor. Above the Niobrara everything is regular.

The discovery of this second area of non-conformity along the base of the mountains within the limits of our field strongly hints at the possibility of others north and south of it, and points to a state of general unrest not only throughout a considerable distance along the range, but also as enduring through the several ages represented by the strata laid down.

The times at which the movements in one area took place may not correspond to those at which the movements in others came to pass.

Faults.—The faults of the Denver field may be classified, according to their origin, under three heads: *a*, those which resulted from forces acting in the general uplift of the Colorado Range; *b*, those which resulted from forces acting independently of the first, but still affecting broad areas; and *c*, those which resulted from local causes alone.

Class "a" includes the larger type of structural faults produced by the same force which caused the main mountain uplift—that is, by lateral pressure acting nearly at right angles to the axis of the range and of the greater folds—hence faults generally parallel in trend to the axis of these folds. It is represented in this field by the fault at the South Boulder Peaks, whereby a double peak has been formed; by another midway between South Boulder and Coal Creeks, occurring entirely within the range; and by a third just north of Deer Creek, by which several hundred feet of the trias have been repeated, with a narrow strip of Archæan also exposed at the fault line. In all of these faults the downthrow is to the west.

Class "b" includes a system of faults in the northwestern portion of the field, in a general way confined to the triangular area between Coal Creek, the mountains and an east and west line a little north of Boulder Creek. Its component lines of dislocation are grouped in such a manner as would at first lead one to suppose the presence of a series of curvilinear faults concentrically arranged and extending in their curvature through nearly the quadrant of a circle. Detailed examination, however, renders this view somewhat uncertain and suggests the possibility of the resultant curves each being composed of three distinct and approximately linear faults, the southern having a north 60° east trend, the medium a north 30° east, and the northern a direction north or a few degrees west of north.

The distance between the faults varies from one to four miles for different blocks, and the stratigraphical throw generally amounts to about 150 feet, the opposing strata being confined to the upper part of the Fox Hills and the basal sandstones of the Laramie. Two exceptions, however, to this regularity of displacement are found in the prominent faults east of Coal Creek, where beds of a much higher horizon, in the shaly zone of the Laramie, are brought in contact with the top of Fox Hills.

The beds of the intermediate blocks may be flat, inclined or rolling, and the effect of the faults may be either repetitive or compensative.

Of the compensative faults the examples are not pronounced, but of the repetitive faults an excellent example is found north of Boulder Creek, where the degree to which the interfault blocks have been tilted the width of the blocks, and recent erosion have carried the westernmost outcrop of coal eastward to Canfield and Erie, notwithstanding the fact that at each repetition the horizon of the coal has been brought far above the present surface level.

The faults of this group are all strike-faults and include not only the normal type, but also the reversed fault; some are undoubtedly developed from monoclinal flexures produced by subsidence, while it is possible that lateral compression may have been sufficiently strong to have produced the reversed ones. The effect of lateral compression is moreover proved by the gentle rolls into which the strata both within and without the fault region are thrown, the axes of the rolls being parallel to the faults and changing direction with them. It is very probable that both subsidence and lateral compression were in play within short intervals of each other during the same geological time, and that it is their combined action which resulted in the curvilinear effect of the faults already mentioned, whether it signify a series of concentric breaks extending continuously through the arc of a circle, or three distinct systems of faults in such relative positions as to produce this appearance. In addition to the above there have been developed in certain localities undoubted torsional strains, an especially good illustration being found in the divergent faults and accompanying folds in the vicinity of the prominent mesa immediately northeast of Marshall.

Class "c" of the faults in the Denver field, comprising fractures of local origin, includes certain ones which are confined to regions of eruptive action, and others not so confined and which are connected with phenomena of an altogether different character. Among the former are three fractures of peculiar occurrence midway betgeen North Table Mountain and Ralston Creek, the singular features of which are chiefly due to exceptional local conditions connected with the neighboring eruptive phenomena. The fractures bound the western, northern and southern sides of a rectangular block of strata of indefinite but not great thickness, beneath which there is probably an important mass of eruptive rock, a part of that which occupies the western of the three rents and forms the prominent north and south dyke of this immediate locality.

The block of strata inclosed by the fractures has a north and south extent of a little over a mile, and an east and west one about twice as great. Its component strata include rocks of the Fox Hills, Laramie and Willow Creek groups, completely shattered and in a most chaotic state, except in the very eastern part of the area, where their uncertain dip becomes a little more regular and gradually shallows off into the horizontal position of the beds beyond the disturbed region.

Regarding the origin of the three fractures, that on the west occupied by the dyke already mentioned probably antedates the others and is the combined result of the general folding taking place along the Colorado Range and the mass of eruptive material seeking an outlet at the sur face through the channel of least resistance. Its plane coincides in general with that of the stratification which is now quite vertical, though at the time of the eruption it was probably considerably less. No displacement resulted from the foregoing phenomena and hence the fracture cannot at this stage be regarded as a true fault. The events, however, which are to be immediately described did produce a displacement along the southern half, and consequently this portion of the fracture thereafter assumed the nature of a fault.

The two east and west fractures resulted at once in faults, the displacement of the beds being very marked. Though their initial cause is to be attributed to the folding of the beds along the range subsequent to the outpouring of the lava, their direct origin is traceable to a local enlargement of the mass of the dyke at this point, which formed a much less yielding rock mass than the clays to the east, and hence, as the folding advanced, at last compelled a rupture and dislocation of the overlying beds.

The resistance to the strain developed by this condition of affairs is well shown at several points in the disturbed area, but more especially along the northern fault-line, where there is abundant evidence in the normally flexed ends of the opposing beds of the presence of a considerable amount of distortion and bending before they finally yielded to the force of compression thus brought to bear upon them.

By the dislocation which followed, the beds involved in the local fold were brought with much violence to their present position, and the discordant juxtaposition of beds now existing there was produced.

The second variety of faults under Class "c" includes certain small fractures in the area of the Golden non-conformity, and one a little more extensive near the southern end of that at Boulder. All are well shown under favorable conditions in the harder strata of the Niobrara, Dakota, Jura, and Upper Trias, and appear at the present time as horizontal east and west displacements of these rocks, of from 18 inches to 60 feet in extent, that near Boulder alone reaching a higher figure, between 400 and 500 feet. As regards the faults in the vicinity of Golden, it is but necessary to recall in connection with the surface details of to-day the topographical and geological features of the ancient fold which was formed at the close of the Colorado, to readily conceive of their being the present representatives of a succession of parallel normal strike faults symmetrically arranged on either side of the fold and having their origin in the movements of that time. The presence of horizontal slickensides, which under ordinary circumstances would be an argument for an actual horizontal throw, are, in this case, but stronger evidence of the view first advanced.

The apparently horizontal displacement referred to as at the southern end of the Boulder non-conformity may very likely have a similar history, though here there are certain evidences which did not exist in the former case, for its origin being synchronous with the general uplift of the range.

COAL.

Geology.—The workable coal of the Denver field is confined to the Laramie group, and occurs at two widely separated horizons, one high up in the shales, where it is developed only in the eastern part of the field, the other in the sandy series at the base of the formation, and which in all probability extends throughout the entire region.

The former field is of comparatively small extent and lies almost entirely to the east of the necessitated limits of the map. The presence of its coal has been proved northward as far as Scranton and southward to Coal Creek (Upper Sand Creek), its eastern limit still remaining undetermined. In both the localities mentioned it is, within a short distance, overlaid by the Monument Creek beds, though from portions of the intermediate area this group has been eroded, leaving the Laramie clays as the surface beds. Like all other coals of the Laramie, the material out of which it has been composed was laid down in a shallow local basin, and in its thickness varied greatly from place to place.

The lower horizon is the important one of the field, furnishing, as it does, nearly the entire amount of coal mined in the vicinity of Denver. The distinguishing features of this horizon are: First, the massive sandstones at its base, lying immediately upon the Fox Hills, and characterized by a narrow median band of vegetable remains sometimes altered to coal, the whole attaining a nearly uniform thickness of from 120 to 150 feet; second, an overlying zone of sandstones and shales in interchangeable proportions, in all, between 50 and 75 feet thick, through which occur the coal beds, and near the base of which is found at certain localities a calcareous sandstone from one to four feet thick, in which are imbedded great quantities of *Ostrea glabra*, together with a few other characteristic Laramie forms; third, the immediate succession above of the great mass of Laramie clays and ironstones already referred to earlier in this paper.

The strata of the lower coal horizon are exposed in a highly inclined position along the foot-hills as far north as Marshall, when, through the combined action of upheaval and erosion, they are suddenly brought into a horizontal position, or one in which they have a slight general dip to the southeast, and the trend of their outcrop becomes diverted in such a manner as to carry them well out on the prairie towards Erie, several miles to the northeast. In this part of the field, by reason of the faults described in the last section, these beds have often suffered sufficient elevation to bring their coals either within easy reach of the surface, or to have caused them, under the influence of erosion, to be entirely removed from certain areas.

The coal of this horizon occurs in several seams, usually four or five, any one of which may develop to a workable size or diminish to the thinnest stratum of brown carbonized leaves or stems. The workable portions assume the shape of shallow lenticular bodies, from three to ten feet thick, and from a quarter to several square miles in area; and since their presence or absence in a certain locality depends entirely upon the ancient conditions of deposition, the greatest uncertainty prevails, not only as to their occurrence, but also as to the maintenance of even a workable width. To this cause is due the fact that the valuable beds along the foot-hills are so often interrupted, and that in the prairie regions the horizon, though it may be within a short distance of the surface, is completely barren. For the same reason, also, it may not be the same seam that occurs in workable size at the several mines along the foot-hills, and from their irregularity of occurrence and perhaps entire absence, no data exist for determining the individual seam opened at the various points. This point especially should be borne in mind in all observations upon the coal, the results of which cannot but be general for the horizon, instead of characteristic of any single bed in it.

Regarding the presence of bodies of workable coal in parts of the field other than those which have already been proved, it is very probable, from the above conditions of deposition and the frequency of occurrence of the known bodies along the present outcrop of the horizon, that other deposits of equal extent and quality exist beneath the great series of Tertiary and Upper Laramie beds underlying the plains. Their great depth, however, which cannot be less than between 800 and 1,400 feet, even from the very point where they bend sharply to a vertical position, taken in connection with the uncertainty of their existence under any definite tract of land, should, in view of the quality of the coal and the capability of the mines already opened, not only in this field, but also in other parts of Colorado, prevent any deep prospecting for coal alone for years to come.

Classification.—The coals of the Denver Basin are discovered, upon chemical analysis, to be divisible into three distinct classes, each of which is confined to a certain portion of the field as at present developed, and, moreover, has for that portion a remarkable uniformity of chemical composition.

Of the divisions of the field thus referred to, one embraces the several areas under which the beds of the lower horizon have an approximately horizontal position, and includes the mines of Marshall, Louisville, Davidson, Canfield, Erie and Coal Creek; a second is confined to the vertical beds of the same horizon, along the foot-hills, and extends from beyond the southern border of the area mapped, northward to Marshall; while the third conforms with the area of the upper coal horizon, in the vicinity of Scranton, just without the eastern border of the map.

The analyses upon which the classification of these coals is based are given in the subjoined table, and are the work of Mr. L. G. Eakins of the U. S. Geol. Survey.

Class.	Description.	Proximate Analyses.						Percentage of Constituents of Fuel.		
		Fixed Carbon.	Volatile Matter.	Water.	Ash.	Sulphur.	Specific Gravity.	Fixed Carbon.	Volatile Matter.	Fuel Ratio. C / V H-C
I	Lower Horizon. Horizontal Beds	44.89	34.27	16.06	4.10	.68	1.338	56.71	43.29	1.31
II	Lower Horizon. Vertical Beds.	36.60	34.30	22.12	6.19	.79	1.332	51.62	48.38	1.07
III	Upper Horizon	29.92	31.17	26.29	12.17	.45	1.346	48.98	51.02	0.96

Class I resembles in its physical appearance many bituminous coals of the East, and in its fuel ratio, or the relation of its volatile matter to the fixed carbon, might be compared with certain coals of the lower portion of the Pennsylvania bituminous series, were it not for the proportionately great amount of water it contains, and the fact that the total percentage of its fuel constituents is much less than that universally present in the Eastern coals. Regarding the water, moreover, it should be added that it cannot be considered accidental, but must be looked upon as a permanent characteristic of the coals of this class throughout the Denver field. This coal withstands weathering well and is the highest of the coals about Denver in economic value.

Class II has, on account of its average composition as sampled at the present depth of the mines, been given a separate division in the scale, but there is reason to believe that its coals are but an altered condition of those belonging to Class I, and that were it possible to trace the horizon in depth, the vertical beds into the horizontal, there would be found a gradual passage in their chemical composition of the one into the other, Class I, of course, having the representative composition of the bed in its original undisturbed position. In accordance with the very probable causes of this alteration, the change in composition would take place in the vicinity of the sharp fold at which the beds assume their different positions. The views just expressed arise from the facts, that the horizontal beds have been least subjected to physical changes since their formation, that they and the vertical beds are of the same horizon, and that in the deepest mine of the latter class, by some 300 to 400 feet, the samples from its lower levels are found to approach in a very marked degree the composition of the horizontal beds, the average of several analyses giving:

Fixed carbon	42.93
Volatile matter	34.19
Water	18.85
Ash	3.58
Sulphur	.45
	100.00
Specific gravity	1.356
Fuel ratio	1.25

Regarding, therefore, these two classes as originally one, a most peculiar anomaly occurs in the character of the alteration which the coal of the vertical beds has undergone; for, contrary to the evidence of other fields under like circumstances, it is found that there has been an actual diminution in the per cent. of fixed carbon, with a maintenance of the normal amount of volatile matter, an alteration the exact reverse of that which usually takes place. In explanation of this peculiarity it has been suggested by Mr. Eakins that after the lighter hydrocarbons of the normal coal had been driven off by the increased pressure, heat and crushing of the beds accompanying the folding of the Colorado Range, their place was supplied by the partial breaking up of the heavier hydrocarbons remaining behind, and that thus the amount of carbon became diminished while the volatile matter remained the same.

Class III is characterized by the excess of volatile matter over the fixed carbon, by the extremely large proportion of water contained, and by its high per cent. of ash. It weathers most easily upon exposure to the atmosphere, its color becoming a brownish black, and there develops sooner or later throughout the more exposed portions of the mass a decidedly earthy appearance in its character. It is, in fact, a lignite, if we regard this term as signifying merely a position in the scale of coals above peat and below the varieties of coal coming near the base of the recognized bituminous series. It is a class in which the fuel ratio more often falls below than exceeds one, at least in America, and it contains those coals which are lowest in economic value in the Denver field.

THE DENVER TERTIARY FORMATION.

BY WHITMAN CROSS.

Introductory.—The following paper is an abstract of a chapter upon the same subject which will be contained in a report upon "The Geology of the Denver Coal Basin," to be published by the U. S. Geological Survey. The work has been done under Mr. S. F. Emmons, Geologist-in-Charge of the Rocky Mountain Division of the survey, and in co-operation with my colleague, Mr. G. H. Eldridge, to whom the greater part of the stratigraphical work has fallen. This abstract is made and presented with the approval of Mr. Emmons.

The formation to be described embraces strata which have not hitherto been distinguished by geologists from the coal-bearing Laramie Cretaceous. The beds have a quite limited extent, and though bearing some fossil remains have not as yet been correlated with any known horizon. They possess inherent characteristics of great interest, and the establishment of the series as a Tertiary Formation has some important relations to certain stratigraphical and palæontological questions. As the beds form the surface about the city of Denver the complex may be conveniently and appropriately named the Denver Formation.

The Denver Formation is, then, one of four distinct Tertiary series in the vicinity of Denver. Below it is the Willow Creek series, identified by Mr. Eldridge and described in the preceding communication. Above it and unconformable with it come the Monument Creek beds, and above them another as yet unnamed series. No one of these has yet been satisfactorily correlated with the great Miocene Tertiary Formation on the plains southeast of Denver.

Area occupied.—The total area of the district occupied by the known Denver beds is somewhat less than 400 square miles. The western boundary is a line running along the western bases of Table Mountain, at Golden, and of Green Mountain, the bare hill between Denver and Morrison. From this line the formation extends eastward, occupying the block of ground between Clear and Bear Creeks, underlying the city of Denver, and stretching off to the southeast until it passes under the Monument Creek Tertiary of the high lands at about the horizon of Parker's Station, on the Denver, Texas and Gulf Railroad. The northern boundary is approximately the northern bank of Clear Creek to the Platte, and the southern bank of Sand or Coal Creek from the Platte to a point about fifteen miles southeast of Denver. The southern limit is a line turning abruptly east at Mount Carbon, on Bear Creek, and running toward Littleton, but bending to a southeasterly course before reaching the Platte, which stream is crossed about four miles south of Littleton. From Coal Creek to the Platte the Formation is limited by the unconformably overlying Monument Creek Tertiary, at the elevation of 5,800 to 6,000 feet.

Within the boundaries indicated the strata lie with practical horizontality, excepting along the western border. They may be seen in numerous outcrops throughout the area, and, although it is beyond the scope of this article to give descriptive details, a few localities will be mentioned at which the formation may be seen in good exposures for study.

Characteristic outcrops.—The entire known thickness of the Denver beds can only be seen by combining the exposures of Table and Green Mountains. Under the protecting basalt sheets of the former may be seen the greater part of the lower 500 feet of the beds, though the actual base of the series cannot be clearly made out, and no outcrop shows the thickness mentioned connectedly. The characteristic features of the Formation may be most advantageously studied in the various outcrops of South Table Mountain.

On the western face of Green Mountain, and in a ravine at its southwestern base, the entire known thickness of the Denver beds and the relations to the underlying Formations are more fully shown than in any other place. The Laramie, the Willow Creek and the lower Denver strata are seen in vertical position at the western base of the mountain, while on the steep slope above the gradual decrease in dip to the horizontal conglomerate of the summit is clearly visible. The estimated thickness of the Denver beds here exposed is about 1,400 feet. The upper half of these strata are to be seen only in Green Mountain, having been eroded away in all other parts of the area.

There are many outcrops of these beds in and about the city of Denver, the most instructive ones being on the west bank of the Platte, and in particular may be mentioned: The ravine crossing the Boulevard at St. Luke's Hospital, Highland; the banks of the tributary of the Platte which crosses the Windsor Addition; and outcrops on the river bank, in cuttings of the South Park Railroad and in gullies opposite Jewell Park.

The "High Line" Ditch shows the Denver beds in many places between the Platte and Cherry Creek, and numerous outcrops may be found in the banks of the chief ravines of the area between Cherry and Coal Creeks.

The strata of the plain portion of the area all belong to the lower 500 feet of the Formation, and the thickness of these beds underlying the city of Denver is very small, judging from the artesian well borings. The only outcrops belonging to this series which seem to have been at all closely examined by the geologists of the Hayden survey are those exposed on Table Mountain, and they have been uniformly referred to the Laramie, both by the geologists and palæontologists.

Stratigraphical relations.—The age of the Denver Formation is as yet by no means closely established, for the numerous fossil remains that have been found in it have, with a single exception, proven to be of little determinative value. Its distinctly independent position as a Formation of Tertiary age has, however, been clearly shown by its stratigraphical relations and by the remarkable composition of its strata. The independence of the Formation was first established by the character of the materials in its sediments; then came the confirmation through the discovery of the earlier Willow Creek Tertiary by Mr. Eldridge; and, last of all, the finding of a fossil which is likely to determine the age within certain broad limits, though its precise value is not yet known.

Although the details of the stratigraphical relations between the Denver and Willow Creek Formations are not very fully known, it is clear that the former occupies a basin excavated out of the latter, or even in some parts cutting into the underlying Laramie. The evidence of this relationship is found in certain places along the southern boundary of the Denver beds and in the hills or bluffs north of the mouth of Clear Creek. From the Platte

River above Littleton the line between the Denver and Willow Creek beds runs diagonally in a southeasterly direction up to the Monument Creek strata of the plateau. No exposures of the actual contact of the two Formations are here known, but the course of the line is pretty well located by outcrops not far away on either side. It is found to be characteristic of the Denver strata near this line that they contain much more quartz and red feldspar and other minerals originating in Archæan rocks than is normal for this horizon. In places there are strata which consist almost wholly of such materials, but these are found on examination to be local developments and to grade off, as seen in continuous outcrops, into normal Denver sandstone. Such admixtures bear witness to the nearness of the shore-line which was here cut out of the friable grits of the Willow Creek.

North of Clear Creek, Mr. Eldridge found most irregular relations between Denver and Willow Creek beds, the former being apparently deposited in hollows and irregularities of the latter. Along the line of Sand Creek the Denver beds rest directly on the Laramie, the earlier deposits having been wholly destroyed.

The fact that the Denver strata take part in the great fold along the base of the foot-hills, as seen in Green Mountain, where the lower beds are in vertical position, is conclusive proof of the comparatively recent age of a part of this movement. That the folding was recurrent or continuous through long periods is shown by the pebbles of cretaceous and still older sedimentary rocks found in the Willow Creek and Denver conglomerates.

The basalt of Table Mountain is contemporaneous with the Denver strata of the horizon at which it is now seen. The small basalt streams below the main sheets, which are covered by Denver sediments, are proof of this. The numerous zeolites in the lower sheet of basalt are doubtless due to the exceptionally favorable conditions surrounding this sheet for a long time, as it lay submerged in the Denver sea, protected by an overlying lava flow.

Mechanical constitution.—In mechanical constitution the Denver beds exhibit a great variability, and illustrate admirably the products of shifting conditions of deposition. In the lower half of the Formation, including all known strata except those in the upper part of Green Mountain, there is a frequently recurring alternation of conglomerates, grits, sandstones, sandy clays and nearly pure clays. The pebbles of the conglomerates here seldom exceed three inches in diameter. The sandstones show typical cross-bedding. Coarse rapidly deposited beds often lie irregularly on the fine clay preceding them, and contain rolled masses of the same. Delicate leaves are preserved in quantities in many layers, and upright stumps of trees are sometimes found. The upper strata are predominantly coarse conglomerates with minor clay and sandy beds.

Peculiar and characteristic nature of the materials in the Denver sediments.—The character and duration of the interval between the Willow Creek and Denver epochs is indicated by the great difference in the nature of the materials composing their sediments. It is a fact of the greatest importance and of thoroughly distinctive value that the Denver strata are mainly made up of the debris of andesitic lava flows. This change in composition of sediments appeared with the earliest Denver beds, and it may almost be said that the lower half of the series is made exclusively of such material, for pebbles or grains of any rock or mineral derived either from the Archæan or from an older sedimentary Formation are entirely wanting in many strata, and are extremely rare in all this portion of the beds. Only adjacent to the shore-line of Willow Creek grits is any considerable amount of quartz, red feldspar, or of granitic fragments to be observed. In the beds of Table Mountain Archæan materials are particularly rare.

Owing to this peculiar composition the sands and clays of the Denver beds may be quickly recognized when their constituent particles are examined under the microscope. Even seemingly pure clays are found to contain fragments of angite or hornblende or plagioclase, such as are seen to be the chief constituents of the andesitic pebbles in the coarser layers. Among the pebbles may be found almost every variety of andesite, from the quartz-bearing biotite rocks, through the hornblendic and angitic forms, to the most basic variety—hypersthene-andesite. Rocks of other families have not been identified. In structure there is also a great range in these rocks, from massive, almost granular holocrystalline types, to those of a vesicular structure, with more or less glass in the ground mass. Many of the pebbles are very fresh, and all the variations in composition and structure that have been indicated are well shown.

The sandstones and clays of the Denver beds as shown on the plains are usually reddish brown in color from oxidation of the iron-bearing minerals, and there is frequently a great development of zeolitic silicates, as the cement of sandstones. Some sandstones near the surface contain as much as 50 per cent. of substance soluble in hydrochloric acid. These rocks are therefore adapted to form exceptionally fertile soils.

Conclusions from the composition of the beds.—Reflection upon this peculiar composition of the Denver strata and its meaning leads to the inevitable conclusion that prior to the Denver epoch there was a time of great volcanic activity in the continental area to the westward, during which a great series of andesitic lavas were poured out. These lavas must have had a great lateral extent and a thickness sufficient to conceal the crystalline schists over large areas. Such a great succession of lavas, related in general types, but varying so greatly within the group, must have required a long time for their eruption.

The enormous lava fields required by the above conception have now been completely destroyed; at least no corresponding rocks are known at present on the eastern slopes of the Front Range contiguous to this district. But the complete destruction of large lava flows on the mountain slopes adjacent to the Denver sea is the great historical fact recorded in the beds deposited. For more than 700 feet the Denver strata are, as a rule, very fine grained; the coarsest conglomerates are made up of small pebbles, and the grits and sands and clays are simply still finer attrition products. Hence these strata, now covering nearly 400 square miles, and of previous much wider extent, represented a vastly greater amount of lava fields destroyed.

That these andesitic lavas practically covered the entire Archæan area tributary to the Denver sea is a logical deduction from the composition of the strata. The Archæan rocks, and particularly the quartz bearing varieties, are much more capable of resisting attrition than are eruptive rocks; and, hence, these materials would have been prominent in the Denver sediments had they gained access to the sea. But any possible doubt as to this conclusion must be dispelled by the proof of its correctness found in the upper half of the formation.

At about 900 feet above the base of the Denver beds, a horizon now only preserved in Green Mountain, there appears a conglomerate containing, in addition to the greatly predominant andesites, pebbles of granite, gneiss, red sandstone, white sandstone, fossil wood and of the peculiar hard conglomerate from the base of the Dakota cretaceous. From this horizon upward for 500 feet the quantity of Archæan rapidly increases, and is more abundant than andesite in the upper strata. These upper beds are also much coarser than those below. This change simply shows that the thick covering of lavas was at last worn through, exposing Archæan schists, and also the upturned edges of the Mesozoic strata which had already contributed to the conglomerates of the Willow Creek. The strong predominance of Archæan in the highest horizons of the Denver beds now remaining shows that the lava flows were nearly gone at that time.

While the eastern slopes of the Front Range west of the Denver basin have not been as yet examined for remnants of lava flows there are several facts which indicate that such remains do not exist. No such bodies have been reported in the knowledge of the writer; the smaller streams heading in the foot-hills do not bring down pebbles of such rocks. Clear Creek, heading in the heart of the range, does bring down pebbles and boulders of various eruptive rocks, but they are different in structure and degree of crystallization, and often in mineralogical composition, from the andesitic pebbles of the Denver beds. These eruptive rocks found in the boulder beds of the Clear Creek Valley from Golden to Denver are of types occurring in dykes and larger masses at the head waters of the stream, near Georgetown, Central City or Idaho Springs, and such masses are unknown in the immediate foot-hills.

From the standpoint of modern petrography it is altogether possible that these masses of more crystalline rocks represent the channels through which the surface lavas came up, or are contemporaneous bodies which cooled at considerable depths. As yet it has been impossible to study the masses in the field and collect fresh materials upon which to institute comparisons.

The fossil flora of the Denver Formation.—In discussing the chronological position of the Denver Formation, there is a good deal of palæontological evidence to be considered, in addition to that of stratigraphical character which has been given. But, as was intimated above, the greater part of this evidence is at present of little value, for reasons which will now be given.

The vicinity of Golden has become celebrated in geological literature on account of the great number of fossil plants which have been found there. The greater number of these plants were found on South Table Mountain, all the strata of which belong to the Denver beds. But, as all earlier geological descriptions of Table Mountain referred its strata to the "Lignitic" or Laramie Group, so all palæontological discussions have considered these leaves as of typical Laramie species. The fossil flora of Golden has, up to the present time, been treated as a unit, and as belonging to one of the lower divisions of the Laramie.

Until the recent publications of Prof. L. F. Ward, the descriptions of Golden plants have all come from Leo Lesquereux. The original notices appeared from time to time in the Reports and Bulletins of the Hayden survey. In his monograph on the "Tertiary Flora of the Western United States" are the revised descriptions of 95 plants accredited to Golden; in the later monograph on the "Cretaceous and Tertiary Floras" are eight additional species from this locality. Deducting two varieties and a species of fossil wood found loose without connection with any strata, there remain 100 distinct species described from the general locality "Golden." The majority of the specimens upon which these descriptions rest have been deposited in the U. S. National Museum, but a considerable number have been lost in transit. All specimens now preserved in the Museum have been carefully examined by the writer* in order to determine, from the matrix, the horizon from which the specimens came. Before giving the result of this scrutiny an analysis of the published data concerning these species is desirable.

Of the 100 Golden species referred to above 81 per cent. are species originally described by Lesquereux; 59 per cent. have only been found at Golden, 52 of them being new species; of the remaining 29 per cent. of new species a large proportion were named from the Golden specimens and afterwards found elsewhere. As to the exact horizons of the species, 3 per cent. only are definitely stated by Lesquereux, under the heading "Habitat," to come from the known coal-measure sandstone, and 13 per cent. are stated to come from Table Mountain. From indirect statements, and by all justifiable inferences, it may be considered almost certain that 9 per cent. came from true Laramie strata and 16 per cent. from Table Mountain. The writer does not find any statements from which the horizons of the remaining 75 per cent. of the plants described can safely be inferred. Forty out of fifty-two new species found only at Golden are described without a specified horizon.

The specimens of these 100 plants now preserved in the National Museum are all catalogued as from "Golden, Colorado," with no specifications as to horizon. Seventy-nine species were found, and the rock carrying each plant

*All facilities for this examination were most courteously granted by the curator in charge of fossil plants, Prof. Lester F. Ward.

was examined. Of these 18 occur in Laramie sandstone or shale, and 59 in distinct Denver beds of Table Mountain, while 7 were found in both rocks, leaving 9 cases in doubt. Two of these judgments are in conflict with the statements of Lesquereux, one in each Formation.

Lesquereux gives the horizon of 4 species which were not found. Combining the two sources of information, it is probable that of the 100 plants 22 species came from true Laramie strata and 63 species from Denver beds, with 9 of these common to both Formations.

Since the publication of Lesquereux's monographs, further collections have been made at Golden by Prof. L. F. Ward, palæobotanist of the Geological Survey and curator of fossil plants in the U. S. National Museum, and by the writer in the course of the present investigations.

Professor Ward has been unable from this new material to distinguish between the two Formations concerned. In his work upon the "Types of the Laramie Flora,"* Professor Ward confines himself to new material not studied by Lesquereux, and but five species from the Golden region are included. One of these came from the Laramie, three from Table Mountain, and one, accredited by mistake to Golden, was collected by the writer in North Denver (Highland.)

These statements, here necessarily very concise, seem sufficient to justify the statement that the fossil plants of the Denver beds cannot at present be used in determining the age of the Formation. Nor can the species concerned be used as determinative forms for *any Formation* until their distribution has been studied with reference to the facts

*Bulletin 37, U. S. Geological Survey, 1887. Also, "Synopsis of the Laramie Flora," in Sixth Annual Report of the Director of the U. S. Geological Survey. 1884-85.

which have been given. Moreover, all conclusions which have been drawn from the evidence of fossil plants as regards the age and relations of Western Tertiary Formations are to some extent subject to revision, for all the Golden plants have been treated as Laramie in these discussions.

Individual species have not been mentioned in the above discussion for the reason that the meaning of the new evidence as to distribution can only be determined by a specialist after renewed investigation. The number of species common to both Formations is probably much greater than is indicated by the figures above given.

Invertebrate fossils.—But few invertebrate fossils have been found in the Denver beds, all of these coming from the ravine by St. Luke's hospital in Highland, where they were found by Mr. T. W. Stanton, in association with fossil leaves and a small tooth of a crocodile. The very imperfectly preserved shells were found in a fine-grained crumbling sandstone. They were submitted to Dr. C. A. White, of the U. S. Geological Survey, for determination. In his reports on them, made to Mr. S. F. Emmons, Dr. White says that the genera *Unio*, *Viviparus*, *Goniobasis*, *Physa* and *Corbicula*, were recognized, and all in forms occurring in the Laramie, though also represented in Tertiary Formations. No definitely characteristic forms are included in the number of fossils as yet found, and they cast no further light on the age of the Denver Formation.

Vertebrate fossils.—The vertebrate remains occurring in the Denver beds are of great interest, and together with those of the underlying Willow Creek Formation present some problems which will require further material before they can be solved. A description of the vertebrate remains found in the Tertiary beds of the Denver basin will be contributed to the final report, by Prof. O. C. Marsh, and a few general statements are all that need be made here.

In the Denver beds occurring on the west bank of the Platte have been found a goodly number of large bones (vertebræ, ribs, leg bones, etc.), which are recognized by Prof. Marsh as belonging to several different genera and species of Dinosaurs of Jurassic or of Cretaceous age, and unknown in more recent formations. The bones are usually well preserved and are not worn. In spite of this fact it is most probable that these remains have been transported from Jurassic or Cretaceous strata to their present resting place. But it is as yet unexplained how it happens that they are unaccompanied by pebbles of the strata which contained them, or of adjacent sandstones. They are now found in fine-grained brownish sandstones of normal character for the Denver Formation.

The fossils which have so far been mentioned do not seem to define the age of the Denver beds any more closely than is done by stratigraphical data. But a fossil now to be referred to has apparently a more decisive value. This is the remarkable *Bison alticornis*, n. sp., briefly described by Prof. Marsh in the Am. Jr. Sc., October, 1887. It was found by Mr. George L. Cannon, Jr., of Denver, in a bank of typical Denver sandstone in the Windsor addition to the Town of Highland. Two long horn cones and a portion of the skull were found in this place. Other fragments, apparently of the same species, were found by Mr. Eldridge in Willow Creek beds north of Clear Creek. This *Bison* is said by Prof. Marsh to indicate "one of the largest of American bovines, and one differing widely from those already described." From this fossil alone Prof. Marsh would conclude that "these deposits are more recent than the Equus beds, and probably Pliocene." In view of the stratigraphical relations it seems probable that this conclusion will need to be modified somewhat when the various Tertiary Formations of this region have been correlated with others of known position.

The survey is under great obligations to Messrs G. L. Cannon, Jr., and T. W. Stanton, of Denver, for information in regard to the vertebrate and invertebrate remains occurring in the Denver beds near the city. The former has discovered a large proportion of the dinosaurian remains as well as the important *Bison,* and the latter found the fossil shells that have been mentioned.

DETERMINATION OF SILICIC ACID BY CONVERTING IT INTO SILICIC FLUORIDE.

BY WM. P. HEADDEN.

The desire to avoid the necessity of making a fusion and afterwards treating the weighed residue with hydrofluoric acid and considering the loss to be SiO_2 in analyses of ores and slags containing $BaSO_4$, or compounds which give rise to to it, led to making some experiments, of which the following is the result:

The material used was a crystalline slag from the Horn Silver dump and contained 35.5 per cent. SiO_2; this determination was made in the ordinary way.

The plan of experimentation was to convert the silicic acid into the corresponding fluoride by mixing the pulverized ore with five times its weight of fluor-spar and heating the mixture with sulphuric acid in a retort—a leaden one was used—the delivery tube of which passed into alcohol containing not less than 92 per cent. anhydrous alcohol, for if it contains more than 8 per cent. of water the silicic fluoride is taken up with gelatinization which is to be avoided. The alcoholic solution was then rendered strongly alkaline by ammonium hydrate or carbonate.

There were several mechanical sources of error. The retort was made in two sections, provided with shoulders, which, though turned up to as true a surface as possible, required luting, especially after the first few experiments. A second source was in the fact that the alcohol was placed in a platinum dish, and the delivery tube was scarcely covered by the alcohol, of which I used 50c.c. in each experiment.

The results varied from 32.2 to 35.3 per cent. There were ten experiments made, eight of which fell within the limits given; the remaining two were rejected because in one case the silicic fluoride escaped from the retort in such quantity as to be easily perceptible, and the result fell below 30.5 per cent. and an accident occurred to the other.

Could the silicic fluoride have been made to pass through a two or three-inch column of alcohol kept cold by surrounding it with ice, or even by cold water, some of the loss would have been obviated, especially at the beginning of the experiments, when air bubbles escaped freely and passed so quickly through the alcohol that some silicic fluoride failed to be absorbed.

The precipitate, which consists principally, at least, of silicic acid, is voluminous but is not difficult to filter, or to wash.

MEETING OF OCTOBER 1st, 1888.

ON THE DETERMINATION OF IRON AND COPPER IN ORES AND FURNACE PRODUCTS.

BY F. GUITERMAN.

The determining factors which influence the technical chemist in deciding upon a line of operation in his work are rapidity of method, combined with a degree of accuracy sufficient to meet the requirements involved.

In this connection I submit to the Society the following modifications of well known methods for the determination of iron and copper in solutions. They involve the use of zinc powder or dust instead of stick or sheet zinc.

As is well known, the titration of the proto salts of iron in solution, by means of a solution of permanganate of potash, gives more or less inaccurate results if hydrochloric acid be present. While the bichromate of potassium solution is entirely indifferent to the presence of hydrochloric acid, the results obtained by its use are affected if copper be present in the solution as cuprous chloride.

In order to obviate this difficulty, and at the same time obtain a speedy reduction of the iron, recourse was had to the use of powdered zinc.

The following preliminary experiments were made:

1. One gramme of iron wire was dissolved in sulphuric acid, oxidized with nitric acid and the solution evaporated until all the latter was expelled. To the concentrated solution 5c.c. of hydrochloric acid were added, then

two grammes of powdered zinc, the mixture well agitated, and when chemical action had almost ceased 50c.c. of boiling water. The solution was then boiled for five minutes and filtered from particles of carbon and lead (the lead being an impurity in the zinc used), floating in the liquid. A drop of the solution tested with the sulphocyanate of ammonium solution showed the reduction of the iron to be complete.

2. Five hundred milligrammes of copper were obtained in a concentrated sulphuric acid solution, to which again 5c.c. of hydrochloric acid were added, then two grammes of powdered zinc and 50c.c. of water. The whole heated to boiling for five minutes. The copper was found to be completely precipitated.

3. One gramme of iron and 500 milligrammes of copper were dissolved and evaporated with sulphuric acid, and the before described operation repeated. On adding the zinc, diluting and boiling, the copper was found to have been completely precipitated contemporaneously with the reduction of the iron.

To determine the accuracy of the method, the following experiments mere made:

1. One hundred milligrammes of iron were dissolved, oxidized and evaporated with sulphuric acid, and the reduction effected after the manner described. After diluting, boiling and filtering, the protoxals were deoxidized by means of a solution of bichromate of potash, with ferricyanide of potassium as indicator. The amount of c.cs consumed were 16.40.

A repetition of the experiment gave 16.35c.c, and a third trial 16.35c.c.

2. One hundred milligrammes of the same iron were dissolved in hydrochloric acid, oxidized by means of

a few crystals of chlorate of potash thrown into the solution, the excess of chlorine expelled by boiling and the iron reduced by means of a solution of proto-chloride of tin. The excess of this reagent was removed by the aqueous solution of bichloride of mercury, and the titration performed with the bichromate solution. Amount of cc. used, 16.35c.c. A repetition of the experiment under same conditions gave 16.35c.c.

3. One gramme of an ore containing about three per cent. copper was brought into sulphuric acid solution, the iron oxides reduced with zinc powder, and the solution titrated. Amount of bichromate solution used, 42.50c.c. The experiment repeated gave 42.50c.c.

4. The same ore (one gramme being again taken) was brought into solution and the iron precipitated therefrom by ammonia. The precipitate was washed, dissolved in hydrochloric acid, and the iron again precipitated, washed and redissolved. It was then reduced by the proto-chloride of tin. Amount of bichromate solution used to reoxidize, 42.50c.c.

The experiment repeated gave 42.40c.c.

The method in operating an ore is as follows: One gramme of the powdered ore is introduced into a flask and covered with 5 to 7c.c. of concentrated nitric acid. This is then heated until all sulphides which may be produced are decomposed and 5c.c. of concentrated sulphuric acid added. The solution is then evaporated till all nitric acid is expelled and the sulphuric acid fumes appear. The flask is then removed from the heated plate and 5c.c. of hydrochloric acid added, letting this run down the side of the flask. The flask is then shaken and the two grammes of zinc powder added and the mixture again shaken. (Should any zinc dust adhere to the neck of the flask it can be rinsed down with a few drops of hydrochloric acid). As soon as the chemical action commences to subside about 50c.c. of boiling water are added and the solution boiled for five minutes. It will be found that all the zinc has dissolved, the iron has been completely reduced and all the copper precipitated. Should the determination of copper alone be desired, the flask can now be filled with water and the copper washed by decantation. As it was precipitated from a very concentrated solution in the first instance, it will be found to be quite dense and that it subsides very rapidly.

For the determination of the iron I prefer to filter the solution, as the filtration proceeds with great rapidity and all particles of carbon and lead are removed. The estimation of the iron is then made by the bichromate solution; the copper, after dissolving in nitric acid, by the well-known cyanide method. The average duration of time for the determination of either iron or copper is hardly twenty-five minutes.

The zinc dust can be measured instead of being weighed.

ON THE TERTIARY DINOSAURIA FOUND IN DENVER BEDS.

BY GEO. L. CANNON, JR.

The Denver and the Willow Creek Groups (Tertiary) have recently yielded a number of vertebrate fossils that promise to seriously modify various existing palæontological beliefs, *e. g.*, the supposed extinction of the Dinosauria at the close of the Cretaceous, the supposed value of vertebrate remains in the accurate solution of chronological problems, or the supposed inability of the highly specialized forms of the higher Vertebrata to survive any marked change of surroundings.

In both of the above formations, forms hitherto regarded as typical of various epochs ranging from the upper Jurassic to the latest Pliocene (even later than the Equus beds) have been discovered in the same stratum and in identical states of preservation and under conditions that, but for the anachronisms involved in such a statement, would be regarded as positive proof of the existence of all forms represented by the fossils at the time of the deposition of the sediment forming these beds.

The Colorado Division of the U. S. Geological Survey has just completed a series of minute studies in the stratigraphy of the Denver coal basin. Abstracts of the monograph on the above subject were published in the *Mining Industry* of the dates July 13, 20, 27, August 3, 10, 1888.

A great angular unconformity exists between the Laramie and the overlying Willow Creek Group, and a less marked unconformity between the latter and the more recent Denver Group, where both of these beds are exposed along the monoclinal fold parallel with the base of the foothills. On the plains, where these beds resume their normal horizontal condition, they are separated by erosive unconformities, the Denver Group resting in hollows of the eroded surface of the Willow Creek Group, that in turn in the valleys of the surface of the Laramie measures. The time necessary for the production of the great amount of sedimentation, and subsequent erosion and tilting of the several beds necessitates placing the time of the formation of the Denver beds near if not beyond the center of Cenozoic time. This conclusion is confirmed by the quite recent character of eruptive material constituting the Denver beds or interstratified with them. Profs. Lesquereaux, Newberry and Ward regard the numerous species of fossil leaves from the horizon in which the bones were found as constituting a typical Laramie flora. It has, however, been recently shown that serious errors in collection have been made in the case of Golden leaves—specimens from beds separated by hundreds of feet of strata and by marked unconformities have been referred to one horizon, and the chronological value of determinations founded on this evidence thereby temporarily destroyed.

Before stating the reasons for regarding the vertebrate fossils of the Denver Group as coeval with formation of this group, a brief history of the various bone discoveries seems desirable.

The majority of the exposures of the Denver beds are found in thickly settled neighborhoods, and, having been exposed for some thirty years to the ravages of numerous collectors and curiosity hunters, have doubtless been robbed of many accessible bones of which we can obtain no information of value in this discussion. Prof. A. Lakes and Capt. E. L. Berthould have, at various times, forwarded small collections of bones from this vicinity to Eastern palæontologists, but the stratigraphy of the country being but poorly understood, they were referred to a lower horizon, the Laramie, where their presence would excite but little attention.

Some bones found on the side of a slight depression in the Denver strata at the southwest end of South Table Mountain were the most important of these collections. These remains include a portion of an acrodont jaw with compressed conical teeth, one of which is stated to have been curved, four inches long, with serrated edges and having the general aspect of a Jurassic Dinosaurian tooth, several dermal scutæ, several different ribs with marked reptilian proximal articulations, portions of large limb bones, having a flattened oval cross section and well defined medullary cavities.

All of the important bones were found within a few feet of each other, and present a fresh unworn surface, with sharp angular edges when found broken. They also possess certain peculiarities of mineralization differing from the majority of bones found in this vicinity. The bones were evidently weathered out of the surrounding rock, but were covered by a thin mantle of loess, and being slightly disturbed by the action of the surface water from a neighboring hillside, the exact spot from which they were obtained and where the remainder of the skeleton rests, has not been ascertained.

In the fall of 1886, Prof. O. C. Marsh examined some small collections obtained by Mr. T. W. Stanton and by the writer, from the Denver exposures on the western bank of the Platte. Nothing of importance was found except a jaw of a species of fluted toothed crocodile of probable Tertiary age and some chelonian fragments and the possible presence of Dinosaurian fragments. In the following spring, the writer obtained several well preserved bones near Denver, that to our great astonishment were pronounced to be the bones of typical Jurassic Dinosaurs, of both herbiverous and carnivorous types, and before we had recovered from the shock of this determination, the identification of a fine pair of horn cores and attached cranial matter, found by Mr. Whitman Cross and the writer, came, announcing the discovery of a new species of Bison (*B. alticornis*, Marsh) of the latest Pliocene time.

About this time, Mr. George H. Eldridge, of the Survey, obtained from the Willow Creek beds a number of similar remains, and stegasaurian and bovine bones were found in the same unholy union in which they occur in the Denver beds. A number of characteristic reptilian bones, found by Mr. Stanton and the writer, await identification. A large quantity of bones of a large herbivorous Dinosaur were very recently obtained from a weathered surface of Denver sandstone east of Green Mountain within a space of one hundred square feet. Having gathered 95 per cent. of the bones known to have been found in this formation, and having made a special study of the superficial geology of the region, I can confidently assert that those bones not found *in situ*, but weathered out on the surface, or mixed with the loess and slightly drifted from the original source, have all been derived from a matrix of Denver sediment. Portions of this matrix are frequently found on the surface or filling hollows of the bones, and the fragments are never more than a few inches from rock of the Denver Formation. The somewhat fragmentary and isolated character of the collections is largely due to the inability of discoverers to devote time and money to the exploration of the surrounding sandstones for the balance of the skeleton and the removal of large quantities of Quaternary accumulations masking the subjacent rock.

The reputation of the parties engaged in the study of the local geology about Denver, and the years of systematic research spent in this vicinity, are, I believe, a sufficient guarantee against the making of any serious error in the estimation of the easily legible stratigraphy or in the collection of the bones. The following reasons forbid the adoption of the assumption that the fossils were derived from an older Formation.

The only horizons in this vicinity from which a sufficient number of Dinosaurian remains have been obtained to be regarded as a probable source of the Denver fossils are the Atlanto-saurus beds of the upper Jurassic and the Willow Creek beds. A narrow belt of exposures of both these Formations occurs along the base of the foot-hills, and extensive exposures of the Willow Creek are to be found at a considerable distance, both north and south of Denver, but in no case is the nearest accessible exposure of the older beds within a short distance of the beds from whence the bones were obtained. As a rule, the distance cannot be less than ten miles. Transportation by any known agency but that of floating ice (the non-existence of which is proved (in this case) by the abundant semi-tropical vegetable remains accompanying the bones) is inseparably connected with the abrasion and the comminution of the transported substance even in the case of the hardest substances. Neither the chemical and mechanical structure of the bones found in any of the Mesozoic or Tertiary beds will permit the belief that the bones could be, or have been, transported for a number of miles and retained a practically unworn surface. Cases where these bones have been washed down a stream or down a hillside prove that a very little transportation is sufficient to wear them into a mass of shapeless fragments.

The bones *in situ* partake more or less of the fractured condition of the surrounding rock. The number of fractures a bone will have is inversely proportional to the diameter of the bone; on weathering from the rock, the separated portions become readily scattered, and it is impossible that a foot or more of thin curved ribs, such as are found in the Denver sandstones, have escaped this general law, or that the disjointed fragments have traveled together for several miles and reunited themselves after the fashion of the fabulous joint snake. Bones, at times over a foot long and weighing from ten to twenty pounds, are found imbedded in fine clay or sandrock. Any current sufficiently strong to move particles of this size would have swept away the surrounding fine sediment. Unless the rocks near the beds from which bones were derived were of an extremely soft nature some fragments of these rocks would be found with the bones. On the contrary the beds are almost exclusively composed of the detritus of the andesite flows formerly covering the foot-hills. The absence of Archæan and Mesozoic material clearly indicates that during the formation of the lower 500 feet of the Denver Group, the Archæan, Mesozoic and even the Willow Creek beds were covered by massive sheets of lava, and the derivation of any material (including the fossil bones) from the deeply-buried beds was impossible.

The chances are infinitely against the probability of two or more bones of the same skeleton being drifted for several miles and stranded within a few inches of each other. In a formation generally barren of fossils a number of bones, *ceteris paribus*, occurring together, may be regarded as pörtions of the same skeleton. An examination of the bones and the localities of Table Mountain and Green Mountain "finds" will convince any unprejudiced person that but one animal is represented in both cases.

In view of the above reasons it seems impossible that the fossil could have been brought from a preceding Formation, and the alternative must be admitted that the diverse forms co-existed during the Denver Group epoch.

The admission that Dinosaurs have survived until the Miocene destroys the value of all conclusion based on the supposed infallibly Mesozoic characters of the fossil forms involving the reopening of the great controversy relative to the age of the Western lignites.

If the highly specialized forms of the Jurassic Stegasaurs have maintained a practically unchanged organization during the great vicissitudes of elevation and climate occurring during the long ages intervening between the deposition of the Atlanto-saurus and the Denver beds, or if the bisons have maintained an equally unchanged form from the Laramie to the beginning of the Quaternary, certainly the belief in the supposed inability of the higher forms of animal life to resist any serious modifications of environment must be seriously modified.

The doctrines of the survival of archaic forms in some localities long after the extinction of the race in other portions of the world, and that which regards our present knowledge of the imperfect geologic record as tentative rather than finally conclusive must receive fresh illustration from these discoveries. If such intervals of time and such a variety of changed conditions have not produced any essential change in a supposed susceptible animal, how weak becomes the position of those who assert that visible causes are sufficient to produce all of the varied phenomena of organic life during the limited time assigned by physicists for the duration of that life on the globe; and what material aid does the reaction against ultra-materialism, toward a belief in the acceleration of the process of development in the hands, and under guidance of intelligent force, receive from the mutilated fragments of the old Tertiary Dinosauria!

MEETING OF DECEMBER 3rd, 1888.

THE RECENTLY DISCOVERED TERTIARY BEDS OF THE HUERFANO RIVER BASIN, COLORADO.

BY R. C. HILLS.

During the past summer the writer has been engaged, on behalf of the Colorado Fuel Company, in a geological exploration of the Raton coal field in Huerfano and Las Animas Counties, and one of the most interesting results of the season's work was the discovery of extensive Tertiary beds typically developed on the upper Huerfano River and its tributaries.

Two distinct epochs are represented in the Tertiaries of the Huerfano basin. The lowest and most extensive, the Huerfano beds proper, are found overlying unconformably the Laramie and Colorado along the shore-line and in part resting on the Archæan, although elsewhere graduating conformably into the upper part of the Laramie, apparently without any recognizable line of demarkation. In appearance they closely resemble the Wahsatch beds of the Uinta basin and those of the San Juan in New Mexico. In the absence of sufficient determinative fossils to define their true relation to other Tertiary terranes, it seems most consistent with the known facts to regard them as Eocene.

The upper beds, occupying a comparatively small area, rest unconformably upon a great thickness of Eocene strata, and, for reasons given beyond, are for the present referred to the Pliocene.

The most typical exposures of the Eocene beds occur on the drainage of the Muddy branch of the Huerfano River, while the best section of the strata is probably to be found in the nearly uninterrupted exposure of inclined beds extending down Poison Cañon and across Muddy Creek to Promontory Bluffs. The total thickness here developed can hardly be less than from 7,000 to 8,000 feet, distributed in descending order about as follows:

Red and yellow sandy clays and marls, sometimes shaly, alternating with yellowish, white, gray and greenish sands.................................2,000 feet

Light-red, white, brownish, or variegated, soft sandstones, alternating with red and yellow sandy clays and marls.................................1,500 feet

Yellowish, or light-colored, soft sandstones and conglomerates with occasional beds of yellow clay or marl............................3,500 to 4,500 feet

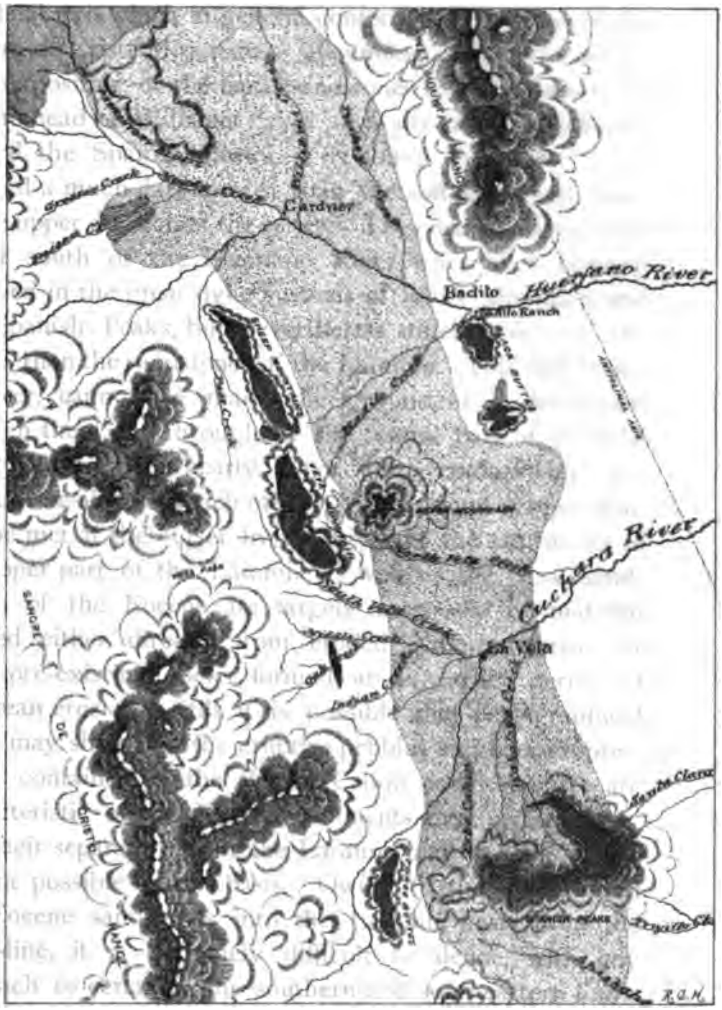
The basal members, consisting mostly of yellow sandstones and conglomerates—dipping about 35° toward the northeast and striking across Poison Cañon somewhat obliquely—outcrop for a distance of over two miles along the cañon or to within three-fourths of a mile of its mouth. With the exception of a particular kind of eruptive pebble, showing partly decomposed feldspars in a purplish compact looking groundmass, these rocks are apparently composed wholly of rather loosely cemented Archæan debris. The sandstones are characteristically massive with rounded and cavernous weathered surfaces. They rarely exhibit any traces of jointing or lamination except in places along the northeastern shore-line where the sandstones are found to be thin-bedded, cleavable and more or less jointed.

The middle division of the series graduates into the upper and lower divisions, forming an intermediate or transitional stage not clearly separable from the others, but yet in the main possessing distinctive features. These beds are well exposed along Poison Cañon near its mouth, where they outcrop for about two-thirds of a mile with an average dip of 40° towards the northeast; the greatest inclination anywhere observed in the Tertiary strata of this area.

Pinkish and variegated sandstones make their appearance predominantly at the base of the middle division. In ascending order these gradually give place to softer strata consisting of reddish brown, greenish and grayish sandy clays, sands and marls, abounding in concretionary nodules of gypsum. The softer beds finally predominate, the sandstones disappear, or become soft and friable, and the exposures have then the characteristic aspect of the upper division.

The latter consists almost entirely of soft sands, clays and marls presenting alternating bands of red, brown, gray and greenish colors which become more or less blended in the surface accumulations imparting to the extensive barren exposures the variegated appearance characteristic of the Wahsatch bad lands.

The strata at the base of this division, near the mouth of Poison Cañon, are highly inclined and conformable with the beds of the transition stage; but the inclination decreases rapidly as the beds pass under Muddy Creek, while around Promontory Bluffs they are nearly horizontal. Promintory Bluffs are situated midway between the two old shore-lines or where the strata attain their maximum development. A few miles to the northeastward the Eocene strata, dipping in the opposite direction to the Poison Cañon exposures, rest upon the southwestern flank of the Wet Mountain Range, the beds occupying a syncline between the latter and the base of the Sangre de Cristo. The



Eocene — Pliocene — Eruptive

SKETCH-MAP SHOWING THE KNOWN EXTENT OF THE HUERFANO BEDS

Scale of Miles

greatest extension of the beds is in the direction of the synclinal axis which in general conforms to the trend of the Sangre de Cristo Mountains. Beginning at the most northerly exposures of the basal sandstones and conglomerates on the head of Williams Creek, and advancing southward toward the Spanish Peaks, it is found that these rocks covered a much larger area than the soft sands and marls of the upper division of the series. They are also noticeably firmer south of the Huerfano River, where they become involved in the great dyke systems of Silver Mountain and the Spanish Peaks, but, nevertheless, much softer, on the whole, than the sandstones of the Laramie. This difference, however, cannot be made the ground of a distinction between them, for throughout the central part of the field the two series are nearly, if not quite, conformable, and blend insensibly into each other. Any attempt at separation will be met at the outset by the fact that the sandstones of the upper part of the Laramie, as well as the basal sandstones of the Eocene, are largely composed of material derived either directly from eroded Archæan areas or from pre-existing rocks formed at an earlier period of Archæan erosion. Still it is possible that petrographical study may show that the eruptive pebbles and finer eruptive debris contained in the Poison Cañon conglomerates are characteristic of the Eocene sediments over certain areas, and their separation from the Laramie may to some extent become possible on this basis. Owing to the transition of the Eocene sandstones into the Laramie away from the shore-line, it is extremely difficult to define, with any approach to certainty, the southern and southeastern limits of the series, and the outline given on the sketch-map, south of Silver Mountain, will no doubt be more or less modified by subsequent explorations. This modification, however, will probably consist of an extension, rather than a contraction, of the area southward. The undoubted existence of the variegated soft sandstones around the Spanish Peaks renders it almost certain that the great development of massive friable sandstones and conglomerates overlying the coal-measures (Laramie proper) on the upper Apishapa drainage must, in part at least, belong to the Eocene. The same remark will apply to coarse massive soft sandstones overlying the coal-measures in the hills a few miles northeast from La Veta. The distance between the northern and southern extremities of the lower division of the series is therefore about forty-five miles, while the average width is only about eight miles. With the probable exception of the mass of the West Spanish Peak it is doubtful if the upper marly beds extend southward much beyond the line of North Veta Creek, or a distance of twenty-six miles from the northwestern limit of the exposures. The variegated soft sandstones belonging to the transitional stage outcrop frequently along the Cuchara valley, around the base of the Spanish Peaks, on Wahatoya and Indian Creeks and in Echo Cañon. They were also observed in the exposures south of the Spanish Peaks, but only for a short distance. The geographical extent of the variegated sandstones is therefore considerably greater than that of the overlying clays and marls, and but little less than that of the underlying yellow sandstones, although the extension of the latter southward may be greater than is indicated on the map.

Rocks which are here regarded as belonging to the lower division of the Poison Cañon series were first observed on the drainage of the upper Apishapa. Around the Spanish Peaks the beds are partly, or in places wholly, metamorphosed; which fact, coupled with the conclusions reached by Hayden and Endlich, first led to the belief that

Carbonic strata had been uplifted by the dynamic movement connected with the upheaval of the eruptive mass of the East Peak and its dyke-like western extensions (see map). But owing to the existence of continuous exposures of the Laramie, Colorado and Dakota a few miles west of the peaks, which seems to have been overlooked by Hayden, the absence of any plane of faulting at their western extremity, and the gradual transition from the unaltered to the completely metamorphosed sediments soon led to the rejection of this view, although the Tertiary age of the altered rocks was not at that time recognized or even suspected.

Further study of the structure of the Spanish Peaks made it clear that they were produced by the upheavel or intrusion of an eruptive mass which itself formed the body of the East Peak, while the tilting up of the displaced sedimentary strata to the west produced the elevation known as the West Peak. Extending westward from the East Peak are two broad dyke-like eruptive intrusions which embrace between them the eastern or highly inclined portion of the West Peak sediments. In the latter the metamorphosed area is quite limited, being situated near the southern of the two eruptive arms, and also at the point where a majority of the numerous dykes of the Spanish Peaks system converge. A second but even more limited area of complete metamorphorism is found on the western slope of the East Peak. The upturned Laramie beds resting directly on the eruptive core have here undergone alteration in proportion to their nearness to the eruptive mass, the lower sandstones and shales being completely altered to quartzites and slates, while overlying these are strata in which the shales alone are metamorphosed. In the saddle between the two peaks the Laramie sandstones and shales are unaltered on the surface, but dip with apparent conformability under the metamorphozed Eocene beds of the West Peak, and have probably suffered partial or complete alteration in the zone underlying them. This unbroken succession of strata, aggregating at least 7,000 feet, made it appear that the altered rocks of the West Peak were probably the equivalents of the Upper Laramie of northern Colorado and provisionally they were so considered, although the unaltered sediments bore no resemblance to the Upper Laramie lithologically. It was not till the upper members of the Huérfano beds were found so fully developed on Muddy Creek that the Tertiary age of the West Peak strata was recognized. The alteration of the beds was complete only in the vicinity of the culminating ridge of the Spanish Peaks. Around their base the alteration of the red marly beds was but partial, causing them to resemble, both in color and texture, the indurated marls often met with in the " Red Beds " exposures. A similar alteration was produced in the marl beds near the eruptive center of Silver Mountain, but excepting these partially altered areas the resemblance to the basal and intermediate members of the Poison Cañon series is unmistakable, even where the intersecting dykes are comparatively numerous. The Huerfano River exposures are, nevertheless, the most typical and of greatest development. Nearness to the great porphyry intrusions of Veta and Sheep Mountains, occurring in the Colorado, does not seem to have in any way affected the Eocene beds, and the few scattered dykes observed in this part of the basin were not capable of producing an appreciable alteration.

The fossil remains thus far discovered consist of a few detached bones of vertebrates (including phalanges resembling those of Coryphodon) and of a species of huge turtle, the latter by far the most numerous. The carapace and plastron of one individual, almost entire, were found in place, but the parts were so fragile that it was thought best not to attempt their removal without adequate means for preserving them. The portion of the beds examined for vertebrate remains seem to be largely destitute of fossils, still, the season being far advanced, only a very small fraction of the entire area could be explored, and the exposures along the shore-line were scarcely examined at all. Worm-burrows were found to be abundant in the vicinity of the old granite beach at the head of Williams Creek, and much fossil wood was observed in the upper division of the series near the northeastern shore-line just west of Badito post-office. For the present, therefore, the Eocene age of the Huerfano beds rests mainly upon the evidence of nonconformity. In this respect their relation to the beds of the Laramie and Colorado around the entire shore-line could not be studied very thoroughly owing to the lateness of the season, and the observations were necessarily confined to a few of the most accessible localities. The existence of nonconformity was, however, found in each case to be unmistakable. On the eastern border of the exposures near Badito post-office the nonconformity with the Laramie amounts to about 15°, this difference being observed between the variegated beds and the Laramie sandstones with which they are in contact, the lower division of the Poison Cañon series being wholly wanting in this locality. On the head of Williams Creek the nonconformity with the easily recognized Middle Colorado,* determined in two places about one-half mile apart, was found to be respectively 50° and 53°, the Colorado

*In the Colorado of Huerfano County there is a well defined sandstone horizon separating the black shales of the lower half of the series from the white calcareous shales situated toward the base of the upper half. This sandstone is referred to as Middle Colorado.

being inclined from 60° to 70° and the basal Eocene sandstones from 7° to 20°. The Eocene is here found in part resting on the Archæan, the Colorado being exposed by erosion.

From Poison Cañon north to the limits of the Eocene area outlined on the map, the Huerfano beds completely overlap the Laramie and in a large part the Colorado also, the nonconformity with the well marked sandstone bed between the black and white shales amounting to fully 50°. About one-half mile south of Poison Cañon Creek the marginal exposures of the Eocene trend abruptly eastward, and crossing the upturned Laramie sandstones continue on a short distance, when they again trend southward across the Huerfano River. The Laramie beds, overturned about 10°, and striking nearly northwest and southeast, are prominently exposed just north of the river, but soon disappear beneath the soil of the valley less than a mile from the point where, if prolonged in the direction of the strike, they would pass under the Eocene beds vertically below the exposures of the middle division.

The point where the Laramie disappears marks the northern limit of its western marginal outcrop, but, as it still shows considerable development, there can be little doubt of its continuing below the Eocene for some distance northward, and although the relation along the contact is not shown, a nonconformity of 50° or more is rendered highly probable. It is the intention in the near future to more thoroughly investigate the matter of nonconformity and also more thoroughly explore the beds for good determinable fossils, especially vertebrates.

From what has been noted regarding the Spanish Peaks eruptions it becomes evident that the formation of the Huerfano Tertiary lake basin antedated the period to which are referred the principal eruptions of the region, and was doubtless directly connected with the general orographic movement which took place at the close of the Mesozoic. At that time the Laramie beds, having a much greater eastern extension than at present, were slowly upturned along the eastern base of the Sangre de Cristo, while the prolongation southward of the parallel movement which produced a partial upheaval of the Wet Mountain Range resulted in the formation of a broad anticline, probably extending as far south as the Purgatoire, but which was reduced to a mere gradual undulation a few miles south of the Apishapa. The intervening synclinal fold to the west was, therefore, correspondingly greater north of this stream and probably more profound within the present limits of the Huerfano drainage than north of it, for the folding strata being then included between the ascending masses of the Sangre de Cristo and Wet Mountain Ranges participated in the general elevation of the entire area. It was these causes combined that produced at the beginning of the Tertiary a long trough-like depression in the Laramie beds, deepest on the Huerfano river, extending southward to the Apishapa and northward to the Wet Mountain Valley. This depression contained the Huerfano Eocene lake and became the receptacle of an abundance of detrital material from the neighboring mountain ranges during early Tertiary times.

The deposition of Eocene sediments in the Huerfano basin terminated at the beginning of a second epoch of disturbance coinciding or nearly so with the time of greatest igneous activity. During this epoch the Sangre de Cristo and Wet Mountain Ranges were again uplifted, the movement being accompanied by additional folding, along the lines of pre-existing plications, in which the Eocene strata then became involved. This movement was no doubt contemporaneous with the successive stages of eruption marking the upheaval of the Spanish Peaks, the formation of the great dyke systems of Huerfano and Las Animas Counties and the numerous eruptive intrusions, conformable with the sedimentary strata which occur along the eastern base of the Sangre de Cristo, including also the upheaval of Veta and Sheep Mountains.

The amount of plication was greatest along the western border or that adjacent to the Sangre de Cristo, which was also the case during the preceding movement. The duration of the second epoch of disturbance has not been definitely ascertained. That it began at the close of the Huerfano Eocene and terminated previous to the opening of the Pliocene is clearly indicated, but whether it extended entirely through the intervening time, or was confined to the early Miocene, or even to the latter part of the Eocene, is largely an open question, and one that will be more or less affected by palæontological interpretations. The degree of folding which the Huerfano beds underwent, and the number of dissimilar eruptive occurrences observed traversing Eocene strata, rather incline one to the belief that the disturbances were distributed through a considerble period of time, probably extending well into the Miocene.

Of the Laramie beds forming the apex of the old anticlinal ridge or plateau bounding the eastern margin of the Huerfano basin, only a part has escaped erosion; but all along the Laramie border the sandstones are found inclined from 5° to 15° southwest, according to the degree to which erosion has advanced westerly through the fold.

This erosion probably began in the early Tertiary or at the time when the Wet Mountain Range and the connected anticlinal uplift to the south acted as a barrier to the passage eastward of detrital material from the drainage areas of the Sangre de Cristo. The broad uplift just mentioned was no doubt resolved into an extensive plateau region toward the eastward, the Mesozoic beds being topographically higher than the same horizons in northern Colorado. This may in some measure account for the fact that during early Tertiary times the southeastern quarter of Colorado was largely an area of denudation, while the corresponding area to the northward was one of sedimentation.

The most natural outlet of the Huerfano lake would seem to have been the Wet Mountain Valley. Considering the fact that the Eocene beds are thickest just south of the Grape Creek divide, the probability is strong that they have a much greater northern extension than is shown on the map, in which case the Huerfano lake basin no doubt included a large portion of the Wet Mountain Valley. This would tend to increase the probability of an outlet in that direction. Throughout the Raton field the plication of the Laramie strata took place parallel with the axis of upheaval of the Sangre de Cristo, hence the disappearance in the Purgatoire region of the synclinal fold of the lake basin means that that part of the field was topographically higher than the synclinally-depressed northern extension of the Huerfano basin. This fact, coupled with the absence of even traces of Eocene deposits on the Purgatoire, or in the Raton Hills, where the great eruptive overflow would protect such deposits from subsequent erosion, renders improbable the idea of an outlet or connection with lacustrine areas to the southward.

As before stated, it will require considerable careful investigation before a line can be drawn with certainty between the basal sandstones of the Huerfano beds and the sandstones of the upper part of the Laramie, in localities away from the old shore-line, even if it is possible to make a definite separation between them. That the lower half of the Poison Cañon series does not correspond to the Upper Laramie of northern Colorado and Wyoming is indicated by the restriction of the former to a lake basin, produced by Post-Mesozoic disturbances. Furthermore, the Upper Laramie is a coal-bearing horizon, especially in Wyoming and Colorado, while nothing approaching coal in any form has been observed in the Huerfano beds.

The upper half of the Poison Cañon series bears a close physical resemblance to the Wahsatch beds of the Uinta basin. In each case there is the same alternation of gypsiferous strata with red, yellow and green marls, sands and soft shales with soft sandstones predominating at the base of each series. The variegated sandstones so conspicuous in the middle division of the Huerfano beds are represented by similar sandstones at the base of the Wahsatch along the western slope of the Great Hogback on Grand River. These sandstones, according to the description by Prof. E. D. Cope, may be represented in the San Juan beds of New Mexico, as also the upper marly series. Nothing corresponding to the soft sandstones and alternating yellow marls, forming the lower division of the Poison Cañon series, appears to have been observed in any of the Wahsatch deposits, nor has anything corresponding to the Puerco marls been observed in the Huerfano basin.

The extraordinary thickness developed in Poison Canon is one of the most surprising features connected with the series, and one that, in spite of the physical resemblance, would throw some doubts on its identity with the Wahsatch. At least one cannot but suspect that even though the upper half of the series should prove to be so, the lower half at least can hardly be regarded as of Wahsatch age. Should, however, a study of the fossils decide this to be the age of the upper half alone the lower half would then fall in line with the Puerco, the Fort Union and probably the beds of the Denver basin.

Beyond what is necessary to justify the conclusion that the entire Poison Cañon series should be referred to the Lower Tertiary it is not intended to institute a comparison between this and other Tertiary terranes with a view to suggest more detailed equivalency. No doubt careful search will discover remains of determinative value, and during the coming season an effort will be made to collect material more satisfactory for the purpose than that now on hand.

The deposits mentioned at the beginning of this paper as probably of Pliocene age, have their greatest development on the southern slope of the divide separating the drainage of the Muddy branch of the Huerfano from Grape Creek and Wet Mountain Valley. The maximum thickness of the beds was estimated to be between 700 and 800 feet. Loosely aggregated coarse conglomerates and sandstones predominate in the lower half of the series, and fawn or buff-colored compact marls, sometimes sandy, in the upper half. The basal conglomerates are distinguished from the conglomerates of the Eocene in being composed of much coarser material and in containing a great number of eruptive pebbles and small boulders representing varieties common to the more recent eruptive occurrences. One prominent bed of conglomerate situated some distance above the base of the series contains cleavable calcite as the cementing material. This bed is exposed on the south side of the divide near the Gardner and Silver Cliff road.

The Pliocene exposures have but a limited geographical extent in the section of country examined, being mostly confined to the vicinity of the Grape Creek divide and to small isolated areas of the basal conglomerate occurring in the neighborhood of Greaser Creek and Poison Cañon. A remnant was also observed, resting on the eroded surface of the Colorado shales, as far east as the southern of the two black buttes near Silver Mountain.

The deposits were traced northeasterly to the head of Cottonwood Cañon and branches of Williams Creek north of Promontory Bluffs, and for a short distance southwest of Muddy Creek, but toward the northwest, or in the direction of Wet Mountain Valley, they soon disappear under accumulations of heavy glacial drift. This takes place near the top of the divide referred to, where the greatest thickness of Pliocene strata is developed, indicating that the beds underlie the valley for a considerable distance in the direction of Grape Creek and Silver Cliff. The inclination observed is nowhere more than a few feet in the hundred, less, generally, than the slope of the land surface in the Huerfano valley. A nonconformity of about 33° exists between the basal conglomerate and the upturned Eocene on Poison Cañon and Greaser Creek, but elsewhere the points of contact with the Eocene are not exposed. Great nonconformity with the Colorado was observed on the southwest side of Muddy Creek.

The dynamic movement associated with the great eruptions of the region, and the folding of the Eocene strata, was evidently anterior to the opoch of Pliocene sedimentation; the slight inclination of the Pliocene beds probably representing the small amount of disturbance that has taken place since Tertiary times. Previously the upheaval of the eruptive masses of Veta, Silver and Sheep Mountains prevented the extension of these sediments southward beyond the present limits of Huerfano drainage; hence sedimentation was restricted to the Huerfano basin and the southern extremity of Wet Mountain Valley. That this part of the valley was included in the Huerfano basin during the Tertiary seems more than probable, considering that the maximum development of both Eocene and Pliocene beds is found but a short distance south of the present drift covered divide. Any fold or uplift that would cause an abrupt termination of the Tertiary beds at this point would be at right angles to the axis of elevation of the Sangre de Cristo and Wet Mountain Ranges, an intervention scarcely to be expected. It is therefore quite reasonable to suppose that the Tertiary beds underlie a considerable area of the drift-covered southern part of Wet Mountain Valley, the drainage of which is northerly into the Arkansas, but which in part formerly constituted the northern extension of the Huerfano lake basin.

Regarding the outlet of the Huerfano lake during the Pliocene, there can be little doubt that, as during the Eocene, it discharged itself through this same valley and to the northward. If from some cause the Pliocene beds were restored to their original horizontal position, the Colorado beds to the eastward would be so elevated, relatively, that it is doubtful if, even now, the Huerfano River could maintain its present direction of flow. Considering the amount of erosion of the Colorado shales since the Tertiary the facts are in keeping with the former existence of a Colorado area on the east sufficiently elevated to cause an outflow through the Wet Mountain Valley.

The great unconformity observed between these later Tertiary beds and the underlying Eocene, the petrographical dissimilarity, the relation to the overlying glacial drift, the slight inclination, and, moreover, the number of eruptive occurrences represented in the conglomerates are thought sufficient grounds, in the absence of paleontological evidence to the contrary, for referring the series provisionally to the Pliocene. It is to be regretted that organic remains could not be found to test the truth of this conclusion, which is much to be desired, as the satisfactory identification of these beds will tend to throw much light on the unsettled question of the age of the later eruptions of this part of Colorado

ANNUAL MEETING DECEMBER 17th, 1888.

ADDRESS OF THE RETIRING PRESIDENT.

R. C. HILLS.

GENTLEMEN—Following the custom established by my predecessors, I beg leave to occupy your attention for a short time this evening.

First, by way of introduction, let me say a few words with regard to the present condition and progress of the Society. That the condition is a healthy one the average attendance during the year and the substantial addition to our list of members will sufficiently assure you. That the progress has been satisfactory is manifested not only by the constantly increasing volume of original matter contained in our publications, but also by the steady growth of our library and collections. In all these respects we may congratulate ourselves on the results of our labors, carried on in the face of a comparatively small membership and under difficulties which only patience and devotion can be expected in good time to overcome.

Not the least of these difficulties, and one which nearly all similar organizations have no doubt experienced during the early stages of their existence, is the lack of sufficient funds wherewith to properly build up, equip and maintain our museum and library in accordance with the object the Society has all along had in view, viz.: the creation, under its care and direction, of a Natural History Museum, as complete as possible in the department of economic geology which shall be accessible to the general public and to the students in our higher educational institutions. We are all aware that the necessity for such a museum exists. Colorado is centrally situated with reference to a vast region possessing mineral resources as varied as they are rich. Many substances of commercial value, that one familiar with the physical appearance of the more common minerals would recognize, are known to occur in our mountains, but are passed unnoticed by the average explorer. Hence the importance of a more general dissemination of useful mineralogical knowledge such as may be acquired by those having access to a well arranged collection of the various economic products of the earth. Moreover, until a suitable place is provided for the reception of the mineralogical and paleontological treasures for which this region is noted, so long will they continue to enrich the collections of the eastern States and of Europe. Aside from the ornament and attraction which such a museum would be to the city of Denver, its technical and educational value to the mining communities of the Rocky Mountains would be very great. I believe that the time has come when we may expect that the more intelligent and public-spirited of our wealthy citizens will appreciate the importance of this part of our work and generously aid the Society in its efforts to carry it out.

Another difficulty, and one that is just now felt to be more serious than ever before, is the want of a sufficient number of resident members who can afford to devote a portion of their time to the affairs of the Society. In other words, we need a few enthusiastic and capable workers, who will take charge of the preparation and supervision of our monthly and annual publications, or by judicious correspondence with other societies and scientific institutions, endeavor to expand our library and collections. We undoubtedly possess, in proportion to our numbers, as large a percentage of active members as any kindred organization, but the majority are non-residents, and the affairs of the Society must necessarily be conducted by members residing in or near Denver. We may rest assured that the newly-elected resident members will generously do all in their power to lighten the burden which now rests on the shoulders of a few. Nevertheless, their aid alone is not sufficient to meet the requirements, and it is very desirable that an effort be made to expand our list of Denver members. Not that I would advise in the least any departure from the standard of excellence adopted in our constitution, but there are no doubt many residents of Denver who are well qualified both by disposition and attainments to become useful members of the Society and who would willingly join if invited to do so.

I desire also to refer briefly to another and larger class of workers; those on whose labors, in proportion as they contribute to the advancement of science, will largely depend the strength of the Society at home and its standing abroad. We may congratulate ourselves upon the fact that nearly one-third of the members have at some time or other contributed original matter to our proceedings, while not a few contribute periodically. This is a showing of which any society might be proud; but, while we accept it as proof of a vigorous existence, let us not flatter ourselves that we are more industrious than our fellow-workers in other parts, for in truth we have manifold opportunities for observation, and comparatively unlimited resources from which to draw original material. For this reason we should, and no doubt could, accomplish even more. The majority of our members are by training and avocation naturally inclined toward chemical, geological or mineralogical studies, which rank all other sciences as factors in the development of a great mineral region. In all these branches material is sufficiently abundant to satisfy the demands of the most enthusiastic investigator.

The papers which have been read before the Society during the year by Messrs. Cross, Eldridge and Cannon are most convincing evidence that one can scarcely pass beyond the city limits without stumbling upon objects of more or less scientific interest. I am bound to believe that the disposition to aid the advancement of science has at least a latent existence among the majority, even of those members who have not yet furnished anything to our proceedings, and that the opportunity alone is wanting to develop, in most cases, active interest and enthusiasm. I believe also that many of the members who have already contributed original papers, or taken an active part in enlarging the collections, would gladly avail themselves of any information calculated to aid them in procuring material for investigation. This brings me to the subject I wish to present to you this evening:

THE FIELD FOR ORIGINAL WORK IN THE ROCKY MOUNTAINS.

I can scarcely hope at this time to do justice to a subject of such magnitude. I even question my ability to fully realize its extent. The many valuable monographs published by the government, together with numerous interesting papers and bulletins, bear testimony to the importance of the work already accomplished in this field. That this is but the first fruits of an abundant harvest must be conceded by any one who will compare the scientific literature on this region with the literature on a like area of similar character in Europe.

Up to a very recent period the prime object of Rocky Mountain exploration was to lay the foundation for subsequent and more accurate work. As the extent to which this object has been carried out has a direct bearing on the present subject, it will be necessary, as I proceed, to refer briefly to the more important results attending past explorations, especially in those branches of science at present most interesting to the members of the Society.

The systematic geology of the Rocky Mountains has been studied most thoroughly in Wyoming, Colorado and northern New Mexico; in Wyoming by the geologists attached to the Fortieth Parallel Survey under Clarence King; in Colorado and partly in Wyoming by the geologists under Prof. Hayden; and in southern Colorado and New Mexico largely by Prof. Newberry, E. D. Cope, Lieut. Wheeler, Prof. Stevenson and others. The surveys of Hayden and King each rested on a system of triangles connected with a carefully measured base-line from which the position of a large number of elevated stations was accurately determined. These stations mark the location of prominent points or landmarks, and, it may be well to bear in mind, can be used as the basis of future and more detailed work; but, outside of the points thus carefully located, only a general idea of the topography is intended to be conveyed in the published charts. The same is true of the geology of the region, for as the accuracy of the field work must depend primarily on the accuracy of the preceding topographical work, it cannot be expected that the systems outlined on these charts have been more correctly represented.

Moreover, previous to the organization of the United States Geological Survey, as now established, the annual appropriations were inadequate for the purpose of even a preliminary survey of so large a territory if its completion was to be looked for within a reasonable time; consequently the purely geological work was often made subordinate to the topographical, and the districts so hurriedly traversed that even the approximate extent of certain systems could only be conjectured. It is not to be wondered at, therefore, that important areas were overlooked and the extent of others sometimes exaggerated; it is rather to the credit of those engaged that on the whole the results are more than in a general way reliable. Still there is hardly any part of this region, except the few districts recently worked up by the Rocky Mountain divisions of the Survey, but what offers grand opportunities for the geological explorer. Assuming that, as a rule, the systems have been correctly identified, the areas assigned to each have still to be outlined in detail and on a larger scale than was formerly thought necessary. At present no satisfactory comparison can be made between widely separated areas of any system owing to the lack of accurate stratigraphical measurements. Carefully prepared sections of the several systems, showing the actual succession and inclination of strata, will greatly advance our knowledge of the relationship existing between these systems through the Rocky Mountains. I have no doubt that much of this work can be carried out by members of the Society. No matter where they reside along the range, opportunities exist for those who can devote a few hours occasionally to such intellectual recreation and the data thus obtained will form a very important addition to the volume of our proceedings.

This does not by any means exhaust the field for original work in the direction indicated. My own observations in different parts of the State incline me to the belief that certain alterations in the geological map of Colorado will soon appear desirable. In a paper read before the Society at the last meeting, attention was called to the existence of extensive Tertiary beds on the Huerfano River. The explorations that led to the discovery of these beds developed the fact that the Laramie has an extent of about 200 square miles greater than is represented on the published map, and that therefore the form and size of the areas alotted to the Carbonic and Cretacic will require considerable modification. Since the Laramie is the coal horizon of the Rocky Mountains this extension is so much added to the area of the Raton coal field.

While speaking of the Laramie, I will mention the necessity which exists for an economic map more correctly representing the extent and value of our coal resources than that published by the government. At the time Hayden's survey was made, it did not appear that the utilization of these resources would be a matter that would occupy the minds of the present generation, and the capacity of the Laramie as a coal-bearing series was but little investigated. Since then the rapid extension of railways in the Rocky Mountains, coupled with the requirements of the great treeless plains country to the east, has created a growing demand for Colorado coal and demonstrated that the future prosperity of the prairie States will be largely influenced by a cheap and inexhaustible supply of this product. Not only do the economic and geological maps of Colorado fail to do justice to the extent of our coal fields, but the published reports greatly undervalue the quality of our coals—matters of more serious import than the State Legislature seems to realize, judging from the absence of anything corresponding to a Bureau of Economic Geology.

Recent observations west of the range have led me to conclude that there is no good reason why the present geological map should not be so modified as to make the outline of the Laramie coincide with the outcrop of the coal measures. While the rocks of the Carbonic and Dakota often contain coal, the Laramie is pre-eminently the coal-bearing formation of the Rocky Mountains. In western Colorado, however, we find the great workable measures referred on the map to the Fox Hills series, and the latter included under the same cartographic symbol with the Fort Pierre, which in Colorado is not coal-bearing. There are no doubt strong reasons for not separating the Fox Hills and Fort Pierre beds, as we find them in Colorado; at the same time there appear no good grounds for regarding the coal-bearing formations separated by the Continental Divide as belonging to distinct epochs; physically they are identical, while the recent investigation of Laramie plants by Newberry tends to show that the flora is identical. The occurrence of Fox Hills shells near the base of the coal measures west of the range of course points unmistakably to marine conditions, but the presence of coal-seams indicate that these conditions were no longer constant, although the transition was doubtless more gradual than that which took place east of the mountains.

Further alterations of the geological map are rendered desirable by the results of the explorations, conducted by S. F. Emmons and his assistants, in the Denver Basin and in the Leadville, Ten-Mile, Silver Cliff and Gunnison districts. Other modifications, which, however, ought to be preceded by more thorough examinations, are suggested by my own observations on a number of hitherto unrecognized occurrences in different parts of Colorado. One which I may mention is an area of the Wahsatch, of undetermined extent, lying about six miles south of the lower White River and nearly on the Utah line. The exposure seems to be due to a local upheaval, and the Green River and Wahsatch beds are considerably tilted along the northern boundary of the area.

Another occurrence of considerable importance is found in the remarkable series of tufaceous beds which extend from the base of Anthracite Range, in Gunnison County, along the western base of the Ragged Mountains and across to the Wahsatch beds on the head of the Muddy branch of the Gunnison River. The exposures are, in places, quite extensive, especially in the valley of the Muddy, while northward they are found, overlaid by the lower members of the Tertiary, tilted up along the Great Hogback as far as Grand River. The area covered by these deposits is represented as Laramie on Hayden's map. They have, no doubt, been carefully worked up in the Gunnison district, and will be described in the forthcoming report by S. F. Emmons.

Other occurrences which seem worthy of consideration are found in the region of the San Juan Mountains. Probably few localities along the range afford a better opportunity for studying the successive geological epochs than the valley of the Rio Las Animas in La Plata County. Beginning with the Middle Carbonic, which is found resting on the Archæan just above the mouth of Hermosa Creek, and following the course of the river southward, one passes successively the Upper Carbonic or Permian, the Triassic or Red Beds, the massive pink and white sandstones, referred by Holmes and Endlich to the Lower Dakota, the Dakota proper, the Colorado, the Laramie with its coal-seams, and, finally, the Wahsatch, all dipping gradually down and disappearing as they reach the valley level. On Hayden's map the Trias is represented as extending southward to the Animas River, but not beyond; whereas, it is present on the east side of the valley and continues on to, or beyond, the Rio Florida, presenting at the same time a greater thickness and more typical development than anywhere along the mountain border to the northward. Occupying the middle of the system are beds of calcareous conglomerate alternating with light-colored fissile sandstones. The former abound in fragmentary remains of saurians, while the latter sometimes contain well-marked leaf imprints. These exposures are entirely different from any referred to the same period in northern Colorado, with the exception of a limited occurrence observed on the north side of Grand River, in Red Dirt Cañon, and, according to Professor Newberry, offer no lithological resemblance to his "bone beds" of New Mexico.

There are two interesting occurrences in Ouray County which remain to be spoken of. On the Uncompahgre River, above the town of Ouray, there is an exposure of slates and quartzites showing a thickness of probably 10,000 feet. They belong presumably to the Cambrian, although their relation to other schistose rocks occurring in the San Juan Mountains remains to be studied. A suite of specimens taken from these exposures is to be seen in the museum of the Society.

Another remarkable occurence is found in a considerable thickness of coarse conglomerate outcropping around the base of Mt. Sneffles, on Cañon Creek above Ouray and on Marshall Creek above Telluride. It rests unconformably upon Mesozoic strata, and consists wholly of conglomerate composed largely of metamorphic debris. Apparently it is a shore deposit in course of formation at the beginning of the eruption of the San Juan breccia immediately overlying it, in which case it probably belongs in the

Tertiary. Incidental reference was made to this conglomerate by S. F. Emmons in his paper on "Some Colorado Ore Deposits." *

The glaciated areas of the State likewise constitute a subject for future study. I had occasion lately to cross a portion of the White River Plateau, and was much impressed with the evidence of glaciation everywhere present, in the form of flutings and scratches, on the flat part of the high country. This portion of the plateau lies between the Flat Top Mountains, near Trappers' Lake, and Grand River. The elevation is from 10,000 to 11,000 feet over an area of about 750 square miles, the Flat Tops rising on an average 1,500 feet higher. From what I have noted in other parts of the plateau I am of the opinion that the entire area was formerly the bed of a large ice field probably as recent as any that have left a record in the main range. Snow never entirely disappears in the cañons which terminate abruptly in the higher parts of the Flat Tops; in fact the elevation and topography are both well suited for the accumulation of snow and formation of glaciers. On the present geological map only the most remarkable occurences of glacial drift in Colorado are shown, while in reality it exists almost continuously along the main, or Sawatch, range and prominent spurs like the Elk Mountains and Sangre de Cristo.

In addition to the opportunities awaiting the student of systematic geology in the territory already covered by preliminary surveys, there are yet greater opportunities to be found in those less accessible parts of the Rocky Mountains which remain comparatively unexplored and where members of the Society have either a temporary or permanent residence. To such members I will suggest

* Proc., Vol. II, Part 2, Page 95.

that the operations of this Society are not bounded by the State line; the results of scientific work elsewhere will always be welcomed and duly appreciated.

There is one branch of geological study that has received comparatively little attention in a systematic way, unless under the stimulus of an apex suit, and that is "mining geology." I can imagine no line of investigation better suited to the training of a majority of our members than that which relates to ore-deposition and occurrence. Endlich and Peale were probably the first to attempt a systematic examination and description of Colorado ore-deposits; but their reports refer exclusively to the older districts of the State, and the thorough study of these deposits did not begin until the geology of the Leadville district was taken up by Emmons. Since then the Ten-Mile, Silver Cliff and Gunnison districts have been carefully examined. The monographs on these districts when published will more than treble our literature on this subject, which at present consists only of the reports by Endlich and Peale already referred to and a few contributions scattered through the Society's proceedings.

The paper "On the Ore Deposits of Red Mountain District," recently presented to the society by T. E. Schwarz, will suggest many opportunities which exist for further work of this nature, and which many members of the Society are quite competent to carry on systematically in their own districts.

It is remarkable to think that the study which has been given to this subject in Europe, and of late years in the United States, should have done so little to increase our knowledge of the conditions governing the formation of ore-bodies. This fact alone sufficiently proves the complicated nature of the problem which seems as far as ever removed from a satisfactory solution.

At the present time the following points may be regarded as of general application:

That the most valuable ore-bodies occur enveloped by, or in direct contact with, either eruptive or highly metamorphic rocks; or, if in sedimentary rocks, then in localities where these have been intersected or broken by eruptive or metamorphic rocks.

That they may occur as the material filling pre-existing fissures or be deposited along contact or fault-planes by the partial or entire replacement of the constituents of the enclosing rock.

That they have been deposited from aqueous solutions, circulating in a more or less vertical or horizontal direction, which have derived their metallic contents from either the contiguous, subjacent, or not very remote, rocks of the region in which they occur.

It may be noted that while these points cover the majority of known metalliferous occurrences, they are very general in character and within the limits given the ore-bodies themselves show great variation in the conditions of occurrence and in mineralogical composition and association. With this fact in mind it becomes evident that, while it is desirable that the study of important vein-systems should be carried to a logical conclusion, which is just as necessary as the mere statement of facts, observations of a local character will usually possess but a local significance; in other words, generalizations based on the study of an isolated district should not be thought of.

It seems rather superfluous, in connection with this part of the subject, to mention particular districts in a field which is virtually unoccupied from the Sierra Madre to the

the Selkirk Range, but I may say that, on account of its extent and the anomalous character of its deposits, I regard the San Juan region as above all others deserving a thorough investigation. It embraces the similarly-occurring veins of San Juan, Ouray, Hinsdale and San Miguel Counties, and the isolated and dissimilar deposits of Dolores and La Plata counties; the latter with its telluride ores. This is really a work of greater magnitude than any yet taken up by the divisions on mining geology now exploring the districts of Colorado and Nevada under the general government, hence its accomplishment will require many years of faithful labor on the part of whoever shall undertake it.

Every paper on this subject, that may be looked upon as something more than a mere sketch, ought to be sufficiently comprehensive to include at least one entire district or group of deposits and be accompanied by a geological map, with one or more geological sections, drawn to a scale not smaller than two miles to the inch. Illustrative specimens of the various ores, rocks and minerals ought always to be presented with the papers. Collections of such papers and maps, properly grouped and bound in volumes of suitable size, might be very useful to persons interested in mines or mining geology, especially when taken in connection with the economic products of the districts described.

I think all will agree with me that no branch of science has been so much benefited by Rocky Mountain exploration as paleontology. The remarkable forms of extinct vertebrate life brought to light by these explorations have no doubt greatly stimulated the efforts of those engaged, while the works of Marsh, Cope, Leidy, Meek, White, Newberry, Lesquereux, Ward, Scudder, Walcott and others form a valuable contribution to the literature of this science. But there are yet many geological problems which paleontology will be depended on to solve, while continued explorations may be expected to provide an unlimited supply of fresh material. It is specially desirable that the flora of the Laramie, east and west of the range, should be more fully compared, and the comparison extended to the Laramie of Wyoming, so as to set at rest the doubt which exists regarding the identity of the beds in these several localities.

The peculiar association of fossil remains in the beds of the Denver basin has just now raised a question as to their age which can only be settled definitely by a further study of new and good material.

The Triassic (?) of Colorado also demands consideration. Newberry long ago investigated the flora of this system in New Mexico, but up to the present time almost nothing has been done toward defining the horizon of the "Red Beds" in Colorado. The exposures west of the San Juan Mountains offer the best if not the only chance in this State for making a collection of Triassic fossils, and I believe those on the Rio Animas to be the best developed and most accessible for the purpose.

For those who desire to make collections of fossils in the various Colorado formations I append the following list of localities: Devonic shells: Cañon City. Carbonic shells, crinoids and bryozoans: Animas River, near Hermosa. Triassic plants and saurian remains: Animas River, below Hermosa and on the Rio Dolores. Jurassic: Atlantosaurus beds, Front Range. Dakota plants: fire-clay beds south of Golden. Colorado: marine shells everywhere abundant. Laramie plants: Walsen's Springs near Walsenburg, Fisher's Peak, Canon City, Erie and Crested Butte. Tertiary vertebrates:. lower Animas River, and at the Grand River exposures. Tertiary plants and insects: Florissant.

A fine collection of the plants of the Denver beds can be made in Green Mountain and South Table Mountain, near Golden, Plants of the Middle Carbonic can be obtained in limited numbers on the Rico stage road near Rockwood station, on the Silverton branch of the Denver and Rio Grande Railway.

We come now to another branch of geological research, as interesting as it is progressive, viz., petrography. Until late years the modern methods of petrographical investigation have been but little understood or appreciated outside of Germany, hence it is not a matter of surprise that only a few of our members possess more than a general idea of the subject. But the publication within the past year of "British Petrography" by J. J. H. Teall; "Rock Forming Minerals" by F. Rutley, and last, but not least, J. P. Iddings' translation, with judicious abridgement, of "Microscopic Physiographie" by Prof. Rosenbusch, will go far to remove the barrier which has stood between English-speaking students and a thorough knowledge of this important branch of study. With the encouragement thus given we may hope that students here in the West will take advantage of the spendid opportunities which this country offers for work in that direction.

The investigations of Von Richtofen and Zirkel, and more recently of Cross, Hague and Iddings, on the eruptive rocks of the Pacific slope and Rocky Mountains, have laid the foundation of petrographical study in the West. The microscopic examination by Zirkel of the rocks collected along the fortieth parallel resulted in that admirable monograph, "Microscopical Petrography." It is to be regretted that the eruptive rocks occurring in the territory surveyed by Hayden were not submitted to the same eminent authority. As it is, our knowledge of the eruptive rocks of Colorado and New Mexico, except in the districts studied by Mr. Cross, is of the most general description, while all the information that can really be gained from the maps is the presence or absence of eruptive rocks in general and not of any particular kind.

Doubtless the most recent eruption that took place in Colorado was that on Eagle River, just above Dotsero, mentioned at a former meeting by P. H. van Diest. It may be described as a mass of scoria, one mile in length, occupying the bed of the river, which, from this cause, is deflected from its course over toward the south side of the valley. The vent from which the lava flowed appears to have been situated in the mountains near by to the northward. This outburst is the only one in the State that can be regarded as contemporaneous with the more recent eruptions of New Mexico, such, for instance, as took place near old Camp Wingate and around Mount Taylor. Of the Tertiary eruptions that occurred in Colorado, the latest is probably represented by the scoriaceous basalts of Battlement and Grand Mesas, the similar material of the Flat Top Mountains and possibly the overflow of Fisher's Peak. These were preceded by overflows of more compact basalts, or allied rocks, poured out toward the close of a period of successive eruptions probably extending back to the beginning of the Miocene or, in the case of the tufaceous beds of the Ruby Peak series, to near the close of the Laramie. It was during this period of eruption that the overflows took place which covered the San Juan Mountains with the 4,000 feet of lava enclosing the numerous ore-deposits of that region. The basal member of the San Juan series consist of about 1,500 feet in thickness of eruptive breccia, in appearance closely resembling that of the West Elk Mountains, and of the Black Range in New Mexico, but is much more extensive and of greater thickness. Most of the productive veins of San Juan are contained in this breccia.

Belonging to the same period are nearly all the eruptive masses east of the Sangre de Cristo Range, as also the dyke systems of the Spanish Peaks and Silver Mountain, the intrusions of white porphyry forming La Veta and Sheep Mountains and the conformable sheets so conspicuous in the Colorado on Indian Creek and the head of the Purgatoire. The older of the Leadville groups is regarded by Emmons as belonging to the later Mesozoic. The eruptions of southern Colorado, with few exceptions, were no doubt subsequent to the Wahsatch, or Lower Eocene, as explained in my paper on the Huerfano River beds. The study of Colorado eruptives by Dr. Cross has developed many new and interesting varieties even within the limited area to which his work has been confined. There is therefore every reason to suppose that further studies of a like character, directed either to the investigation of eruptive masses, or towards the extensive areas of crystalline schists, will be richly rewarded.

The preceding remarks have had reference exclusively to opportunities for study in the branches directly related to geology. There are, however, other lines of investigation more remotely connected, which also deserve to be recognized. Those which are at present most interesting to us are mineralogy and mineralogical chemistry; the latter, which may be made to include the analysis of soils and rocks, must depend for support largely on the active interest taken in the former, and it is consequently for the mineralogists that the following observations are intended.

The most remarkable mineralogical occurrences in the Rocky Mountains are those of Pike's Peak and of Boulder County. Many of the Pike's Peak minerals, including those associated with cryolite, have been described by members of this Society, and an excellent representative suite is to be found filling one of the cases in the museum. The telluride minerals of Boulder County have been mostly studied by Genth, also to some extent by Silliman, with the result that nearly all the known species are found to occur there, and Coloradoite (mercury telluride) has not yet been announced from any other locality. Very little crystallographic work seems to have been done on these tellurides, the complaint being that crystallized specimens are extremely rare. No doubt this is largely true; still it is a question if few have taken much pains to collect and preserve fine specimens unless prompted to do so by evidence of intrinsic richness. The fact that the chemical work performed on these minerals has been restricted to Genth's investigations, carried on in the East, justifies the conclusion that they deserve additional study. The mines of Clear Creek and Gilpin Counties have produced well crystallized specimens of common metallic minerals, yet but little that was new or rare. The San Juan mines have furnished three minerals new to science, viz., alaskaite, zunyite and guitermanite, besides several rare ones like hubnerite, cosalite and sylvanite. The extent and variety of the mineral deposits of the southwestern counties may lead us to regard this part of the State as a very promising field for mineralogical work. The Gunnison region is also known to contain some interesting minerals, particularly in the metamorphosed Carbonic strata of Italian and Snowmass Mountains. The so-called "mineral wool" of Poverty Gulch, near Crested Butte, has recently been analyzed by L. G. Eakins, and shown to be a new sulphantimonite. Another promising locality is to be found in the vicinity of Mount Antero, rendered specially interesting on account of the rare beryllium minerals there found associated, including the bertrandite identified last summer by Penfield. The section of country around Salida is also one of promise. It has already furnished good specimens of garnet, epidote, pyroxene and corundum, the two former being remarkable for the size of the crystals.

In addition to chemical and crystallographic work on minerals, complete analyses of the soils of the great valleys of the State, and of the waters of the different mineral springs, as once suggested by Mr. Pearce, will furnish original material for some half-dozen of our members who have access to laboratories where such work can be done.

The field for original work which I have thus imperfectly outlined is, beyond all question, a grand one; it remains for us to show to what extent we are capable of utilizing its resources. In conclusion, let me say that all should feel called upon to further the objects for which this Society was organized so far as they can without detriment to their own interests.

OBITUARY.

Samuel Fowler Rouse, M. D., Died February 5th, 1888.

Doctor Rouse was born at Bordentown, New Jersey, April 21st, 1844. He studied medicine at Lawrenceville, New Jersey, and subsequently in New York City. He soon after removed to Iowa, and practiced his profession for several years at Burlington. Later on, he became engaged in the coal trade, and was finally appointed General Agent of the Colorado Fuel Company at Denver. He was elected a member of the Society June 7th, 1886, and up to the time of his death took an active interest in its affairs.

PROCEEDINGS

—OF THE—

COLORADO

SCIENTIFIC SOCIETY

VOL. III, PART II.

1889.

PUBLISHED BY THE SOCIETY,
DENVER, COLO.

COMMUNICATIONS

AND

ADDRESSES.

MEETING OF JANUARY 7th, 1889.

REMARKS ON THE PLICATION OF THE COAL MEASURES IN SOUTHEASTERN COLORADO AND NORTH-EASTERN NEW MEXICO.

BY P. H. VAN DIEST.

The most southerly of the Laramie coal-fields, of the eastern slope of the Rocky Mountains has its greatest width in the Raton Hills near the Colorado-New Mexico line: narrowing thence in a northerly direction to and beyond the Cuchara and southerly to a point a short distance beyond the Cimarron.

Its original extent, to the north and south, has been diminished by erosion, which, removing the Laramie beds, brought the shales of the Fort Pierre group of the Cretaceous to the surface. This would have also been the case in the middle of the field, along the State line, had not the strata containing the coal-beds been protected, to some extent, by a cap, or overflow of basalt, forming the Raton Mesa. The area of the field bounded by the Cuchara, on the north, the Cimarron on the south, the foothills of the Sangre de Cristo Range on the west, and Chicorica Mesa on the east, is not less than one million acres, within which area the coal is of an excellent quality for domestic purposes, and is in places well adapted for coking.

Mr. John J. Stevenson, late of the Wheeler Survey, reports 32 beds or seams of coal, aggregating 105 feet in thickness. These coal seams are separated by layers of sandstone and shale, the total thickness, between the Marine Cretaceous shales and the basaltic cap being about 1800 feet.

The beds of workable thickness, that is over three feet, are named following Stevenson's example, from the locality where they are most prominently exposed. These beds, beginning with the lowest are: The Dillon, Trinidad, Upper Willow Creek, Reilly Cañon, Lower Vermejo, Upper Vermejo, Potato Cañon, Long's Cañon, Cameron, Raton, Caliente, and the Upper Red River Cañon, beds.

None of these beds extend over the whole area of the coal field; the lower beds having naturally the greatest extent. The higher beds do not, as a rule, reach the outside limit of the field, and even in the central parts are interrupted, where erosion was deepest. Some beds ramify, thin out, or disappear entirely, others vary in thickness and quality at different localities. The Trinidad bed, which north of the Colorado-New Mexico line is a rather persistent bed of workable thickness, and of good quality, shows six feet of coal with much admixed shale at but a single place in New Mexico, viz: Crow Creek, and only at a few other places does it exist even as a very thin vein. The Dillon bed which in New Mexico is generally well developed, but of insignificant thickness on the Colorado side of the boundary line, is exposed along the eastern rim of the Laramie in nearly every cañon, and contains coal of good quality.

Several prominent folds occur in this field; although they are minor folds compared with the bold flexures west of the field, along the Sangre de Cristo Range, but, nevertheless, these minor folds are economically of great importance, since they elevated the Laramie formation sufficiently to render the mining of its coal possible, without deep shafting.

These folds can be observed by going up any of the cañons which run from the Sangre de Cristo Range, down to the valley of the Canadian. Truax Cañon, the first cañon to the right above Dawson's farm, on the Vermejo, contains considerable coal in a vein of workable thickness.

Here the slight reverse dip near by indicates the existence of an anticlinal axis, which is plainer and more prominent southerly in Cerososo and Poñil Cañons. It may be that this fold extends across Chicken Creek and North of the Colorado-New Mexico line. Possibly the fold there observed is a separate, more easterly and more limited fold. The anticlinal on Chicken Creek is distinguishable, although rather flat. The synclinal trough east is easily recognized southeast of Morley, by the inclination of the sandstone beds, where they have been quarried for abutments for railroad culverts.

Near the mouth of Vermejo Cañon, one observes prominent exposures of the persistent and extensive Dillon bed. About four miles above Dawson's farm, splendid croppings of coal six to seven feet thick, are found along the road. A mile further on in Stag Cañon, a side cañon of the Vermejo, there is a seam four or five feet thick which probably belongs to the lower Vermejo horizon. A couple of miles above, near the water line of the creek, are the outcroppings of the Upper Vermejo or possibly the Potato Cañon bed, which is here but 18 inches thick.

The road now leaves the bed of the stream and bending towards Caliente Creek, reaches at a higher level the Caliente coal-beds. In Caliente Cañon this bed is six or seven feet thick, but is in many places somewhat broken up. This bed apparently continues to the South Fork of the Purgatory River, where it shows four feet of solid coal. It appears also in the Upper Red River Cañon, but here it is very much broken up by sheet-like intrusions of basalt between the overlying sandstones, changing the coal into natural coke. Fragments of graphite were found in the debris of a disturbed coal-bed near the mouth of Potato Cañon.

A synclinal crosses Sales Cañon on the Vermejo not far east of the anticlinal axis, which can be observed on the eastern side of the Vermejo Valley, whence it extends in a northerly direction to La Junta at the mouth of the South Fork of the Purgatory River.

West of this axis, coal croppings are seen for several miles to near the Elkin's post office, where the coal vein is several feet thick, with partings of thin seams of clay. West of the Elkin's post office, not far from Cameron's store, the Cameron bed, three feet thick, appears. This bed can be traced to the South Fork of the Purgatory River, where in Dillon Cañon, it is two feet thick, but only shows as blossom near Raton.

Passing the synclinal again, to the west lower beds are reached. Near the mouth of York Cañon, a bed of coal, three feet thick, crops out. Above this bed the sandstones contain many fossil leaves. Higher up this side cañon the Upper Vermejo bed has a great development. Before reaching this bed, a lower one can be traced in a northwesterly direction by blossom, and in many places, where the hills are thickly covered with debris, and the outcrop concealed, its existence is shown by material brought to the surface by burrowing rodents.

Above the Elkin's post office, the Vermejo widens out into a park, the creek forking midway. This is a little beyond the point where the axis of the Vermejo anticlinal crosses the creek, and where it can readily be found by the reversed dip of the strata, north and south of the creek. On the east side of the park a lofty and steep bluff rises above the valley, showing at its base the Cretaceous shales, and above these the halymenites sandstones, followed by the strata of the Laramie with blossom of coal. All these beds dip to the east. West of the park towards Rock Creek, the dip of the strata is northwest, and occasionally we find blossom of coal-beds, which are here much broken up. On the Vermejo side, a half-mile east of Rock Creek Cañon, there is a small side cañon to the north, in which may be observed conglomerates and sandstones, enclosing in places small nut-like lumps of coal, probably derived from a much broken up layer near by.

The Vermejo fold, as already mentioned runs north and south. It can be traced northerly to the confluence of the North and Middle Forks of the Purgatory River, and southerly to Poñil Creek, being prominent near Rincon, at the bend of the South Fork of the Purgatory River, where the Fort Pierre shales are brought to the surface.

On the Poñil side, near Martin's ranch, in a lateral cañon about three quarters of a mile northeast of the road, is the probable southern limit of the Vermejo fold. This fold has not had here the effect of lifting to the surface strata underlying the coal formation, but appears well marked as a fault, or break by which the strata are thrown over each other, like beds in an unconformable position. The same peculiarity is observed at the northern limit of the fold near the mouth of the North Fork of the Purgatory River, except that the overthrow took place from the other i. e., the west side.

If folds in the earth's crust are due to the horizontal pressure brought about by cooling and wrinkling of the surface, then by virtue of gravitation, those parts which move towards the center of the earth will act as a wedge, and press together in a horizontal direction the strata not sharing in the downward movement, thus causing within them the formation of anticlines and synclines. Without doubt the main pressure in this field, came from the west, as the folds are prominent on the range side and become flatter and die out, as it were, towards the plains on the east.

The greatest pressure appears to have been developed on the northwest side of the Vermejo Park, and consequently the resistance must have been greatest on the southeast side, by which action the folding was most pronounced near the middle of the flexure, rending the layers at the extremity, and shoving them over each other.

Downward movements of the strata between the greater flexures, west of the Laramie, creating down-throw faults which no doubt influenced the folding of the Laramie beds, can be observed at several places; for instance, west of Moreno Valley, on Six Mile Creek, west of Baldy Peak, near the head of the South Fork of the Purgatory River, and east of Costilla Peak in the Stonewall Valley.

INFORMAL NOTES.

Mr. Geo. L. Cannon, Jr., called the attention to an article of O. C. Marsh in the December number of the "American Journal of Science," describing a new family of horned Dinosauria, allied to Stegosauria, found in the Laramie formation of Montana, and remarked in connection with this article that remains of Stegosaurs were discovered in section 15, township 4 south, range 69 west, seven miles southeast of Golden.

These remains were originally covered with a layer of loëss, but by the effect of a cloudburst were exposed to view. The finding of remains of Dinosaurs and Stegosaurs would indicate rather the Cretaceous than Tertiary age of the Laramie beds.

MEETING OF FEBRUARY 4th, 1889.

ETCHED BERYLS FROM MOUNT ANTERO, COLORADO.

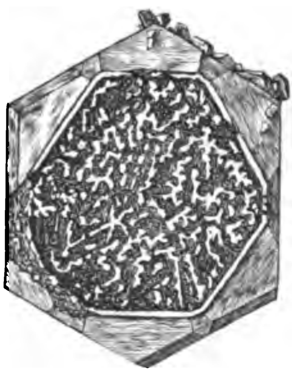
BY R. C. HILLS.

A number of Mount Antero beryls that have recently come into the writer's possession are nearly all etched in a manner which, so far as can be ascertained, has not been observed on beryl from any other locality.

The crystals in question are from cavities containing the beryllium minerals phenacite and bertrandite. The former frequently occurs in characteristic form implanted on the beryls; the latter implanted, or partly penetrating, while in rare instances both these associated minerals may be found so implanted on one specimen.

The only forms determinable in the etched crystals are: ∞ P, oP and 2P2, although ill-defined scalenohedral planes are evidently present.

The peculiar etching represented in the diagram is confined to the basal plane in all the crystals on which it has been observed, while the pyramidal planes exhibit merely a roughened, lusterless surface. The basal plane presents a number of closely-crowded, irregular or convoluted ridges extending up to the level of the original face and terminated by intact portions of it; the shallow spaces between the ridges representing the extent to which the substance has been removed.



× ⅓

Surrounding the etched surface is a narrow, well-defined glistening bead, more or less continuous and of even breadth, corresponding to the bounding edges, or border of oP. The etching is usually somewhat deeper near this border than elsewhere. It is, nevertheless, a remarkable fact that the inner edges of the surrounding bead are, in all cases, clean cut, and as free from irregularities as a line drawn with a fine instrument.

The etching, when once begun, appears to have been confined mainly to the spaces first attacked. As a consequence the substance in these spaces may have been eaten away to a considerable depth, and yet the parts of the surface not originally attacked will, in common with the surrounding border, still present coincident reflections.

In addition to the associated beryllium minerals above mentioned, two others of secondary origin are noticeable. The most common of these has the ordinary form and appearance of adularia, although the crystals are too small and lusterless to admit of determinative measurements. Some of the beryls are partly covered with clustered crystals of this mineral, associated with a few bertrandites and phenacites belonging to the same period of growth.

The remaining mineral consists of light-colored, or purplish, octahedrons of fluorite, which are by no means common. Orthoclase, in large twins after the Carlsbad law, and smoky quartz are ordinarily associated with the beryls and belong to the same period of formation.

About three-fourths of the crystals in the lot, showing terminations, are etched in the peculiar manner described; the exceptions being those that are perfectly transparent and without any trace of prismatic striation.

ANALYSES OF THREE DESCLOIZITES FROM NEW LOCALITIES.*

BY W. F. HILLEBRAND.

1. Mayflower Mine, Bald Mountain Mining District, Beaverhead County, Montana.

Through Messrs. W. H. Beck and George E. Lemon, of Washington, D. C., was received about a year ago for examination a large lump of friable, uncrystallized material having a dull yellow to pale orange color, and consisting chiefly of a vanadate, but carrying a large percentage of gangue. Two samples as pure as could be selected from different parts of the lump were analyzed, with the following results:

	I.	II.	Mean.	Molecular ratios.		
PbO	56.02	55.84	55.93	.2508		
CuO	1.16	1.13	1.15	.0145	.4718	4.02
FeO	0.70	0.70	0.70	.0097		
ZnO	15.96	15.91	15.94	.1968		
V_2O_5		20.80	20.80	.1140		
As_2O_5	0.32		0.32	.0014	.1173	1.00
P_2O_5	0.27		0.27	.0019		
H_2O	4.37	4.36	4.37	.2428		2.07
SiO_2	0.20	0.16	0.18			
CaO	0.10		0.10			
MgO	0.06		0.06			
			99.82			

From I 27.62 per cent. of gangue insoluble in cold dilute nitric acid has been deducted, and from II 22.20 per cent.; manganese was present in the gangue in small quantity, apparently as pyrolusite, but it was not dissolved by the acid. The insoluble portion was found also to retain very small quantities of lead and zinc, which were

* This paper has appeared in the Am. Jour. of Sci. for June, 1889.

estimated and included in the analysis as probably belonging to the vanadate. The water had to be estimated indirectly by deducting from the total amount of water afforded by the dried mixture of vanadate and gangue that belonging to the latter alone, which was found as follows: The mixture dried at 100° C. was dissolved in cold dilute nitric acid, and the insoluble matter collected in a Gooch crucible was dried at the same temperature and then ignited. The loss on ignition gave the water in the gangue, there being no ferrous iron to influence the result. The traces of SiO_2, CaO, and MgO may be neglected as probably derived from the gangue. The water, it will be noticed, is double that required by descloizite, $R_2(OH)VO_4$, but in view of the liability to error inherent in the method of water estimation employed this is not deemed sufficient cause for separating the mineral from descloizite, although the close agreement of the two water determinations, made as they were on samples containing different proportions of gangue, would indicate the correctness of the formula $2[R_2(OH)VO_4]+H_2O$.

Other specimens have since been received from the above named persons in which the earthy vanadate was associated sometimes with compact cerussite and galena in process of alteration. A dull reddish substance which constituted a part or even the whole of some lumps contained, besides silica, iron and some antimony in an oxidized condition, but carried little or no vanadium.

Prof. F. A. Genth has already called attention* to the occurrence of vanadinite and probably of descloizite in the Bald Mountain mine, Beaverhead County, Montana. His specimens, however, showed the supposed descloizite as a pale brownish crystalline coating on yellow ferruginous quartz, whereas the present mineral shows no evidence of crystalline structure.

* Proc. Am. Phil. Soc., xxiv, 38, 1887.

2. *Commercial Mine, Georgetown, Grant County, New Mexico.*

This is one of the most interesting occurrences of descloizite known, because of the extreme brilliancy of coloring of the mineral. The ore bodies in the Commercial mine, as well as in the adjoining MacGregor and Naiad Queen mines, occur in limestone immediately under an overlying slate, and appear to narrow in depth where certain eruptive dikes cut through the lime, as Mr. MacIntosh, foreman of the Commercial mine, informed me. The absence of the superintendents of the several mines and the very brief visit I was forced to make prevented obtaining more certain and detailed information.

In places where the rock is most fractured and crushed the descloizite appears in greatest quantity and finest condition as an incrustation on quartz, often covering large surfaces, and in color varying from yellow through all shades of orange red to deep reddish brown, the last named colors predominating. The black color so frequent in descloizite from Lake Valley, New Mexico, caused by a superficial coating or admixture of pyrolusite, is, so far as my observation extended, wanting, hence specimens from Georgetown are likely to be much sought after for their showy appearance. A specimen in one of the banks at Silver City, New Mexico, taken from one of the Georgetown mines, resembled a stalactite in form. It was probably fully three feet in height by six to eight inches or more in diameter, and was deep reddish brown in color.

The incrustations are, for the greater part, distinctly crystalline and are generally made up of aggregates of more or less globular forms of a size ranging from microscopic to a diameter of one or two millimeters. Each of these is composed of a great number of apparently flat crystals, intergrown and projecting sufficiently from the surface to give brilliant reflections when observed under the lens, and to the naked eye a frosted appearance where the globular growths are largest. The richest reddish brown color is always coincident with this development in size. The globular character changes frequently to acicular. In such cases the incrustation seems to have originally formed on bunches of radiating acicular, almost colorless, vanadinite, which frequently appears thus coating the quartz and running under the descloizite incrustations. Sometimes the vanadinite has entirely disappeared and then there may be a hollow through the center of the descloizite needle.

The occurrence of vanadate of lead in the MacGregor mine at Georgetown has been noticed by Prof. Genth (l. c., p. 38).

The specific gravity of the mineral was not determined; the hardness is about 3.5; the color of the powder is orange-yellow. An analysis gave the following results after deducting 11.91 per cent. of insoluble matter, almost entirely quartz:

		Molecular ratios.			
PbO	56.01	.2512	.4843	.4788	4.12
CuO	1.05	.0132			
FeO	0.07	.0010			
ZnO	17.73	.2189			
V_2O_5	20.44	.1119	.1178	.1162	1.00
As_2O_5	0.94	.0041			
P_2O_5	0.26	.0018			
H_2O	2.45	.1361		.1361	1.17
Cl	0.04	.0011			
SiO_2	1.01				
CaO	0.04				
MgO	0.03				
	100.07				

The third column of molecular ratios gives those values after allowing for admixed vanadinite calculated on the basis of the chlorine found. A further correction has probably to be made for an admixed soluble hydrous (zinc?) silicate, which might make the ratio approximate more closely to 4 : 1 : 1.

3. Lucky Cuss Mine, Tombstone, Cochise County, Arizona.

Mr. W. F. Staunton, Superintendent of the Tombstone Mining, and Milling Co., and Mr. Frank C. Earle, assayer at Tombstone, kindly placed at my disposal for examination specimens of a vanadium mineral, the identity of which had not been established. It was found in the Lucky Cuss mine as an incrustation, sometimes half an inch thick, on quartz, showing more or less botryoidal surfaces of an indefinable dull greenish color. On a fractured surface the color is brown; the luster is resinous; the structure granular, only occasionally diverging fibrous; the hardness 3.5; the specific gravity of sample analyzed, containing a little impurity, 5.88 at 19° C.; color of powder lemon yellow. Analysis gave the following results after deducting 0.67 per cent. of insoluble matter.

		Molecular ratios.			
PbO	57.00	.2556	.4485	.4385	3.93
CuO	11.21	.1412			
FeO	trace				
ZnO	4.19	.0517			
V_2O_5	19.79	.1084	.1145	.1115	1.00
As_2O_5	1.10	.0048			
P_2O_5	0.19	.0013			
H_2O	2.50	.1389		.1389	1.25
Cl	0.07	.0020			
SiO_2	0.80				
CaO	1.01				
MgO	0.04				
K_2O	0.10				
Na_2O	0.17				
CO_2	0.82				
	98.99				

The low total is probably owing to a loss of zinc during analysis. Calcite was present as an impurity, and as the CO_2 just suffices for the CaO and MgO, these are rejected in considering the composition of the vanadate. The figures in the third column of molecular ratios are found by allowing for probably admixed vanadinite calculated from the chlorine found. In another specimen a qualitative test for chlorine indicated a greater admixture of vanadinite. As in the case of the descloizite from Georgetown, New Mexico, previously described, a further allowance has perhaps to be made for a soluble hydrous silicate. There can be no doubt that the general formula for the vanadate is that of descloizite.

In almost every respect this mineral resembles, so far as the published descriptions allow of judging, the descloizite of Penfield,* the cupro-descloizite of Rammelsberg,† and the ramirite of de Leon,‡ perhaps also the tritochorite of Frenzel,‖ to the similarity of which with his variety of descloizite Penfield draws attention in his paper. Prof. Genth's surmise (l. c., p. 39) of the specific identity of all these substances seems highly probable. Characteristic for the present variety is the greater replacement of the lead-zinc vanadate—true descloizite—by the isomorphous lead-copper vanadate, and the lessened tendency toward a fibrous structure, which in the other varieties described seems to be a decidedly pronounced feature. Possibly this last characteristic of the Tombstone mineral, if it be not accidental in view of the few specimens (three) examined, is a condition of the first.

According to Rammelsberg§ the lead-copper vanadate corresponding to the lead-zinc vanadate (descloizite) is mottramite or psittacinite, though it seems not improbable that it may be the chileite of Dana's Mineralogy. Domeyko's analysis,¶ which led Kenngott to ascribe the above name to the Chilian mineral, show a deficiency of 2.5 and 2.8 per cent., which may very well be V_2O_5. At all events

* Am. Jour. Sci., [III] XXVI, 361, 1883.
† Monatsb. Berl. Acad., 1883, 1215.
‡ La Ramirita, nueva espèce mineral, Mexico, 1885.
‖ Tschermak's Min. and Petr. Mitth., III, 506, 1880; IV, 97, 1881.
§ Chemische Natur der Mineralien, p. 32.
¶ Ann. d. Mines, [IV] XIV, 150, 1848; Phil. Mag., [III] XXXIV, 395, 1849.

a recalculation of his analyses based on this assumption leads to a proportion for $PbO + CuO : V_2O_5 : H_2O$ of nearly 4 : 1 : 1.

In view of the well defined character of all these highly cupriferous varieties of descloizite it would be well to designate them once for all by some distinctive name. Tritochorite would have precedence if the substance to which that name has been given is really identical with the others, but Rammelsberg's cupro-descloizite is more appropriate as indicating at once the relationship to descloizite, and I would suggest that it be henceforth used for all cupriferous descloizites showing the physical characteristics of the mineral above described.

NOTE.—Since the foregoing was written there has appeared in the Bull. Soc. Franc. Min., Feb., 1889, p. 38, a paper by F. Pisani, in which he gives another analysis of the Mexican cupro-descloizite and discusses briefly the relations of various vanadates. The essential identity of all the above enumerated cupriferous lead-zinc vanadates, with the addition of another — schaffnerite — concerning which I have been unable to find any further reference in mineralogical literature, is therein upheld, and the suggestion of Penfield's regarding the possible identity of tritochorite and cupro-descloizite is confirmed by Frenzel himself, who is quoted as writing to Professor DesCloizeaux that he had not thought it necessary to consider as an essential constituent the two per cent. of water which he had found in tritochorite.

Laboratory of the U. S. Geological Survey,
Washington, D. C., Feb. 9, 1889.

NOTES ON THE ABORIGINAL REMAINS, NEAR DENVER, COLORADO.

BY GEO. L. CANNON, JR.

The aboriginal remains of this vicinity, although nearly as numerous as the proverbial Hibernian Ophidia, may possibly present a few points of interest.

The aridity of the region not only compels the natural lines of travel to follow the water courses, but also locates the mass of the population in the river bottoms. Hence as several locally important streams empty into the Platte River near Denver here, if anywhere, must be found the traces of any large or highly civilized population—the site of Denver being the natural center of any population, historic or prehistoric.

A careful examination of the field, a diligent search through the files of local papers and other records, and extended interviews with old timers have failed to reveal evidence of the existence of a civilization higher than that of the Arapahoes, the Utes or the Cheyennes that inhabited northern Colorado prior to the advent of the '59ers. Outside of the recollections and the scanty published statements of the early settlers about the only evidence we have of our aboriginal population are the few stone arrow-points lost in hunting and the small quantities of stone flakes that mark the site of some prehistoric encampment.

Along the bluffs bordering the western bank of the Platte and the south side of Clear Creek may occasionally be found spots where the ground is sparely strewn with fragments, cores and chips of stones used in the manufacture of arrow-heads and other tools. Diligent collecting could not obtain from any of the places more than a few pounds of flakes and in most places a handful would be all that could be obtained. The materials used in the manufacture of stone weapons have been derived almost exclusively from the neighboring river beds or hillsides where the removal of the loëss has permitted the exposure of the ice-drift material, at the base of the loëss. As a rule every exposure of formations yielding materials suitable for this purpose will bear evidence of the careful search by the Indians for the desired substances by the presence of shattered and chipped boulders and abundant flakes and chips. It is rare to find, in any of the encampment sites along the Platte any material that can not be found in the immediate vicinity. Arrow-points and other tools are extremely rare; a fact in some measure due to the collecting of thirty years incident to the proximity of a large population.

Notwithstanding the thousands of excavations which have been made in and around Denver, the writer has been unable to learn of the opening of more than two Indian graves and these as proved by the contents accompanying the body were of quite modern origin.

The results attained from the exploration of the older Quaternary deposits of Europe and America should prompt a careful search of all fresh exposures of either the Loëss or the River-Drift formations for relics of early man.

In 1878, the late Thomas Belt of London, England, obtained from the cutting of the C. C. R. R., at the end of the Argo line of horse-cars, the upper portion of a human skull. This relic was found firmly imbedded beneath forty-five inches of undisturbed loëss, and, if a supposed fragment of a human rib, found some seventy yards down the cut be excepted, was apparently unaccompanied by other portions of the skeleton. The isolation of the fragment and its white pulverulent appearance corresponds to the general characteristics of the Loëssial fossils. The locality presents no special advantages for purposes of interment and the very gently sloping hillside lessens the probability of the scattering and covering of modern bones by wash from the upper portion of the hill. It is to be regretted that Mr. Belt's sudden death prevented the gathering of other data than those contained in the Proceedings of the American Association for the Advancement of Science for the year 1878. In the writer's opinion the evidence of the high antiquity of this fossil must remain a matter of doubt.

Great care must be taken to avoid mistaking the effects of the powerful torrential drift of the region for evidences of the great antiquity of human relics now buried under a considerable thickness of earth, e. g. the "fossil bear trap" in the collection of the Mercantile Library, found four feet below the surface and some four hundred feet from the Platte River. Near Zang's Brewery a number of flakes were found in the Loëss under circumstances that a person unfamiliar with the deposit would have been led to infer indicated a remote antiquity.

Reports have been received of the existence in the Foothill and Hogback regions of various aboriginal structures of stone but the writer's investigations would not lead him to the belief that we have unequivocal evidence of the existence of a civilization higher than that of the nomadic Indians of the Plains. It is very doubtful if the town-building tribes of the Southwest ever wandered far into inhospitable regions north of the Arkansas, although a skull of marked Central-American type was said to have been found in Clear Creek Cañon and at the mouth of said cañon it is stated that there formerly stood a square fort and a mound of earth of "Aztec" workmanship.

The facility with which stone buildings can be erected in the region along the base of the mountains has led to the construction of many buildings in isolated places for temporary use for such purposes as the taking up land or the getting out timber, and it is quite possible that when the shifting population of a new country shall have forgotten the purpose of their erection that they may be regarded as the work of prehistoric inhabitants.

Near the Foothills, Indian remains become more abundant. On nearly every prominent hill stone circles mark the site of the old signal fires of Indians; some as indicated by the depth to which the stones have sunk are of some antiquity.

Near Green Mt., a favorite resort of the Indians for obtaining quartzite, agatized and jasperized woods, may be found rows of stones sometimes arranged in the form of a rectangle or at other times as if to mark the sides of a path. A rude semicircle of basaltic boulders on a butte south of South Table was possibly used as a breastwork.

Along the base of the mountain it is quite common to find places where large quantities of chippings and tools can be found. Some of these old encampments are situated in places admirably adapted for defense as on the Castle Rock and other projections of the Golden Mesas. Others occur in the meadows, especially in the valley between the Dakota hogback and the Archæan foothills; the white Triassic hogback seeming to be an especially favorite site.

The variety and beauty of the stones used in making arrow-heads testify to the taste used by the Indians in making their weapons, and to the extent and diligence of their searches for desirable material. Some beautiful collections of siliceous stones have been gathered at the arrow maker's shop near the old Apex ranch. Quartzites of various shades and wood agates and wood jaspers were favorite materials. Quartz crystal, smoky topaz, carnelian, chalcedony, petrified bones, and hornstone were used less frequently. The presence of moss agate, obsidian, and rhyolites from some distant volcanic region indicates either the extent of the wanderings of these Indians or of the existence of some commerce between them and other tribes. It is possible that differences noticeable between the chippings from the camps in the Hogback region and those out on the plains near Denver may be due to difference in the tribes, those of the first named district being the relics of the mountain tribes, the Utes, and the other of the Arapahoes.

While some specimens of exquisite finish may be found on the weapons, the majority are not noticeable for perfection of workmanship, especially is this the case with the celts and the rude scrapers and hammers.

Bits of sandstone containing ochre and fragments or thin slabs of gritty sandstone, polished by use, are frequently found along with the chippings.

The bodies of Ute Indians have been interred near Morrison and speedily resurrected by avaricious settlers.

All over the plains the sods of buffalo grass are covering the fire-reddened stones that mark the old homes of the former owners of the plains and foothills. With the dying out of the embers of the last camp fire of Peah's band on their memorable return to Middle Park the land was forever resigned into the hands of its present occupants.

MEETING OF APRIL 1st, 1889.

THE PLASTICITY OF GLACIER ICE.

BY JOHN F. MAIN.

Since Forbes made his classic experiments on the motion of glaciers, a controversy has been in progress on the causes of that motion. Briefly stated, Forbes' observations led him to conclude that a glacier is practically a river of ice, subject to laws of motion similar to those which govern rivers in their courses. The snow falling in the extended basins which lie at the heads of the valleys, becomes consolidated in a way not yet fully made out into the mass, partly snow, partly ice, which is called *firn* or *névè*. This in its turn becomes gradually transformed into the highly heterogeneous compound called glacier ice. In these successive transformations, which the fine powdery snow of the Alpine heights undergoes, the amount of included air diminishes. The proportion in the upper snow (Hochschnee) is very great, in the *firn* it is less, in the glacier ice least of all. The transition from the snow to the *firn* and to the ice is gradual, the operations which cause the transformation are unknown. Change of temperature, the great pressure called into action by the weight of the snow above, and the melting and evaporation of the upper layers are undoubtedly the chief factors in producing the alteration, but how they act, in what proportion they each contribute to produce the result is not known. Equally obscure is the mode of genesis of the structure discovered by Forel, of Geneva and called by him the *grain du glacier* and by German writers, the *gletscherkorn*. If we take a block of glacier ice and expose it to the sun or in a warm room, the surface will soon become very irregular and a rough crystalline structure will exhibit itself. It will be found that the mass is composed of a number of irregularly shaped bodies, whose surfaces fit those of the neighboring bodies. The bodies are the glacier grains. Each one is a distinct ice crystal the optical axis of which has as a rule a different orientation, from those of neighboring crystals. The size of the grains varies, increasing from the magnitude of millet seeds or of even smaller seeds, at the beginning of the glacier, to that of hen's eggs or even of melons near the end. Each grain is a definite crystal, exhibiting the rings and cross of an ordinary uniaxial crystal, when a section perpendicular to the optic axis is viewed in polarized light. Such is the heterogeneous compound, a kind of conglomerate of ice crystal, which constitutes the mass of a glacier.

Forbes showed what later observations have confirmed that such a mass moves as if ice were a plastic substance like a river of pitch or tar. Its motion is greater in the middle than at the sides, but all parts of it move steadily down the valley in which it lies. When the valley contracts, the rate of progress is greater than where the gorge widens. The law of continuity of fluid motion applies also to a glacier. When two or more affluents meet, the glacier moves more rapidly, owing to the contracted channel, than in the tributaries before they have united. The conclusion arrived at by Forbes was that glacier ice is a plastic substance. But experiments on hand-specimens of ice show its leading characteristics to be brittleness and it was hence concluded by Tyndall and others that ice is not plastic. Experiments by Pfaff, Matthews and others on the bending of bars of ice under their own weight indicated, on the other hand, that ice might be plastic under a long continued stress. Happening to be in St. Moritz, in Switzerland, in the winter of 1886, I determined to apply the accurate methods of modern testing to determine whether ice under tension exhibits the continuous yielding characteristic of a plastic body. For some months in that climate a temperature obtains several degrees below freezing point. I made several experiments, all of which led to the conclusion that ice, at temperatures below freezing point, stretches continuously when subject to tension. To give an idea of the amount of extension I may refer to one experiment in which I found that a bar of ice stretched at the average rate of 0.02 millimetre per hour for three days per length of 10 centimeters, the temperature during the course of the experiment not rising above $-2°$ C.

These experiments, although they conclusively proved that at least some varieties of ice act as plastic bodies, left much to be ascertained in determining the behavior under various conditions of temperature and of tension. On leaving St. Moritz I handed over my apparatus to my friend Mr. J. C. McConnel, and he, in company with a friend, pursued the investigation. His first experiment, made with ice cut from the surface of the water in a large bath, gave no extension at all, or none which could not be attributed to the change of temperature. Examination with a polariscope showed that the ice examined belonged to one crystal. In my own experiments the ice was frozen rapidly in a mould, and the polariscope showed a conglomerate of crystals, with optic axes variously oriented. Hence McConnel's first experiment revealed the hitherto entirely unsuspected fact that whilst a single crystal of ice is rigid, a collection of crystals will extend continuously under tension. After trying lake ice he next obtained some pieces of glacier ice, and here he found striking evidences of plasticity. One specimen showed a mean hourly increase of $.013^{mm}$ to $.022^{mm}$ per length of 10^{cm}. In a second case the rate was $.016^{mm}$ at the beginning and slowed down to .0029. In a third experiment, beginning at $.012^{mm}$ the extension increased with greater tension to $.026^{mm}$ and continued to stretch with unaltered tension until it reached the extraordinary speed of 1.88^{mm} per hour per length of 10^{cm}. Reducing the tension slightly, the speed fell at once to .35^{mm}, and gradually declined to .043^{mm}. "The lowest temperature reached during the experiments, excepting with the intractable bath ice, was with this specimen. During 12 hours, with a maximum temperature –9° C., and a mean temperature probably –10.5° C., the rate under the light tension of 1.45 kilo. per sq. cm. was .0065^{mm}."

McConnel also found that ice, even at low temperatures, showed a continuous compression, when the specimen examined was heterogeneous in structure, like glacier ice. With a pressure of 3.2 kilo. per sq. cm. he obtained a mean hourly yield of 0.035^{mm}, 0.056^{mm} and 0.007^{mm} per hour per length of 10^{cm}.

As with homogeneous ice under tension so also under compression there was no continuous yielding observed, when the pressure was applied, at right angles to the optic axis, of a single crystal of ice.

Changes in the amount of tension applied were found to produce changes in the rate of extension altogether out of proportion to the change of stress.

The greatest rate of extension recorded by Heim, in his classic work on glaciers, corresponds to a mean extension of 0.0029^{mm} per hour per length of 10^{cm}. Only one of the three specimens of glacier ice tested by McConnel showed a less rate of extension than this, and that was exposed to less than one-third of the breaking tension.

The series of experiments have completely proved that ice is to be regarded as a plastic body, when composed of a number of crystals, whilst it behaves as a rigid body when the specimen of ice is homogeneous in structure. The continuous extension must be due, it would seem, to some action taking place at the interfaces of the crystals. What the nature of this action may be we cannot represent to ourselves. There must obviously be a change in the shape of the crystals which compose the mass, and probably a transfer of molecules from one crystal to another across the interface. It has been suggested that probably any saline impurities in the ice crystals would collect near the outside boundaries of the separate crystals. From the lower freezing point of the saline solution, a film of liquid would exist between the crystals, which would probably assist the passage of the molecules from one crystal to another. But, whatever be the explanation there can be no doubt of the fact that the progressive motion of a glacier does not find its proper explanation in the theory of regelation. The experiments referred to show the possession of the plastic property at temperatures far below that of freezing, when no pressure likely to be called into action would be sufficient to cause the partial liquefaction, which occurs in regelation.*

The experiments also serve to explain many discordances in previous work, by showing how the texture of the ice specimens modifies the results obtained. Much requires to be done in investigating the extension when a single crystal is stressed in directions variously inclined to its optic axis. When this has been accomplished the mathematical data will be at hand for computing the resultant effect due to the mutual action of two crystals upon each other.

The investigations will probably extend our knowledge of the conditions under which ice freezes with vertical or horizontal optic axis. About this absolutely nothing is at present known.

These questions, arising from the desire to ascertain the cause of the orderly procession of great glacier masses, bring us speedily to the confines of the interesting and most difficult problem of ascertaining the nature of molecular interaction and of the processes of structural growth in crystals. The experiments may be regarded as having finally set at rest the *quæstio vexata* of the plasticity or non-plasticity of glacier ice, and this is a great point gained.

* A pressure of 133 atmospheres is needed to lower the freezing point of water 1° C.

How much more we may hope to learn from them if faithfully pursued we do not know. From the varied and sublime phenomena which accompany the genesis, formation and wasting of a glacier to the ultimate action of the minute particles which compose a bit of ice seems a long step. Yet the forces in operation are the same. Thus we are led from one of the grandest and most imposing spectacles of Nature to the investigation of the laws of physico-chemical action, which every advance of Science pushes into greater prominence. The effect of lapse of time in producing chemical change is becoming every day more recognized. The curious phenomenon known as the fatigue of metals presents the importance of time as a factor determining the condition of molecular aggregation.

Helmholtz has remarked that ice, with its clearness and easily ascertained molecular structure, may be expected to throw much light on all these questions. It will thereby help to enlarge the boundaries of our knowledge in that direction in which the next great advance may be anticipated in the successful exploration of the hidden recesses of Nature.

INFORMAL NOTES.

Mr. Richard Pearce called attention to a large specimen from the Seven-Thirty mine, which is remarkably illustrative of rock impregnation. Percolations of fluids through the rock had changed, as this specimen showed, the character of the granite for several inches on each side of the narrow joint space, which was filled with high grade mineral, tetrahedrite and some native silver. But the richest parts are the sooty black spots spread in the granite alongside the ore-seam. This material is rich in silver, and freed from adhering rock, appears under the microscope to be argentite.

MEETING OF MAY 6th, 1889.

STEREO-CHEMISTRY.*

BY CHARLES S. PALMER.

Objectively considered scientific argumentation is of various grades, from speculation to well grounded hypothesis, to proof capable of prediction, and finally to approximate certainty ; and subjectively such argumentation may leave the impression of possibility, or plausibility, leading to probability, or to approximate knowledge. Bearing these grades in mind, what is the nature of the "Atomic Theory" of modern chemistry? In brief, the original conception of an atom is a small discrete part of some particular kind of matter (any element), as evidenced by its *smallest* combining weight. All elements having gaseous or vaporizable compounds fall into an accordant system of combining weights whose standard unit is the half hydrogen molecule. Fortunately most of the other elements have combining weights in harmony with the system, as shown by their atomic heat constants. Now, are these combining or atomic weights the relative weights of real parts of matter? Fortunately reaction chemistry takes up the line of argument and shows clearly that the atoms are distinct parts of matter; thus, ammonia, NH_3, allows the hydrogen to be substituted in *three* distinct stages ; methane CH_4 similarly in *four* stages, and so on in all the innumerable series of the better understood chemical compounds. Furthermore, reaction, analytic and synthetic can indicate the chemical arrangement of atoms in certain molecules; thus, the formula of acetic acid which has the empirical

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*** This article is not published as an original paper, but simply as an abstract of an instructive and entertaining lecture by the author, on some recently discovered isomeric compounds.**

form $C_2H_4O_2$ is capable of expansion to the form $CH_3.CO.OH$, and even farther. Now, *primarily* such a "graphic" or "structural" formula indicates *nothing* as to the geometrical or space relation of the atoms in their grouping; but secondarily, if the atoms are *real material things*, such a formula must reflect, even though faintly, the real arrangement in space. Chemists have been wisely cautious and conservative in granting this latter corollary.

Carbon is the only element having a complex chemistry which is fairly well cleared up. Methane CH_4 is the point of attack; its derivatives are many; when such a carbon atom is "linked" at once to four different atoms or radicals, we meet certain varieties of isomerism incapable of explanation on any basis which is too timid to conceive of the probable space arrangement of atoms, but which finds clear ground on such a supposition. Such a carbon atom is said to be "unsymmetrical;" it is directly involved with hemihedrism, and heteromorphism in crystalline form, and with rotation of the plane of polarized light; such instances are found in the well known cases of amyl alcohol, valeric acid, malic, lactic, and tartaric acids, and in the sugars, etc. From these and other facts, over ten years ago the hypothesis was framed that methane CH_4 has the structure of a tetrahedron (Le Bel. & Vant' Hoff). Such an original if changed by substitution to the "unsymmetrical" condition has two possible forms of arrangement, viz: the so-called right and left-handed form, each of which is symmetrical with the other by reflection, as by a mirror. Recently Wislicenus has developed the speculation.

It was supposed that extra isomerism was possible in ethylene derivatives; thus $C_2H_2R_2$ is capable of existing in the forms

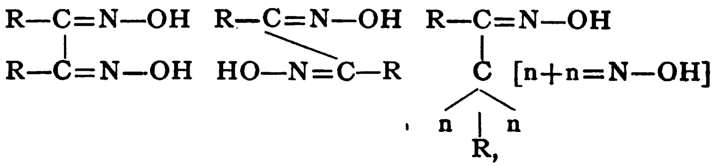
$$\begin{array}{c}a\\ H{-}C{-}R\\ \|\\ H{-}C{-}R\end{array},\qquad \begin{array}{c}b\\ H{-}C{-}R\\ \|\\ R{-}C{-}H\end{array}\qquad \left[\begin{array}{l}\quad\;\; c\\ H{-}C{-}H\\ \& \;\;\|\\ R{-}C{-}R\end{array}\right]$$

This seems to be illustrated in the well known instances of fumaric and maleic acids, in the ethylene-di-iodides, in the totane dichlorides in derivatives of itaconic, citraconic and mesaconic acids, and in the acrylic and cinnamic acids. This indicates that the carbon atoms when joined by "double linkage," or when in the ethylene condition are not free to rotate in the line of axis.

It had been supposed that when two carbon atoms were united by "single linkage," free rotation about the axis line joining them would be possible, and that chemical isomerism would not be possible in such a case, due to internal immobility. Now, within a year Victor Meyer and Karl Auwers (Ber. d Deutsch Gesell., Vol. XXI, p. 784, 3,510; Vol. XXII, p. 705), have examined this carefully and find that, although under certain circumstances, carbon atoms united by a single band cannot furnish instances of isomerism, yet in other conditions their derivatives offer abundant illustration of such chemical atomic allotropy. Thus, succinic acid $(CH_2 . CO_2H)_2$ benzil $(C_6H_5 . CO)_2$, and glyoxime $(CH : NOH)_2$ furnish but one marked chemical form each; while on the other hand the di-hydroxy succinic acids (dextro, levo and inactive tartaric acid) furnish three isomers; the benzil monoximes furnish two isomers, and the benzil dioximes furnish three isomers. Careful investigation showed that each isomer had its own series of derivatives; that in the case of several isomers one form is the more stable to which the other forms tend to pass; that these are *real metemeric* isomers and not merely polymeric forms. This latter point was clearly shown by determining the molecular weight, either by the old vapor density method for the vaporizable compounds, or by the more recent method of M. Raoult for non-vaporizable substances. [In a word, by the amount of the lowering of the congealing point of the standard solvents, when they have dissolved a known amount of the substance in question, and are then subject to a low temperature.]

The chemical relations of these isomers was also cleared up by appropriate oxidation, reduction, dehydration, etc. The isomers are referred to the following types which cannot well be exhibited on paper, but only by the use of models:

I. II. III.



We are thus brought to recognize a large number of compounds whose relations and differences we can explain only on the supposition that the atoms are *real material* things, capable of the same complexities of relative arrangement which belong to large tangible masses of matter. I would recall the opening words regarding proof and conviction of mind—the scientific spirit must not dogmatize. But let us notice that although these atoms are, and always must be, intangibly small, yet the explanation given above is the only one yet offered to explain these isomers, which on any other explanation are apparently anomalous. Thus we are forced to recognize a new departure in chemical theory, viz: The consideration of the *space relations* and *arrangements* of the atoms as *real* things or *parts* of *matter*. This is Stereo-Chemistry. Matter has weight, extension and inertia in the *mass;* it seems to hold these in the *molecule;* it seems in the highest degree probable to hold these properties in the *atom*. Matter thus has not been resolved into anything vague and immaterial; in the smallest divided granulation yet cleared up, it still holds up as the permanent basis of the objective realities of daily life.

This much must apparently be insisted upon by chemistry.

INFORMAL NOTES.

Mr. Geo. L. Cannon, Jr., exhibited a horn core of some animal, probably allied to the new family of horned dinosaurs, the ceratopsidæ. The specimen was found in the Denver sandstones, and appears to be of more rudimentary form than those obtained before from this horizon, or those from the Laramie beds of Wyoming.

MEETING OF JULY 1st, 1889.

INFORMAL NOTES.

Mr. Geo. L. Cannon, Jr., gave some informal notes on the formations in Eastern Colorado. The heavy deposits of loëss that mask the entire plains country attain near Wray, on the B. & M. R. R. a thickness of over 225 feet. A gradual change can be noticed in the physical and chemical properties of this deposit in going eastward from Denver. On the "flats" between the streams, the loëss is covered by extensive superficial deposits of æolian origin.

The erosion of the Republican River has exposed an interesting deposit of probably Pliocene age, containing boulders of a variety of andesitic material and layers of agate. In the absence of Laramie beds in the region, this bed is underlaid by Fox Hills sediments. The comparative thinness of the loëss near Sterling and Akron permits the exposure of a sandstone containing numerous remains of large mammals. The top of the mesa known as Fremont's Butte may be named as a typical exhibit of this formation. On Horsetail Creek it forms with the softer Fox Hills group, mesa-like hills.

Mention was also made of various economic features of this country, the dependence of the water supply on the nature of the Quaternary formation, the prospects for coal and oil, and the so-called "geyserite" and its uses.

MEETING OF OCTOBER 7th, 1889.

ADDITIONAL NOTES ON THE HUERFANO BEDS.

BY R. C. HILLS.

Since the publication of a previous paper on "The Recently Discovered Tertiary Beds of the Huerfano River Basin," further explorations in that region have developed additional points of interest and importance.

In the first place, from observations along the eastern border of the basin, certain corrections of the outline of the beds as shown on the map accompanying the original paper, are considered necessary.

The extent of the beds in the Cuchara valley has been found greater than there represented, the lower series being well exposed along the bank of the river near Wahatoya siding on the D. & R. G. Ry., about two miles east of the limit first given. On the other hand, the area of the beds north of the Huerfano will have to be reduced nearly to the same extent that the Cuchara area will be increased, it being found that the eastern boundary lies wholly on the southwest side of Turkey Creek instead of to the northeast of it as shown on the map.*

Another correction has been rendered necessary by the discovery of an exposure of the Marine Cretaceous, about one-half mile wide, crossing Poison Cañon obliquely and separating a limited area of the Lower Huerfano from the main body of the beds. The Cretaceous is apparently overturned — that is, inclined to the westward like the Laramie exposures a short distance to the southward—and contains a conformable intrusive sheet of dolerite.

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* Published with the paper above cited in the first part of this volume.

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The dip of the Huerfano beds at the point of contact with the Marine Cretaceous could not be clearly made out, but it is somewhere between 35° and 40° eastward, indicating great angular non-conformity. Passing into the Tertiary basin, in the direction of Muddy Creek, the inclination rapidly increases up to 80°, then rapidly diminishes until in the distance of a mile the beds are nearly horizontal,—the greatest inclination being where the overturned Laramie should pass beneath the Huerfano.

With the assistance of Messrs. Kebler and Storrs some rough measurements were made of the thickness of the beds near the mouth of Poison Cañon; which were found, on the whole, to agree very closely with the original estimates. It appears, however, that the beds will be more clearly defined by restricting the designation "middle division" to about 300 feet of massive, pink and white sandstone which forms a well marked horizon between the upper and lower beds, and is recognizable wherever it occurs throughout the basin. With this modification the thickness of the three divisions is as follows, beginning at the top:

Marls, clays, soft shales and sands, of red, gray, yellow, green and purple colors, red predominating,	3,300 ft.
Pink and white massive sandstones,	300 ft.
Soft sandstones and fine conglomerates of a yellowish tint, with occasional bands of yellow clay or marl,	3,500 ft.

The last figures may be in excess of the true thickness as superficial deposits make it necessary to estimate the point of contact with the Marine Cretaceous.

The total thickness developed in Poison Cañon is no doubt greater than is now exposed in any other part of the field. This is mainly due to the fact that there has been less erosion in the Huerfano basin than in the Cuchara Valley where the upper half of the series has been mostly carried away. At the same time the total thickness developed at West Spanish Peak—where the variegated beds have suffered less from erosion than elsewhere on the Cuchara drainage—is considerable and may approach the average exposed in the Huerfano basin.

The beds of the lower division outcrop only around the border of the basin and are not always present, for instance between the Huerfano River and Black Buttes, on the eastern border, the variegated beds overlap and are in direct contact with the Laramie with which they produce an angular non-conformity of from 15° to 20°. Further southward, in the ravines tributary to the Cuchara and on the stream itself, the soft sandstones and conglomerates of the lower division are fairly well exposed graduating below into the sandstones of the Laramie. Nowhere is there the slightest angular non-conformity between the two formations where they have been observed in direct contact along the eastern border and over the greater part of the field sedimentation appears to have been continuous and uninterrupted. If such non-conformity exists it must be sought for along the western margin of the basin where the Laramie beds underwent the greatest amount of folding during the general movement at the close of this epoch. As stated in the original paper the Laramie previous to its disappearance just north of the Huerfano is overturned about 10° and soon passes under the beds of the lower division in Poison Cañon which are not overturned. Hence, although the point of contact cannot be seen, an angular non-conformity of from 30° to 50° may be inferred. Moreover, in this part of the field the lower members of the Huerfano series are decidedly unconformable with the Marine Cretaceous which is usually conformable with the Laramie; rendering presumable the existence of non-conformity between the former and the latter also.

The pink and white massive sandstones of the middle division form the majority of the exposures in the Cuchara Valley and around the base of the West Spanish Peak, They also appear in nearly horizontal position at the eastern base of Silver Mountain.

The variegated marls and sands, representing the upper members of the Huerfano section, extend well up on the sides of this mountain and from its northern base form continuous exposures to the Huerfano River. North of the Huerfano they are exposed over the greater part of the basin containing them. East of Silver Mountain they extend nearly to the boundary of the Tertiary exposures. The sedimentary mass of West Spanish Peak consists mostly of these beds but slightly altered at the base of the mountain, where they rest on the pink and white massive sandstones just mentioned, but near the top are partly and in places wholly metamorphosed. The alteration and induration of the marly beds, caused by proximity to the laccolithic mass of the mountain and by the numerous radiating dykes, has been the means of preserving them from the erosion which has removed the upper members of the series over the greater part of the Cuchara basin. Hence the remnant found at West Spanish Peak is an isolated occurrence some distance removed from the main body to the north.

Between Muddy and Turkey Creeks there exists detached deposits of volcanic ash,—consisting of flat, angular particles of glass, which rests directly on the marls of the Huerfano beds, and from the vertebrate remains found in them are evidently of Pliocene age. They are usually overlaid by beds of coarse sand and clay, and in a few places by ancient deposits of travertine partly consolidated into limestone. The ash-beds probably belong at the base of the series of marls and conglomerates exposed near the Grape Creek-Muddy divide and described in the original communication as Pliocene.

The search for mammalian remains in the deposits referred to this age has met with best success in the ash-beds, from which have been taken a number of bones including teeth and portions of the jaws of Horses and Camels probably belonging to the Upper Pliocene.

Further search, under the direction of the writer, in the upper beds of the Huerfano series, resulted in the finding of a number of species of mammals among which *Tillotherium*, an Eocene genus, is the best preserved.*

Search in the beds of the lower division near Poison Cañon failed to reveal anything of value, in fact the character of the material is not well suited for the preservation of animal remains ;—but other localities may yet afford them.

It may not be out of place to state here what should have been mentioned in the previous paper,—that is, that any conclusions, based on stratigraphical evidence alone, of the existence of fresh-water Eocene beds east of the Rocky Mountain divide would probably meet with grave objections from those most familiar with the events of the early Tertiary. The fact that up to the present time no Eocene lake-basin had been discovered east of the Green River, Uinta and San Juan basins lying between the Rocky Mountains and the Wahsatch has led most geologists to conclude that all the Eocene fresh-water sediments were deposited in that great geosynclinal, and that all the adjoining territory east and west became subject to erosion subsequent to the general elevation and mountain making which accompanied the revolution at the close of the Laramie Epoch. Hence the vertebrate remains brought to light are of more than ordinary value as proving the correctness of the conclusions announced in the former paper, which might otherwise be questioned by those who had not familiarized themselves with the facts. But the Huerfano beds furnish one of those instances where the stratigraphical and structual evidence would admit of but one interpretation.

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* These remains have since been placed for identification in the hands of Prof. Marsh, who recognized among others the Eocene genera *Tillotherium*, *Hyrachyus* and *Glyptosaurus*.

In the Huerfano region we find two parallel ranges—the Sangre de Cristo and Wet Mountains—originally part of the old Archæan archipelago, which underwent similar crumpling and elevation at the time of the general movement known to have taken place at the end of the Mesozoic. The lateral pressure which effected the upheaval of these ranges produced at the same time a deep synclinal depression in the Laramie beds between them, and the bottom of this depression, in the region of maximum folding, must have been below the drainage level at the beginning of the Tertiary. Consequently, the sediments succeeding unconformably the Laramie must have been deposited during the early Tertiary or Eocene Epoch. Again, sedimentation ceased and the beds were tilted up at the beginning of the second grand disturbance which is generally supposed to have taken place at or about, the close of the Eocene. Here, then, occurred a repetition on a smaller scale of the conditions attending Eocene sedimentation in the great fresh-water basins. In other words the laying down of the Huerfano sediments took place in the interval between two periods of great dynamic movement whose relations to the geological time-scale are well understood.

Since this paper was read additional remains have been discovered among which *Palæosyops* is represented by a portion of the mandible of one individual and the crown of a last inferior molar tooth of a second one; together with the rhomboidal bony plates of a fish allied to *Clastes* if not of that genus. Altogether some 15 or more species are represented in the collection which will be turned over to Prof. Marsh for indentification.

The evidence thus far accumulated points strongly to the Bridger age of the upper division of the Huerfano series, although it is doubtful if the lower division, in which vertebrate remains have not yet been found, can be included in the same category. The absence of anything equivalent to the Uinta indicates that the second period of disturbance, which brought about folding of the Huerfano sediments and which was probably associated with the earlier eruptions of the region, began in this epoch.

The author desires to acknowledge his indebtedness to Mr. J. Milligan of Gardner, through whose diligent explorations all the vertebrate remains were brought to light.

ADDITIONAL NOTES ON THE ERUPTIONS OF THE SPANISH PEAKS REGION.

BY R. C. HILLS.

In a former paper on this subject there were certain eruptive occurrences, properly belonging to the region considered, concerning which no mention was made for the reason that while their existence was known they had not at that time been investigated. Since then several of these have been examined, and others noted whose existence was not previously suspected.*

In describing the masses of white porphyry, which occur in laccolithic form along the northwestern border of the Raton coal field, it was stated that, with the exception of a few thin dykes and intrusions near the summit of the Spanish Peaks, this particular kind of eruptive was restricted to the Oak Creek, Veta Mountain and Sheep Mountain localities. These masses of porphyry differ from the other eruptive masses in the Raton field in not having a corresponding system of dykes. This fact would lead one to suppose either that the vent through which the material exuded was situated immediately beneath the outcropping masses, or else that the material was not sufficiently plastic to allow of its flowing for any considerable distance towards the surface through comparatively small cracks or fissures, supposing the original source to have been situated somewhere to the eastward and that the porphyry was forced for a greater or less distance through the Marine Cretaceous shales underlying the coal measures before reaching its present position. If the original channel were so situated then the force necessary to elevate such enormous masses several thousand feet above the

* The location of the several eruptive masses here mentioned will be understood by reference to the map of this region published in the first part of this volume.

level of the coal field would also be sufficient to cause the injection of the same material some distance laterally into the strata notwithstanding comparative want of plasticity.

The extent of the intrusion would no doubt be much less than in the case of the Silver Mountain laccolith which has for its western extension the mass of North Veta Mountain, equal in height and bulk to the associated white porphyry mass of South Veta Mountain, and for its eastern extension the Black Buttes. It now appears that there may be an eastern extension of the white porphyry also, such as one would expect if the channel through which it came were situated somewhere beneath the coal measures east of the laccoliths, for a large body of this material was found protruding through the Huerfano beds, near the contact with the Laramie, several miles to the east of Silver Mountain.

If the chemical and mineralogical composition of the rock should prove this isolated body to be identical with the main mass of the porphyry—as one cannot but infer from its appearance—the probability will be strong that the great intrusions along the northwestern border of the field, which are evidently related to each other and derived from the same source, are but the expanded extremities of an extensive sheet underlying a large area of the coal field, but which is not represented by a dyke system owing to original want of fluidity.

In the former pages relating to this subject it was shown that without exception the great laccolithic bodies of this region expanded to their present form altogether in the soft beds of the Marine Cretaceous—like the majority of such occurrences in this State, and in the Henry Mountains of Utah as described by Gilbert. There is, however, in the northern extremity of the field, one exception, well worthy of notice, where expansion took place at a lower horizon. Badito Cone, known locally as "Sugar Loaf," situated at the southern end of Greenhorn Mountain, just north of the Huerfano River, is of this description. The conical mass of the mountain is a typical laccolith but without any system of radial dykes, the few which do occur near its base, and which were mentioned in the original paper as containing petroleum, being composed of entirely different material. The rock forming the shell of the laccolith is brick-red Triassic sandstone encircling and nearly covering the eruptive core and dipping away on all sides at a high angle. Near by to the north appears the granite body of the Greenhorn Mountains. On the south a long ridge extending towards the Huerfano marks the line of a long narrow intrusion, connected with the main mass of the laccolith, but forced for a distance of nearly a mile into the soft Jurassic shales overlying the Triassic beds. Evidently the expansion of the mass must have taken place at a considerable depth from the surface to admit of such an intrusion being formed and a great amount of erosion was necessary to reveal the true structure of the cone as now presented. The material of both the intrusion and the laccolith is identical in appearance, being light-colored and finely crystalline, but without pronounced macroscopical characters such as would enable one in the field to co-ordinate it with any of the eruptive masses yet described.

Another but much smaller and less typical laccolith occurs a few miles west from Sugar Loaf. It has been named Turkey Creek Butte from the stream near by. The rock appears to be identical with that of Sugar Loaf but unlike the latter it took the ordinary route on its way to the surface and bulges up in the soft Marine Cretaceous beds.

About two miles south of Turkey Creek Butte there is another similar occurrence, but of doleritic material, protruding through the shales of what probably corresponds to the Montana group as recently defined by Eldridge—that is, the upper part of the Marine Cretaceous.

Still another isolated butte may be mentioned, of similar material, and occurring at about the same horizon. This is a small sharp spike prominently exposed near the Huerfano River about six miles west from Huerfano station on the D. & R. G. Ry. It is known as Huerfano Butte and has been said to have suggested the name of the river, which is Spanish for Orphan.

In the same section of country several small dykes not previously noted have been added to the long list of occurrences of this character which remain to be studied microscopically before any description of them can be undertaken.

Several new dykes and intrusive sheets have likewise been discovered in the Las Animas part of the field, the most noteworthy being the group of doleritic sheets intruded into the Marine Cretaceous a few miles east from the mouth of Cañon de Agua. The presence of these sheets, causing induration of the adjacent shales, has enabled the strata to better resist erosion in this locality than in the surrounding country, thus giving rise to the piñon-covered mesa known as the Black Hills.

The geology of the entire region included in the Raton coal field presents many points of interest, yet none that will compare with the peculiar phases of eruptive dynamics so clearly exemplified. Before the study of this region shall have been completed the portion lying in New Mexico will probably afford some interesting facts relating to past eruptions. The possible connection of these eruptions with those of the Sangre de Cristo, and of the Rio Grande region west of the Sangre de Cristo, will necessitate more or less investigation in that country before the relation of the several occurrences can be thoroughly understood. As these investigations progress the results will, from time to time, be communicated to the Society.

NOTES ON THE OCCURRENCE OF SESQUISULPHATE OF IRON IN NEW MEXICO.

BY RICHARD PEARCE.

This very interesting mineral came into my hands about a month ago. It was sent by Mr. Salazar of Las Vegas, N. M., to Argo to determine what it was, with the suggestion that in all probability it was native sulphur. On examination, however, I soon found that it was a species of iron-vitriol.

On comparing it with the various minerals under this head, as described in Dana's Mineralogy, I find that it corresponds in color, hardness, etc., with "copiapite," but Dana gives this mineral as insoluble in water, whilst the specimen I have is entirely soluble in cold water.

In its behavior with water it approaches "coquimbite" which is said to be wholly soluble in cold water, but when boiled it becomes thick and an abundant precipitate of ferric oxide is thrown down.

All that I have done is to determine the sulphuric acid, which amounted to 38% ; but I have submitted the mineral to Dr. Hillebrand for a thorough investigation and I hope we shall soon be favored with his report.

It is said to occur in large quantities about 50 miles from the railroad associated with another mineral belonging to the alum group which has not yet been determined.

A rough examination showed the existence of "magnesia."

Dr. Hillebrand has promised to investigate this mineral also, and he will doubtless contribute at an early date, a paper giving some interesting facts in regard to these new finds.

I cannot discover that the "sesquisulphate of iron" has ever been found in this country before.

SUBLIMED TELLURIUM.

BY RICHARD PEARCE.

I have recently found some extremely beautiful crystals of tellurium which have been formed in the process of kiln roasting of pyritous ores from Leadville. The ore which yielded the tellurium came from the Louisville mine. This ore consists almost wholly of pyrite with a sprinkling of "sphalerite" containing gold and silver in varying quantities ranging from 10 ozs. up to 40 ozs. silver, and about $\frac{1}{10}$ of an oz. of gold per ton.

The ore shows no indication to the eye of the existence of tellurium and I had no suspicion of its presence until I found it on the surface of the kilns, sublimed on pieces of ore, which had not reached a temperature sufficiently high to effect any change. It is not the custom to find coarse-grained pyrite, with large developed crystals, associated with as much silver as the ore contains, and the presence of tellurium would almost indicate the existence of a telluride of silver containing some gold. If the tellurium exists in the ore as Ag_2Te, which is the formula for "petzite," 20 ozs. of silver per ton would represent 7.4 ozs. of Te, or .000253 per cent., a quantity so minute as to escape observation.

Dr. Hillebrand has promised to have some crystallographic measurements made in order to determine whether it varies materially in form from native tellurium.

MEETING OF NOVEMBER 3d, 1889.

A PRELIMINARY PAPER ON THE ERUPTIVE ROCKS OF BOULDER COUNTY AND ADJOINING COUNTIES, COLORADO.

BY CHARLES S. PALMER.

Colorado is already classic ground for the students of all departments of Geology. Stratigraphical Geology, Palæontology, Dynamical Geology, Mineralogy and Petrography have each been pursued in special lines.

But the ground to be covered may fairly be called immense. The work already done, though for the most part of the highest order, is only a beginning and much more must be done in the lines indicated before our knowledge of the geological structure of Colorado shall be complete.

The phenomena of abundant and varied rock types, eruptive, metamorphic and clastic, offer a fascinating inducement to continue the work.

From the accident of circumstance, the writer is placed in a region rich in petrographical material, so rich that one may easily lose his way in work too discursive and general to be of any value.

Therefore it seems wise to select a region, small as compared with the State area, though large indeed in its limits in which to work for a term of years until the more important observations, measurements, and analyses shall have been made, and the more obvious deductions shall have been established; and thus, that a comparatively finished piece of work may be performed.

When the means are limited and the helpers few, a worker must, indeed, be ambitious to hope to contribute anything of value, as compared with such results as those of the workers of the Division of the U. S. Geological Survey, until recently, stationed in Colorado.

But the work they have discontinued must go on, and one who attempts this will surely find himself in sympathy with the aims of the Colorado Scientific Society.

The materials within the limits of this paper will be mainly comprised of a brief description of the region including, 1st, The Clastic rocks which are the foundation; 2d, The chief classes of Eruptive and Massive rocks; 3d, The questions and problems which obviously present themselves; namely, as to the association, origin, period, and manner of extrusion; the nature and manner of alteration, metamorphism, etc.

It will be found that even in this limited region there is a good assortment of rock types, and that many of the problems, both new and old, which are of interest and are at present, subjected to discussion elsewhere, find abundant illustration here.

I.

Geological Horizons and their representatives, the Clastic rocks.

It is always a gratuitous work to describe this part in detail; yet as it must be borne clearly in mind to grasp the significance of the relation of the extruded to the bedded rocks, a brief resumé will be in order. Boulder County is approximately about twenty-five miles wide by thirty-five long; the eastern half in the plains, the western half in the mountains. Long's Peak is in the northwest corner.

The Snowy Range, including Mts. Audubon and Arapahoe forms the western border. The eastern half is occupied by the successive geological strata from the most recent, back to the Jura-Trias. As elsewhere, for the most part, along the mountain front the strata lie with only a slight, generally eastern, dip which increases rapidly toward the west near the foot hills, till in the hogbacks, it is almost vertical or may be locally reversed. As the Triassic sandstones, which in Boulder County are the lowest of the regular stratigraphical series, are thrust up on the eastern slope of the foot hills they stand directly against the prevailing rock type of the mountainous part of Boulder County, which for purposes of convenience may be provisionally called an *Archæan gneissoid-granite.*

II.

The Chief Eruptive and Massive Rocks.

The study of Hayden's geological atlas of Colorado would hardly offer a suggestion of the richness and variety of the rock types which here penetrate, there overlie the gneiss and granite of the region between the foot hills and the range.

It would be well to pause here to indicate the sense in which the word *eruptive* is used; not to anticipate, nor to exclude unduly, subsequent discussion as to the real eruptive character of many rocks here described, the term will be used to include not only all true *eruptive* rocks, but also all heavy metamorphic rocks where the metamorphosis has evidently gone so far that the results closely approach the conditions of the true eruptive or massive rocks.

In view of the unfinished state of this work, it will be understood that this enumeration is only provisional and liable to slight changes as my study goes on.

In general, this enumeration proceeds in geographical order from the east toward the west.

GROUP A.

Heavy, "Trap," or "Basaltic" Rocks.

These include (a) the well known *olivine-dolerite* of Valmont Butte, (b) a probably similar rock, at Mt. Haystack, ten miles north, (c) the trap rock of Golden (said to contain leucite), (d) the trap dykes east of Sugar Loaf, probably identical, moreover, with those which appear by the roadside in Four-Mile Creek, and also in Left-hand Cañon, near Hanging Rock; further investigation will probably add others to this list.

This class should be investigated first, but as I have had intimation that Mr. Cross has done some work on them, at least, on the Valmont Butte and the Golden Mountain, which will be shortly published in the Monograph on the Denver Basin, all special work on this class will be deferred till such publication, in order that there may be no unnecessary duplication.

GROUP B.

The Quartz Porphyries.

So far as I can find in any geological report there is not an allusion to this interesting local find; Zirkel in the 40th Parallel Reports describes rocks which may be similar. The chief outcrops indicate a dyke [at present in considerable confusion from the fault at the mouth of Boulder Cañon] which runs from the front foot hill southwest of Boulder in a direction north and west for six or eight miles toward Sunshine. This dyke either bifurcates or has several lateral extensions toward the north.

It is being subjected to careful investigation and will be described in detail later.

With this class is possibly to be grouped a large dyke at Ward.

GROUP C.

Porphyries and Porphyrites.

These include a large group of grey, reddish and purplish grey rocks with well defined crystals of feldspar in a fine grained base. They include the top of Mt. Sugar

Loaf, the hills to the west, north, and northwest, toward Ward, and also toward the hills north of Left-hand Cañon, and cover an immense territory. They are probably concerned to a large degree with the mineralization of the county.

GROUP D.

Granites and Related Rocks.

These include (a) a fine grained granitite on the railroad grading in Four Mile Creek below Salina, (b) a coarse grained porphyritic granite which occurs in Four Mile Creek west of Salina, (c) a reddish granite found abundantly in the fault in Bear Cañon: associated with this group is the hornblende granite of Caribou Hill, also the granite outcrops of the center and summit of the Snowy Range, also the many *pegmatite* veins, many of which are mineralized.

The particular consideration of the paragenesis of the mineral veins will deserve detailed examination later.

GROUP B.

The Quartz Porphyries.

The quartz-porphyry of Flag-staff Hill. On the eastern slope of Flag-staff Hill [see Map I] about a mile and a half southwest of Boulder is the first outcrop noticed by the writer.

The rock would easily pass, on cursory examination, for a badly decomposed biotite-granite, indeed the first stray fragment found lay on my desk for several weeks unrecognized in its real nature.

It contains as macroscopic ingredients, a little irregularly crystallized quartz from two to five millimeters in diameter; a fair amount of badly decomposed fieldspar, many crystals of which are five millimeters in diameter, and also as the characteristic mineral, a black mica magnificently crystallized, usually in hexagonal forms which will average about two millimeters in diameter.

This mica, provisionally called *biotite*, gives the rock in its present condition its peculiar granitoid appearance and may be one reason why the real nature of the rock has been previously overlooked; for erratic blocks of the rock are sufficiently numerous by the roadside in the western part of the town to attract the attention of any careful observer.

There is also a little light colored mica visible to the eye which may be muscovite but is more probably bleached biotite.

These minerals are usually so irregularly grouped through the rock as to give the granitoid appearance previously mentioned. There is another FACIES of the rock having a remarkable gneissoid or schistose structure. This latter form is evidently the result of secondary stratification and will receive particular attention later. Most of the rock is so badly decomposed that the specific gravity varies considerably, but a typical specimen of the granitoid variety gave the figures 2.43.

A typical specimen of schistose variety gave 2.45.

The mineral chiefly concerned in the weathering is, of course, the feldspar which was presumably originally othoclase or microcline.

On weathered surfaces the altered feldspar is white or grey, but on fresher surfaces the kaolinized surfaces have a yellowish or pinkish color.

A careful examination of the rock betrays at once its real nature. The macroscopic ingredients are imbedded in a fine, compact groundmass which to the naked eye is homogeneous, crypto-crystalline and of a structure and appearance resembling hornstone. Even to the naked eye it has a slightly weathered aspect, probably due to the decomposition of its feldspathic ingredients.

A rough estimate would judge this groundmass to make up about fifty per cent. of the rock. The microscopic investigation of this groundmass entirely justifies our supposition of its nature as being a true porphyritic base intermediate between and containing illustrations of granophyre and felsophyre, in short, a fairly typical microfelsite base.

The arguments for the eruptive nature of the rock are, so far as observed, the following: (a) the true porphyritic character of the rock as seen in hand specimens; (b) the intrusive nature of the rock, as observed in the field work, it being found as a true eruptive intercalation between the red sandstone Triassic beds of Flag-staff Hill; (c) the development of a true fluidal and schistose structure, locally, as hitherto mentioned. As shown on the map, the eruption of this quartz-porphyry penetrated not only the Triassic [and Jurassic ?] but also the schists on the road to Sunshine and probably the Triassic and Cretaceous about six miles north of Boulder, as a detached fragment comparatively fresh, was found in a brook by the roadside in that direction.

The work of slicing the rock, with the attendant microscopical examination and the analysis of the rock, as also of its ingredients as separated by the heavy solutions, is being carried on in the University Laboratory with the assistance of Mr. Henry Fulton.

Mr. Fulton has also assisted largely in the field work and due credit should be given him for this. The University is provided with requisite material for prosecuting petrographical work of this sort, and as rapidly as time allows, the investigation will be pushed in the lines indicated and the results will be communicated from time to time to the Society.

Laboratory of the University of Colo.
Nov. 2d, 1889.

ADDRESS OF THE RETIRING PRESIDENT.

RICHARD PEARCE.

In preparing the customary address which is expected from the retiring president, I have thought that perhaps some few remarks based on my own personal experience in regard to the paragenesis of gold-bearing ores, might form an appropriate subject.

The ambitious amateur prospector who is generally ignorant of the science of mineralogy, or the laws which appear to regulate the association of minerals, and who is constantly blundering over imaginary riches, which he thinks are in store for him, might well be saved disappointment and loss of time, were he better acquainted with what the old Cornish miner would call the "kindly" or "unkindly" appearance of the ore or rock he discovers.

It is a well established fact that certain metals have each their own particular associates, or kindred surroundings; this is particularly the case with such metals as: gold, silver, tin, etc., as for example, it would be utter waste of time to look for gold, in paying quantities, in a vein of magnetite, or a lode of pure calcite, and no one in his senses would dream of looking for tin, in a vein of calcite or barite.

In the few remarks which I may have to make in this address, I shall limit myself to some observations having a bearing on gold ores, and it will be necessary for me first to explain that I only include those ores which are more valuable for their gold than for any other metal. The class known as silver ores, which contain gold, but the principal value of which is the silver, has generally different characteristics and may, for convenience of study, come under a separate head.

I shall have to limit my remarks, more particularly, to the gold ores of the Rocky Mountains, although from my experience of ores from other localities in different parts of the world, the conditions appear to be almost identical.

The peculiar geological features which belong to gold have been so well described, by the various writers on that subject, that it need not here be referred to.

Gold may be said to be intimately associated with silica, for wherever it is found, this substance appears to be its principal matrix. Pyrite, chalcopyrite and other minerals, in a great many cases help to build up the matrix for gold, but it rarely happens that silica is entirely absent, in fact I doubt very much, if a gold ore has ever been met with in which silica does not to some extent enter into its composition ; on the other hand, I have seen, as a result of my own experience, only two examples of the existence of any marked quantity of what might be termed basic minerals, such as calcite, dolomite, chalybite, etc., as playing any important part in the composition of gold ores.

Anhydrous oxides of iron, such as magnetite and specular iron, do not usually associate themselves with gold, but limonite, and the other hydrates of iron and manganese are common members of the gold family, and are present as products of the decay and alteration of pyrite, and also from the circulation of mineral waters charged with iron, through gold-bearing veins.

The only example that has ever come under my own observation, in which calcite plays any important part in the composition of a gold ore, is from a mine in the Tintic district of Utah. The ore from this mine has frequently assayed as high as 10 ozs. of gold per ton, with very little silver ; and a large percentage of the material consisted of crystallized calcite, with manganese peroxide in the form of wad. Silica, however, is always present, and in no inconsiderable quantity, and the material of the vein exhibits strong evidences of alteration by the action of siliceous waters. The indications are that some secondary action has taken place, by which the calcareous material has become partly silicified, and at the same time impregnated with gold.

An occurrence of this kind is, however, extremely rare, and forms an exception to the general rule, namely: that calcareous material is not the proper matrix in which to look for gold in quantities sufficient for economic working.

Magnetite and specular iron are not unfrequently present in the rocks in which gold veins occur, but rarely, in the veins themselves. A well marked example of this is seen in Gilpin County, Colorado, where the gneissoid rocks, in which the gold veins are found, are frequently impregnated with the mineral magnetite, but not a single example of magnetite existing in the lode itself, has ever came under my observation.

Barite.—Barite, which is a frequent associate of silver, and which in some cases, forms almost the entire matrix for silver minerals, is rarely found to play any part in the composition of gold ores. I have, occasionally, seen traces of the mineral in small, scattered, crystals, notably in the "Little Annie Mine" in the San Juan district, and in the Tintic mine, before referred to, associated with calcite. Such occurrences, however, are rare and barite cannot claim to have anything but a very remote relationship to the gold family.

Fluorite.—Although fluorspar is a common associate of lead, copper, and sometimes tin, it rarely occurs with gold. The telluride district of Boulder, Colorado, forms, however, a very interesting exception to this rule, for here we find the tellurium-gold minerals, such as: sylvanite and calaverite, occurring enclosed in a matrix consisting of fluorite, dolomite, and quartz, forming a remarkable and unique example of a gold-bearing gangue.

The minerals which enter into the composition of veins, in which gold occurs in paying quantities, may be classed into three divisions. First: — Earthy minerals forming the gangue. Second:—Heavy pyritous minerals and other sulphides.

Third:—Tellurium and bismuth which are generally intimately associated with the gold.

The minerals coming under the head of the first division, comprise quartz, amorphous and crystallized, and occurring in almost every form characteristic of that mineral. Aluminous material, having no very definite mineralogical characters, but consisting mainly of silicate of alumina, with variable quantities of oxide of iron and magnesia, the whole enclosing fragments of the adjoining rock. In some of the more recent gold formations, as for example the deposit at the Bassick Mine, Colorado, boulders and fragments of porphyry are found cemented together in the form of breccia, the cementing material being silica in a condition which clearly indicates it owes its origin to siliceous springs. Little siliceous bubbles are plainly seen in some specimens of the ore which I have examined, and these have in all probability been formed by the intermittent action of steam on gelatinous silica.

The aluminous material which almost invariably forms no.small part in the composition of the matrix, is produced by the decay or kaolinization of the feldspar which enters so largely into the composition of what may be termed gold-bearing rocks. In certain districts the rock itself has been so altered by metamorphic action, and so impregnated with pyrite, and other minerals containing gold, that it has been found profitable in many cases to work it for gold.

The gold veins of Gilpin County show this condition in a remarkable degree; the vein proper, or fissure, is frequently limited to a very small thickness, the vein filling consisting of a highly indurated material, and composed of quartz and silicate of alumina. On each side of this vein, however, a quantity of material occurs which consists of decayed, or disintegrated gneiss, and in some cases, porphyry, which is generally regarded by the miner as a part and parcel of the vein. This is often rich enough to be mined and milled at a profit.

Pyrite.—Pyrite may be said to be a constant associate of gold, and in many instances it forms a large percentage of the mineral matter forming the vein.

I think it may be generally conceded that pyrite having a large coarse-grained structure, and a well defined crystalline appearance, is uniformly poor in gold. This, I think, holds good in almost every district where gold occurs associated with pyrite. The finer the grain and the fewer the crystals the greater the chances are in favor of the existence of gold in paying quantities.

The pyrite ores of Gilpin County, which may be taken as examples of typical auriferous pyrites, occur in a variety of forms. The highly crystalline variety, from which specimens, having well defined crystals, are obtained in abundance, contain little or no gold, but a change frequently takes place in the same vein, to a finer grained mineral, which is generally attended by an increase in the richness of the ore.

It may be stated that with very rare exceptions, an abundance of pyrite in a lode is almost a sure indication of its poverty in gold. I have seen exceptions to this rule in the large pyritous deposit which was discovered some fifteen years ago in the Gunnell mine; this pyrite exhibited little or no crystalline structure, but consisted of immense masses of fine grained pyrite, rich in gold.

Pyrrhotite or Magnetic Pyrites.—This mineral is rarely found to contain gold, and does not form any part, so far as my experience goes, in the composition of the gold-bearing veins of Colorado. I have seen one example, however, of a rich auriferous pyrrhotite which was said to be found somewhere in Oregon, but this is the only instance that has ever come under my notice.

Chalcopyrite.—It not unfrequently happens that this mineral, copper pyrites, is found associated with pyrite in gold ores, and in many cases, it would appear that its presence is an indication of an increased quantity of gold, but this can hardly be regarded as a rule.

So far as Gilpin County is concerned, I have no hesitation in saying that pyrite containing a moderate amount of chalcopyrite is generally richer in gold than when that mineral is altogether absent; but on the other hand any large increase in the amount of copper reverses the order of things, and the ore becomes poorer in gold.

In the majority of cases I think it would be found that the bright yellow copper pyrite is less likely to be rich in gold than the pale material formed by an admixture with pyrite.

Fahlerz, Tennantite and Enargite.—Sulph-antimonides and sulph-arsenides of copper occur sparingly in gold-bearing veins, but their presence may be said to indicate increased richness in silver rather than gold. I have never known an instance of the occurrence of these minerals, rich in gold, but on the contrary, the presence of enargite, in particular, indicates poverty so far as gold is concerned.

Sphalerite.—This mineral, zinc-blende, is a very common associate of gold, and in some cases, forms a very prominent feature in the composition of the ore. Its presence, however, is, I think, always an indication of increased richness in silver, and may be regarded as being an associate of silver rather than of gold. An ore is rarely found which is absolutely free from this mineral so far as the mines of Colorado are concerned. I have often observed specimens of sphalerite literally coated with gold, but if the mineral could be separated from this coating, I very much question if it would be found to contain gold in paying quantity. In other words there is not the same tendency to an intimate admixture or relationship of gold with sphalerite as in the case of the other minerals: iron and copper pyrites.

Galenite.—Galena, like zinc-blende, is often found sprinkled through auriferous ores, but rarely in large quantities. These zinc and lead representatives appear to have a tendency to run together, and they indicate generally an increase in the amount of silver in the ore.

Arsenopyrite.—Whilst this mineral occurs in some localities, as for example in California, Montana, and in Canada, associated with gold, it appears to be absent, or nearly so, in the gold ores of Colorado. I have been able to find but one characteristic specimen in any of the gold districts of the State; it occurs, however, sparingly as an associate of silver.

A hydrated sesqui-oxide of iron of various shades of color, and containing variable quantities of silica, alumina and magnesia occurs abundantly in gold veins near the surface, and is naturally the result of oxidation of pyritous ores by the action of circulating waters; it is virtually what is generally termed a gossan, and contains the gold in a purer condition than the pyrites found below the zone of oxidation.

Tellurium and Bismuth.—I hope on some future occasion to lay before this Society some results of investigations in reference to the occurrence of tellurium-bismuth-gold minerals, and their associates, but for the present I take the liberty of referring to a paper of mine read at the Washington meeting of the American Institute of Mining Engineers, which deals, in a cursory way, with this subject.

The general conclusions to be drawn from the few hasty remarks in this address are as follows:

Gold-bearing ores in Colorado, may be said to consist of a class of minerals, which may be regarded as associates of gold, and with few exceptions these same conditions appear to prevail in other districts.

The common associates are:—quartz, in a variety of conditions; silicates of alumina and magnesia; pyrites; chalcopyrite; sphalerite; galenite; and minerals which contain tellurium and bismuth; hydrates of oxide of iron and manganese.

The rare associates are: arsenopyrite; fahlerz; enargite; tennantite; chalybite; barite; calcite; fluorite.

There is one point which is worthy of notice in connection with this subject, and which I have briefly referred to in a former paper, viz: "The Association of Gold with Sesquisulphate of Iron." I am glad to be able to state that Mr. Guiterman has taken the matter up in a paper which he will submit to you.

The occurrence of gold in nuggets in the quartzite at Ouray, associated with sesquisulphate of iron, and the recent example of similar occurrence at Red Cliff, as shown by Mr. Guiterman, will tend to support the views of Prof. Wurtz, as given in Dana's Mineralogy, under the head of gold, which reads as follows: "It occurs both disseminated through the mass of the quartz, and in its cavities; the large masses and the finer crystallizations are mainly in the latter; and Prof. Wurtz has suggested that these have been formed by a slow aggregation and crystallization carried on through the solvent power as regards gold of persulphate of iron, this salt being formed from the decomposition of the pyrite present in the quartz veins."

The presence of this salt in considerable quantities forming a matrix for these extremely beautiful nuggets would tend to support this theory of Prof. Wurtz, in a remarkable manner, and would appear to be of great interest in explaining the origin of similar deposits.

I cannot close this paper without once more calling the attention of the members of the Society to the urgent necessity for further work in this interesting and instructive direction. Our collection might well be complete with a series of minerals and rocks illustrating the mode of occurrence of gold in this State.

The Society has accomplished much already in that direction but a great deal yet remains to be done.

PROCEEDINGS

—OF THE—

COLORADO

SCIENTIFIC SOCIETY

VOL. III, PART III.

1890.

PUBLISHED BY THE SOCIETY,
DENVER, COLO.

COMMUNICATIONS

AND

ADDRESSES.

MEETING OF JANUARY 6th, 1890.

PRODUCTION OF CA[illegible]

ERRATA.

On page 30, line 7, for "orogenetic," read "orogenic."
" " 137, " 26, " "the protoxals were deoxidized," read "the protoxides were reoxidized."
" " " " 29, for "were," read "was."
" " 192, last line, for "trace of prismatic striation," read "trace of etched prismatic striation."
" " 284, line 3, for "Three," read "The."
" " 362, lines 3 and 6 from bottom }
" " 363, lines 3, 6, 13 and 21, } For "Unita" read "Uinta."
" " 364, line 18, }
" " " " 8, for "Mountain," read "mountain."
" " 371, " 6, for "Morino," read "Moreno."
" " 403, " 11, " "region," read "Region."
" " 429, " 31, " "pleutonic," read "plutonic."
" " 430, " 8, " "—," read "-"
" " 449, last line " "– ," read "-"

level, is about 15 to 16 miles in length from north to south, and 5 to 7 miles in width, from east to west, covering an area of about 70,000 acres; its bottom is nearly flat, the depth seldom exceeding 20 to 30 feet, and varying but little at any point. On the east side of the lake the Sierra

MEETING OF JANUARY 6th, 1890.

PRODUCTION OF CARBONATE OF SODA FROM THE ALKALINE WATERS OF OWEN'S LAKE.

BY ERNEST LE NEVE FOSTER.

Inyo County, California, is remarkable whether viewed from a physical, geological or mineralogical standpoint. Its physical characteristics show it to contain the extremes of altitude and depression to be found in the United States. In the Sierra Nevada Mountains, Mt. Whitney towers over 15,000 feet in height, whilst in Death Valley, 60 to 70 miles to the eastward, is found a depression upwards of 100 feet below the level of the sea. The mineralogical resources of this area are mines of gold, silver, and lead, also the ores of copper and antimony are to be found in considerable quantity, though they are not at the present time utilized. It further contains deposits of borax, which supply by far the largest portion of this article extracted in the United States, and last but not least, is the growing importance of the industry developing at Owen's Lake by the manufacture of Carbonate of Soda from its waters near Keeler.

Owen's Lake is a sheet of water formed in a basin probably of volcanic origin, there being abundant evidences of volcanic action in the surrounding mountains, many of which are covered by a deep flow of lava. The lake is situated at an elevation of 3,600 feet above sea level, is about 15 to 16 miles in length from north to south, and 5 to 7 miles in width, from east to west, covering an area of about 70,000 acres; its bottom is nearly flat, the depth seldom exceeding 20 to 30 feet, and varying but little at any point. On the east side of the lake the Sierra

Nevadas rise rapidly and abruptly to their greatest heights, and are traversed by deep cañons and gorges down which the mountain streams flow into the lake. On the west side is the Inyo Range—at this point known as the Cerro Gordo Mountains—in which occur the Silver-lead mines of the district of the same name, not a single stream flows from this side into the lake. To the south are small ridges and mountains forming a natural barrier to any outlet in that direction, whilst from the north the lake is fed by Owen's River, a stream which rises 100 miles to the north in the White Mountains, and flows down through Owen's Valley ; this stream is about 50 feet in width and six to seven feet deep, flowing at the rate of about four miles per hour. The volume of water it discharges into the lake has been estimated as 50,000 miner's inches [the California miner's inch is one square inch under four-inch pressure, or 200 miner's inches are equivalent to one cubic foot per second]. The lake having no outlet its level is maintained by the constant evaporation going on from its surface. The waters of the lake are alkaline, caused by a concentration of the salts brought down by the streams which feed it ; a comparison of its contents, with those of other alkaline lakes is shown by the following tables :

ANALYSIS OF WATER—CONTENTS PER LITRE.

	Lake Albert.	Lake Mono.	Big Lake Ragtown.	Owen's Lake.
SiO_2	0.232	0.0700	0.304	0.220
$MgCO_3$	......	0.1928	0.862	0.055
KCl	1.027	1.8365	4.817	3.137
$NaCl$	21.380	18.5033	71.507	29.415
Na_2SO_4	1.050	9.8690	19.170	11.080
$Na_4B_4O_7$	......	0.2071	0.402	0.475
Na_2CO_3	10.611	18.3566	16.731	26.963
$NaHCO_3$	4.872	4.3856	15.220	5.715
Al_2&Fe_2O_3	......	0.0030	......	0.038
$CaCO_3$	......	0.0500	......	......
	39.172	53.4729	129.013	77.098

The process of obtaining the soda carbonates from the water of the lakes, is based upon the solubility of the several salts it contains, and is conducted in the following manner:

The water in its natural condition is pumped into large vats; this is done by means of a windmill when it can be used, or at other times by a Junior Westinghouse 10 H. P. engine, either of which operate a Chinese pump, but for the new works now building, a centrifugal pump, driven by steam, is to be used.

The vats are made on the banks of the lake, from a clay bed which occurs in some places along its shores; this clay is from six inches to sixteen feet in thickness. and is not at all points suitable for making vats, being in some places impregnated with alkalies or sand, so that it will not bind. Judgment is therefore required in selecting suitable sites for these vats. The construction of the vats to prepare them for use, and make them water-tight has to be carefully attended to; first, the sand and loose soil upon the surface is removed by scraping, next the underlying clay is reduced to a fine tilth by plowing and harrowing to a depth of 15 to 18 inches, then, after grading and building banks around the vats, which average ½ acre in size, a heavy roller is used on the bottom of the vat to beat it down hard, after this it is filled with water, and the vat allowed to soak for a week or ten days, when the water is drawn off, and the bottom is again well reworked with the roller, after which it will generally be found to be water-tight and ready for use; at presen tthere are about 35 acres of these vats along the shore of the lake.

The vats being ready, the water from the lake is pumped into them, to a depth of about 15 to 20 inches, this occurs about October or November, the density of the water being about 10 B., and natural evaporation is then allowed to proceed during the cold months of the year, the rate of evaporation is from 1/8 to 3/8 inch per day, according to the weather—the most rapid evaporation occurring when there is wind. The evaporation thus going on, gradually increases the density of the water, but in order that crystallization shall not occur at this period of the process, the liquor is not allowed to attain a greater density than 23 to 24 B., this is effected by constantly adding new water from the lake, to replace that extracted by evaporation. When the warm months of the year, say about June to September come, the collection of the Soda crop is commenced. The water is then allowed to evaporate till it reaches a density of about 29½ B., or the point of saturation, when the formation of crystals at once commences. The crystal here produced has a different form than the usual soda crystals, and as may be expected its composition is neither that of the normal carbonate nor of the bi-carbonate, but is a salt which contains one molecule of normal carbonate in combination with one molecule of bi-carbonate, together with water of crystallization. This product goes by the name of "Hot Weather Soda," because it has to be crystallized during the hot weather, an entirely different form of Soda, that is to say, a mixture of carbonate and sulphate of soda, crystallizing in cold weather, the temperature of the water appearing to have an important bearing on the form in which the salts crystallize from this water, and consequently upon the successful separation of the carbonates afterwards. It is noticeable that the "Hot Weather Soda" is unaffected when exposed to the air, whilst that formed in cold weather undergoes a change, giving off a portion of its water and crumbling to powder. When the crystallization has been completed, the remaining mother liquor is allowed to drain off and return to the lake. This liquor carries with it the alkaline chlorides and sulphates, with the other impurities contained in the original water, also about 10 per cent. of carbonates. The amount of carbonates collected by this process is about 40 per cent. of that originally contained in the water.

The "Hot Weather Soda" is next collected from the bottom of the vats, in crystallized slabs 1 to 2 inches thick, these on first being taken out have a salmon-pink coloration, as shown by the specimen herewith exhibited; upon exposure to the sunlight this coloration disappears and it becomes pure white. The coloration is claimed to be due to a certain amount of the scum of the lake getting into the vats with the water, it being so fine and penetrating that it is inexpedient to attempt to completely separate it. The formation of the scum upon the lake appears to come from certain animal organizations which occur in the lake, by some said to be of a sponge nature. When fresh these appear in little green balls floating in the water; the decomposition of these causes the scum, and also gives rise to a peculiar effluvia which is noticeable along the bank of the lake toward which the wind is blowing. The greatest quantity of this scum is said to form during the months of July and August.

The "Hot Weather Soda," as collected, is washed under a stream of ordinary lake water to free it from mechanical impurities in the form of clay, which frequently adheres to it, when taken from the bottom of the vats, also to wash out any mother liquor which may remain in the interstices of the crystals, the evaporation of which on this soda would leave a larger percentage of undesirable alkaline salts in it, and result in the production of a less pure article of carbonate of soda. The washed "Hot Weather Soda" is then stacked and ready for the subsequent process of separation. For the purpose of separation this soda is crushed small enough to pass through a ⅜-inch mesh screen, the machinery used for this purpose is a steel cylinder, about two feet in length and sixteen inches in diameter, studded with teeth about one-inch square and one-half-inch high; this revolves near a series of parallel, horizontal steel bars, the upper and first ones being about two inches from the roll, and each succeeding one nearer until the last one is just clear of the roll, outside the bars, a screen surrounds the cylinder; the "Hot Weather Soda" is fed to this through a hopper, and passes out through the screen into a chute, from which it is carried by an elevator to another large hopper; from this it is dropped into circular wooden vats, about 8 feet in diameter, and 8 to 10 feet deep, filled with fresh water, this is kept in motion by an agitator, whilst the whole is heated by a steam coil to a temperature of 165° to 175° F. [or just below the limit at which bi-carbonate of soda would be decomposed], in the tank about ⅓ of the way down, a screen is placed to hold the large particles of soda until they are dissolved. When the solution is completely saturated, it is allowed to settle for from six to eight hours, during which time it does not lose over 1° in temperature, by this means all the coarser sediment, clay, sand, etc., settles to the bottom. The liquor thus obtained is drawn off and filtered through a Johnson Filter Press, the filtered liquor being then conducted into square wooden tanks, about two feet six inches deep, here it is allowed to cool, for from 24 to 36 hours, but is drawn off before the temperature falls below 60° F.

The effect of dissolving the "Hot Weather Soda" in pure fresh water, is to decompose it, and the liquor as it comes from the press has a composition of about 95 per cent. of carbonates, which of about 43 to 45 per cent. is in the form of bi-carbonate, together with whatever slight impurities may exist. Whilst the temperature is falling in the tanks to 60° F., about 25 per cent. of the carbonates crystallize out in the shape of bi-carbonate of soda. At about 60° F. the remaining liquor is drawn off into similar tanks, where the cooling process is continued till it is quite cold; here normal carbonate of soda [sal soda of commerce] is crystallized, but it contains a bi-carbonate impurity of the remaining 18 to 20 per cent. of that salt, which was retained in the solution when drawn off at 60° F. When the solution has entirely cooled down the remaining liquor is drawn off and allowed to flow back into the lake The crystallized bi-carbonate of soda is next taken from the tanks, and placed in a centrifugal drier and washed, the wash water being saved and re-used; on being taken from the drier it is placed in a room kept at a temperature of about 104° F., where it undergoes a further dessication, after which it is ground to a fine white powder, under a millstone, and is ready for the market. The bi-carbonate of soda thus produced is very pure.

The sal soda, mixed with bi-carbonate produced by the crystallization in the cooling below 60° F., is placed in large crates, so formed that they can be easily knocked apart; these are about one foot wide, ten to twelve feet long, and six to seven feet high; in these it is allowed to dry out by the air or wind for five or six months, at which time it will contain about 20 per cent. of water. This is next calcined at a dull, red heat in a long, revolving cylindrical furnace, similar in construction to the long rotary roasting furnaces, sometimes used for calcining ores, except that the heat is obtained from below, instead of the flame playing through the cylinder; this drives off all the water, and the excess of carbonic acid, the resulting product is pure, merchantable soda ash.

For the year 1889, the crop of soda obtained is estimated at about 1,000 tons, but for the year 1890, it is estimated that with the same facilities the yield will be at least double. This is due to experience gained in the manner and time of carrying on the first atmospheric evaporations.

These works commenced operations about five years ago, since which time experiments had to be made continually, in order to reach the present simple and successful method of treatment of the water, so as to separate the carbonates from the sulphates and chlorides, and it is only now that this point can fairly be said to have been reached.

The evaporation from the surface of the lake has been calculated by the Signal Service Bureau to be equal to about one hundred inches per annum. Since the commencement of operations at the lake, there has been a fall of about 7 to 8 feet in its surface, in fact, it has been known to be receding for a number of years previously.

In connection with this lake, it may be interesting to some, to have a brief description of an occurrence, to which the name of Owen's Lake Caviare has been given by some persons, on account of its resemblance to that Russian delicacy in appearance. It is the egg of a fly which infests the borders of the lake in millions, and is found floating on its waters; the flies feed on the scum before mentioned, and it is remarkable that no matter how thick they get they never alight upon or annoy human beings. The development of these eggs into flies is a matter of interest. The egg floating upon the water is first transformed into a small wriggler, larva or worm having two big eyes; these worms are about as thick as small twine, and possibly a quarter of an inch long, having delicate fins on tail, back and gills, like a miniature fish, and are almost transparent; they will live in the water until it reaches a density of about 20° B. The next form it takes is that of a crysalis, about the size of an ordinary maggot, this is encased in a shell, and is said to often be collected by the Indians, dried and used as a food. The chrysalis in their turn are transformed into flies.

IDENTIFICATION OF A DINOSAUR FROM THE DENVER GROUP.

BY GEO. L. CANNON, JR.

The American Journal of Science, for January, 1890, contains an article by Prof. O. C. Marsh, descriptive of some Dinosaurian remains found by the writer in the Denver beds, near Sec. 28 S. R. 69 W., a preliminary notice of which had been given to the Society at the meeting held October 7, 1889.

The specimens form the type specimen of a new genus and species, *Ornithomimus velox*, Marsh. Two other species of the same genus, recently found in the same horizon in Montana, are described in the same article under the names of *Ornithomimus tenuis* and *O. grandis;* the three species constituting a distinct family of the *Ornithopoda*, to be known as the *Ornithomimidæ*.

The Colorado specimen is of a reptile, about the size of a kangaroo. In common with other members of the *Ornithopoda* it possesses marked affinities to modern birds, the subordination of the anterior limbs, bi-pedal method of locomotion, hollow limb bones, and feet of marked avian characteristics. Comparisons of the tibial and pedal bones of the Ornithomimus, with corresponding portions of young turkeys and young ostriches show many points of almost exact correspondence. The most striking feature of the foot is the arrangement and relations of the three functional metatarsals. In all reptiles known hitherto and especially in Dinosaurs, the second, third and fourth metatarsals are prominent at their proximal ends, and the third is usually the largest and strongest. In the *Ornithomimidæ* the reptilian features cease and those of typical birds take their places; the place of the third metatarsal being taken above by the second and fourth, while the third is crowded backward and very much diminished.

The species obtained from the Ceratops beds of Montana, are larger than the Colorado species; the *Ornithomimus tenuis* being about twice as bulky, while the *O. grandis* is still larger.

MEETING OF FEBRUARY 3d, 1890.

ON A REMARKABLE CRYSTALLINE COMPOUND OF ARSENIOUS AND SULPHURIC ACIDS.

BY RICHARD PEARCE.

In the year 1868 I wrote to the Chemical News a short notice of the occurrence of a crystalline compound of $As_2 O_3$ and SO_3 in one of the culverts connected with the calcining furnaces at the Morfa Silver Works, Swansea, England. At that time I was not aware that such a compound was known to chemists, and failed to get a response to an enquiry as to whether anything of a similar nature had been observed before.

Since that time I have had during my metallurgical experience, frequent opportunities of seeing the same substance as a product of kiln roasting, but only recently I came across what appears to be a remarkable example of this same compound in a form and under circumstances which eclipse any former occurrence of the substance. The usual condition of the material was small spear-shaped crystals of a pearly lustre, soon spoiling in contact with moist air.

On pulling down lately one of the calciners at the Argo Works, which had been in use for about eleven years, some three feet below the top of the hearth was found a magnificent cluster of large crystals coating lumps of slag, which had been used as a filling, when the hearth was made.

These crystals were in many cases more than one inch in size and beautifully modified. The form will, in all probability, be found to be monoclinic. They are semi-transparent to transparent; color, white; cleavage, perfect; lustre, somewhat pearly and adamantine. On exposure to moist air the surface of the crystals become opaque from the separation of the As_2, O_3. Organic matter, such as wood or paper, is blackened and charred by the action of the SO_3. Some of the crystals were preserved by keeping them in sealed bottles.

In contact with water the crystals become immediately opaque, and on boiling them rapidly disintegrate and pass into solution.

The compound corresponds to the formulæ As_2, O_3, SO_3. Theoretically it should contain SO_3 28.77 per cent., As_2, O_3 71.23 per cent. On analysis I found SO_3 28.91 per cent. and As_2, O_3 68.22 per cent., leaving 2.9 per cent. which is easily accounted for by the presence of some sand adhering to the crystals and some slight loss in manipulation.

MEETING OF APRIL 7th, 1890.

INFORMAL COMMUNICATIONS.

(1) Mr. Hills exhibited some crystals of vanadinite recently received from Silver District, Arizona. The crystals are chiefly interesting from the fact that they are nearly all crater-shaped, owing to successive additions of crystal substance each extending outwards beyond the preceding one; the series of steps thus produced corresponding to so many basal planes more or less modified, both inside and out, by various pyramids. The comparatively large size (5^{mm} to 8^{mm} in length) and deep-red color, very pronounced even for that locality, are additional points of interest.

(2) Mr. Pearce called attention to some interesting facts relative to the existence of tellurium and bismuth in the sulphide ores of Leadville. The discovery some time ago of metallic tellurium, sublimed during kiln-roasting of pyrites from the Louisville mine, prompted the investigation of other Leadville ores; and it was then found that tellurium can be detected in nearly all the sulphide ores of that district. Most frequently it appears in combination with silver (hessite?) as a gray film, of secondary deposition, on pyrites. As evidence of the general distribution of tellurium, Mr. Pearce further stated that Messrs. Knight and Vyvian Pearce had examined the fumes of roasting pyrites from other districts and ascertained its presence in varying amounts up to two per cent. Mr. Pearce had likewise found bismuth, as well as tellurium, in nearly all the pyritiferous ores of Gilpin County, indicating a more general distribution than is commonly believed.

MEETING OF MAY 5th, 1890.

INFORMAL COMMUNICATION.

Mr. Hills exhibited a specimen from Bisbee, Arizona, consisting of a cluster of large pseudomorphous crystals of malachite after azurite, on which are implanted smaller crystals of unaltered azurite. The pseudomorphs show the usual radiating fibrous structure. The azurite crystals have the same crystallographic orientation as the particular pseudomorph on which they are implanted and, consequently, have in each case the same orientation among themselves.

The azurite crystals are thought to belong to a second period of growth, occurring before the original and larger crystals had been completely altered to malachite. As shown by numerous examples of such pseudomorphs, from Bisbee, the alteration generally begins at the point of attachment and extends radially towards the surface of the crystal which is the last to be subjected to alteration. Usually a thin, lustrous shell of azurite remains on the pseudomorphs from this locality, the specimens above described being an exception.

The tendency of a secondary growth of crystal substance to assume a parallel position is well known, so that a second crop of crystals might be formed on others, retaining but a mere shell of the same composition, and be similarly oriented.

Nearly all the large Bisbee azurite crystals are shown to be more or less altered to malachite when broken open, and it seems probable that in many cases an addition of azurite substance and interior alteration to malachite may have been going on simultaneously.

MEETING OF JUNE 2d, 1890.

IRON-ORE BEDS AT THE PROVINCE OF SANTIAGO, CUBA.

BY F. F. CHISHOLM.

The Cuban Bessemer iron-ore beds occur in the Province of Santiago, near the southeast coast of the Island of Cuba, on the lower slopes of the Sierra Mæstra, a lofty range of mountains, running east and west, and maintaining an average height of about 4,000 feet for some 20 miles, parallel with the coast line—the crest of the range being distant from the coast about 7 or 8 miles. The mass of the Sierra Mæstra is a coarsely crystallized eruptive which is probably syenite. The under portion of the south slope of the range is covered by a mantle of diorite; below the bordering foot-hills the syenite again appears and continues nearly to the coast-line, between it and the sea being a width of about a mile and a half of coral and coralline limestone. The Sierra Mæstra is cut on the south by numerous small streams and rivers which flow into the ocean, forming a series of nearly parallel valleys, which are characteristically deep-cut, and not very tortuous, owing to the easy erosion of the soft eruptives. The coral and coralline limestone which form the coast-line are cut through at right angles by these streams, forming comparatively narrow gorges bordered by abrupt cliffs. Between the main range and this coralline border the rapid disintegration of the syenite has caused the formation of a valley of erosion, parallel to the Sierro Mæstra. The syenite is traversed by numerous dykes of pronounced diorite. The slopes of the mountain sides are steep and covered with heavy masses of timber and dense undergrowth and in most of the streams flowing to the south the supply of water is scant, many of them being dry except during the wet seasons, while in others the water which flows continuously on the higher slopes disappears below the open gravelly detritus which form the floor of the east and west valley. The coral border along the coast varies from a mile to a mile and a half in width, as far I could judge, and presents three very striking benches or terraces, which have apparently been formed by periods of rapid emergence between which were intervals of comparative rest, giving time for the formation of new coral beds. At the mouths of nearly all the small streams which flow into the Carribbean Sea in this district, occur small inlets characterized by the depth of the water near the shore, the borders of these inlets being benches of coral still submerged. These benches extend some distance beyond the average shore-line, and some of these inlets would form excellent harbors if any effective means could be devised for protecting the loading piers from the strong southeast winds which prevail during a large part of the year.

The limited time at my disposal and the entire absence of any openings which show rock in place, whether ore or country rock, rendered it impossible for me to arrive at any satisfactory conclusions regarding the geology and manner of occurrence of the ore, from observations confined to the Berraco group. The conditions at Berraco, however, are, I judge, precisely similar to those found at Juragua, 16 miles further west. In every detail of topography and surface geology at the two groups there is a strong parallelism, and it is quite safe to accept the general conclusions drawn from a study of Juragua as substantially correct as applied to Berraco. A rather elaborate study of the geology and ore deposition of the Juragua district has been made and an abstract has been published in a small pamphlet. After even a hasty inspection of the various mine openings on the Juragua group, I am very strongly inclined to question the conclusions which have been arrived at by Prof. James P. Kimball, ex-Director of the U. S. Mint, concerning the genesis of these ore deposits, if I am correct in my undertanding, that he attributes their origin almost wholly to metamorphism of coralline limestone by the action of surface-waters carrying iron-oxide leached from the overlying mantle of diorite. I presume, that at the time of Kimball's visit to the Juragua properties, many of the largest openings had not been made, and hence the large extent of outcrop of these iron bands, now exposed for considerable distances vertically, was not seen by him. On the Berraco group I saw no limestone, and at Juragua my impression, after seeing some of the limestone masses remaining there, was that they had been mechanically carried to their present position after having been detached from fringing wreaths of coral by sudden or violent uplifts. That the outcrops of some of these ore beds have been enriched by secondary deposits of ferric oxide derived from the overlying diorite mantle, is not at all improbable, but I consider the influence of all atmospheric agencies in the production of these great ore bodies very insignificant.

At the north opening on the Union Mine of the Juragua group, a vertical face 200 feet high, has been made, exposing a section across an iron band or vein, showing portions of the inclosing country rock on both sides, this country rock being an eruptive, probably diorite, and showing no limestone. The structure here is very distinct, and the cut shows a well-defined, nearly vertical body of iron-ore maintaining practically the same thickness from top to bottom, with well-defined, positive planes of demarkation between the ore and the country rock. On the east wall of this ore body in contact with the ore, occurs a wavey band of chloritic clay, enclosing small lenticular masses of vitreous quartz, all of these masses having their greater axes substantially parallel to the dip of the ore body. Between this clay band and the country rock occurs a persistent band, about two feet thick, of loosely compacted sand, strongly colored by the presence of manganese. The plane of contact between this outer band and the enclosing country rock is sharply defined, and the distinct coloration from manganese is entirely lacking in the wall on the one side and in the vein on the other. Other openings on the Juragua Mines showed similar, but less clearly marked conditions.

My conclusions, after going in detail over most of the exposure made by the Union cut, were that, whatever the exact character of the ore deposit, the present position of the ore cannot properly be considered the result of local metamorphism of limestones by the action of surface waters containing iron leached from the overlying mass of iron-bearing diorite. I am much more strongly inclined to consider the ore here either the result of concentration within a diorite dyke which was originally characterized by the presence of a large percentage of iron, or else a distinct band forming a portion of a larger dyke. In other words, I am strongly of the opinion that the source of the ore is from below, and consequently that the loyalty of these deposits may be relied on below the limits of atmospheric action. I regret that I was unable to go into the question in detail, and get positive facts in support of my belief, but that I am obliged to admit that my examination was too superficial to enable me to prove my views.

The Berraco group of mines includes four mining claims, the California, Trinidad, Sta. Maria, and Nueva Caridad, the total area being approximately 525 acres. The iron-ore beds of the Berraco group have a general northeast and southwest course and cross the extreme summit of the Trinidad Hill, at an altitude of 600 metres above the sea. One of these ore beds extends down the southeast face of the hill for over 500 metres. Three distinct bands of heavy iron float can, I think, be positively identified, these bands being probably nearly parallel to each other but, as at only two points, both on the same southernmost band, I was able to find the ore unquestionable in solid rock, it was not possible to determine these facts certainly. Throughout its entire length, the course and position of the centre band can only be traced by the continuous bed of surface-ore, this material varying in size from small fragments not exceeding a pound in weight, to enormous boulders containing from 50 to 100 tons of massive hematite, almost all of this being iron-ore of remarkable richness and purity.

The gross amount of ore lying loose in this ore band is very great, probably far exceeding a hundred thousand tons, but there were no data upon which to base a reliable estimate, as I was able to see only a limited portion of it, the dense undergrowth preventing an examination of the surface. This band of surface-ore in some places is over three hundred feet wide. Most of the ore appears to rest directly upon the vein beneath, the soft country rock weathering away rapidly while the exposed hard ore simply crumbled and settled down.

COMPARISON OF ANALYSES.

	Metallic Iron.	Sulphur.	Phosphorus.
Kimball on Juragua, . .	64.75	0.146	0.037
Graham on Sigua, . .	64.00	0.040	00.016
Berraco, calculated, . .	63.151	0.012	00.242
Berraco, average sample, .	60.	0.027	0.027

IRON ORE IMPORTED FROM CUBA TO THE UNITED STATES.

Year.	Long Tons.
1885, ...	28,209
1886, ...	51,268
1887, ...	109,928
1888, ...	117,504
1889, ...	225,525
Total, . .	532,434

All of this ore came from the Juragua Iron Company, Limited. Declared value of ore in Cuba in 1888, $2.40 per ton.

GOLD DEPOSITS IN THE QUARTZITE FORMATION OF BATTLE MOUNTAIN, COLORADO.

BY F. GUITERMAN.

At the suggestion of Mr. Richard Pearce, whose recent researches on gold, its alloys and its mineral associates, have been productive of such remarkably interesting and unexpected discoveries, the writer undertook to gather for the Society a few facts relative to the nature of the very rich auriferous ore deposits, that are found and mined in the Ground Hog Mining Claim, located on Battle Mountain, Red Cliff Mining District, Eagle County, Colorado.

The ores found in this mine would naturally have attracted attention from their extreme richness in gold, this being found not infrequently in the nugget form, but the mineralogical character of the ore, which forms the matrix of the gold, adds a heightened interest to the investigation.

The quartzite rocks between which the deposits are found, have an average dip of about 10° to the northeast. The contact between the two layers is sharply defined, the contact filling being a quartzite breccia, more or less iron-stained, and at times impregnated with unaltered pyrite. This breccia filling has an average thickness of perhaps 4½ feet, occasionally expanding to 6 feet, and contracting to a minimum of 4 feet. The ore chimneys occurring in this filling are found at intervals, their presence being invariably marked at the outcrop by what is locally termed the "joint clay," an aluminous deposit, heavily iron-stained, occurring on top of the ore body and following it along the roof for a distance of perhaps 200 feet, when it gradually thins out, disappearing entirely when the unaltered sulphide is reached.

The ore chimneys have a maximum width of about 4 feet, their thickness being limited to the distance between the floor and roof.

While the quartzite roof is invariably smooth, the lower quartzite which forms the floor is quite rough, in fact almost corrugated in appearance, and gives strong evidence of the chemical action exerted upon it, attendant upon the deposition of the ore. The floor is at times impregnated with the ore, which does not, however, extend for any great distance into it.

As stated, the ore chimneys, which are continuous, have a maximum thickness of 6 feet, the pay ore itself being confined at times to a thickness of a few inches, and again swelling from floor to roof.

The pay ore in the oxidized portion of the deposit carries, on the average, about 7 ounces of gold and 50 ounces of silver to the ton.

In mining the ore it is customary to follow the floor as a guide. The individual ore chimneys are connected laterally by cross chutes giving the appearance, in section, of net work. It is a common occurrence for an ore chimney to divide, the separate branches either re-uniting further on or again splitting up; the whole ramification coming together again at intervals into one main chimney. The rock, which fills the space where the divergence has taken place, is of the same nature as the breccia filling, only more compact, and is impregnated to some extent with pyrite. These fillings are termed "Islands," or "Rib Rock," and are left standing as pillars after mining the ore.

The characteristics of the quartzite ore deposits may be summed up as follows:

At the outcrop of the ore chimney, the appearance of the "joint clay," a zone of oxidation for about 200 to 250 feet, which gradually merges as the natural water level is approached through a zone of mixed oxides and sulphides to the zone of unaffected sulphides.

It has been mentioned that the "joint clay," gradually disappears as the sulphides are approached, and it is interesting to note, that while the silica contents of the ore in the zone of complete oxidation are from 30 to 60 per cent. these also lessen as the zone of the unaltered sulphide is approached, diminishing from a maximum of 60 per cent. to an average in the sulphides of 2½ per cent.

In alluding to the zone of complete oxidation, it must not be understood, that it is a zone entirely free from sulphur. On the contrary, it is present in appreciable quantities, being combined however with oxygen, in the form of sulphuric acid, which in turn is united to the sesquioxide of iron, the combination forming the crystalline minerals, coquimbite or copiapite.

The following analysis of a sample representing several car loads of ore from the Ground Hog Mine, made by Mr. F. C. Knight, of the Boston and Colorado Smelting Works, will show to what extent this sulphide is present:

Hydrated sesquisulphate of iron,	12.00
Hydrated sesquioxide of iron,	54.30
Silica and alumina,	31.20
Barium sulphate,	2.70
	100.20

On the Ground Hog Mining Claim there have been two chimneys of ore developed, 600 feet apart, the deposits having the essential characteristics of the quartzite deposits, previously described. These deposits have been followed from the outcrop for about 250 feet in length. While several later branches, which will undoubtedly connect these chimneys, have to some extent been exploited, the connections have not been entirely established, but from what is known of adjacent quartzite mines, it is not at all likely that the ore chimneys in the Ground Hog will prove an exception in this feature to the other deposits.

Both the ore chimneys in the Ground Hog have been prolific in nugget production, although in physical appearance, the nuggets of the two ore chutes are quite dissimilar. The nuggets occurring in the ore deposit worked by Messrs. Brock & Co., under lease, are isolated and have a peculiar spirally twisted appearance, often taking the shape of bent horns, while in the ore chute operating under lease, by Mr. John Baumeister, the nuggets are inclined to be lumpy, a closer inspection revealing that the lumps are composed of individual crystalline particles of greater or less size, cemented together by the sesquisulphate of iron and horn-silver. In each case the nuggets are found in troughs in the quartzite floor, imbedded in clay and intimately associated with very rich silver ore, which proved on examination to be horn-silver, a most remarkable association in itself.

With and in the vicinity of the nuggets are also found lumps of the sesquisulphate of iron, somewhat contaminated by an admixture of clay, which show high gold results on assay, but from which it is impossible to obtain a color by panning!

No tellurium or bismuth has been detected in such samples of the Ground Hog ore as have been subject to my consideration, the examination for these elements having been made in conjunction with Mr. Pearce. Tellurium has, however, been found in the district, and it is, of course, among the possibilities that these elements will be discovered later on in this particular deposit.

While it has been assumed, by both Wurtz and LeConte, that the secondary deposition of gold, in the shape of crystals and nuggets, was accomplished through the medium of a solution of persulphate of iron, derived by the slow oxidation of iron pyrites, I think I am safe in saying, that it has remained for the discoveries in the Ground Hog Mine to demonstrate, almost beyond question, the correctness of that theory.

The opening of ore bodies in the quartzite zone of Battle Mountain, showing the successive and unbroken development of the oxidized ore from the sulphide, and the culmination in the Ground Hog Mine, where not only the sesquisulphate of iron is found, rich in gold, but in which its presence cannot be demonstrated owing to its extreme fineness, by the miner's test of panning, and finally the cementation of the nuggets by the sesquisulphate to a large degree, is to my mind as strong a proof of the correctness of that supposition as is ever likely to be reached.

MEETING OF JULY 7th, 1890.

(Georgetown Meeting.)

GEOLOGY OF THE ROSITA HILLS, CUSTER CO., COLORADO.

BY WHITMAN CROSS.

The mining district, within which the towns of Silver Cliff and Rosita are located, has been made the subject of detailed study by the division of the U. S. Geological Survey, under the direction of Mr. S. F. Emmons. This paper is a concise summary of the general geological results reached during this investigation, and is presented with the kind permission of Mr. Emmons.

The district in question is situated on the eastern slope of the beautiful Wet Mountain Valley, a long depression with general north and south course, and several miles in width, which lies between the Wet Mountain range on the east, and the Sangre de Cristo range on the west. It has been shown by Mr. R. C. Hills,* as a result of his studies in Huerfano basin at the southern end of this depression, that it has existed in practically its present form since very early Eocene times. The Huerfano beds described by Hills were deposited in a synclinal trough, whose axis corresponds to the general course of the Wet Mountain Valley. The great age of the valley is also indicated by other less direct evidence.

Silver Cliff is situated on the gentle valley slope, just above the broad level bottom-land. The "cliff" is about 50 feet high and is merely the southern end of a rhyolite flow whose borders are generally covered by Pleistocene

* Proc. Colo. Sci. Soc., Vol. III., Part I., 1888, p. 148. "The recently discovered Tertiary beds of the Huerfano river basin, Colorado."

gravels and soil, and which forms an insignificant feature of the general topography.

Three miles east of Silver Cliff and five hundred feet above it is the base of a compact group of rounded hills, four by five miles in extent, differing widely in contour and origin from the adjoining hills and mountains of the Wet Mountain Range. This group of hills has been named the Rosita Hills, from the little town nestling in their midst.

The Rosita Hills are almost exclusively made up of eruptive rocks, the products of a series of eruptions. These rocks interpenetrate and overlap each other in a very intricate manner, and although erosion has been considerable, it has revealed a knob of Archæan, belonging to the floor on which the eruptives rest, at but one point within the area. The Hayden Geological Map of Colorado represents a band of "trachoreite" extending for twenty miles along the western base of the Wet Mountains. This representation has only the merit of indicating the presence of eruptive rocks in the region. "Trachoreite" has no petrographical signification; there are many small bodies of various rocks, and they are not connected to form any such mass as that represented.

The principal part of the geological history of this district which can now be read is that of the sequence of eruptions that built up the Rosita Hills; of the single one at Silver Cliff; and of the periods of decomposition and erosion to which the eruptives have been subject. To the period of decomposition may be referred the interesting ore deposits contained in these rocks, whose existence has made the district known.

Prior to the series of eruptions which produced the larger masses of eruptive rock, there were intrusions of syenite and diabase, which appear in narrow dikes coursing through the Archæan schists of a large area at the north end of the Wet Mountains. As these dikes are vertical and cut across the strike of the upturned schists in all directions, the date of their eruption is evidently later than that of the main folding of these schists, but they were eroded in common with the schists in producing the surface upon which the later volcanic flows were poured out. They are therefore pre-Tertiary

The eruptions which took place in the small area of the Rosita Hills were so closely related, and the phenomena were such, as to justify the conclusion that they came from a common source and are to be treated together as products of a single volcanic centre. Six important and several minor eruptions took place from the Rosita volcano—as it may be called. The first three eruptions were of andesite, then came rhyolite, followed by a fourth andesite, and to close the series a trachyte was poured out. Some of the outbursts were violent, others were quiet, and one of them was followed by typical solfataric action. This is the history of a volcano.

The first eruption of the volcano was explosive, the product being a hornblende andesite, now seen in the form of breccia, tufa, or mud-flow, according to the fineness of the fragments and the part played by water in their arrangement. Such an outburst must have built up a cone of ejected fragments, but this was evidently much modified in form before the succeeding eruption of massive rock. This first andesite is the reddish or purplish rock now seen about the town of Rosita, on the adjacent slopes of Pringle Hill, and in Mount Robinson. In it is the Humboldt-Pocahontas vein, the best known of the region. The different textural modifications are found in irregular relationships to each other, and no direct evidence locates the exact site of the vent from which the material came.

The second eruption, which followed the first after a period of some duration, covered a large area to the northwest of Rosita. The product of this eruption was a holocrystalline, fine-grained, massive andesite, carrying hornblende, augite and biotite in varying quantities, and forms to-day the greater part of the northern half of the Rosita Hills. The effusion of this rock was evidently quiet, and probably took place through fissures. It is much less easily decomposed and eroded than the earlier fragmental material, and many of the high points in the hills are in this area. Rounded contours and even slopes are characteristic of the entire group, but especially so of the space occupied by the Bunker andesite—as this type has been called to distinguish it from a similar one of another eruptive period.

The Bunker andesite is cut by several bodies of a granular rock, a diorite which is of considerable petrographical interest, but plays a subordinate part in the make-up of the hills. It is limited to the area of the one andesitic type, and on grounds which cannot be fully given at this time it is considered as belonging to the general eruptive period of the andesite which it cuts. The petrographical interest attaching to this rock lies in the great variability in mineral composition met with in its mass. The average rock consists of plagioclase, orthoclase, augite, biotite, and magnetite, but there are places where each of these components so increases in amount as to radically change the character of the rock. Thus there are smaller masses in certain dikes which consist chiefly of augite and magnetite; others in which the plagioclase predominates very strongly; elsewhere orthoclase is more abundant than usual, and hornblende ordinarily replaces augite to some degree in the same rock. Still further modifications are produced by an increase in the magnesia contents, causing a development of olivine. In many places the diorite is traversed by granitic veins, composed chiefly of orthoclase and quartz. These veins are so evidently limited to the diorite bodies, and have such a direct connection with the other variations mentioned, that they too are considered, in common with the rest, as due to "differentiation" of the dioritic magma during its consolidation. All of the varieties mentioned excepting the granitic pass by gradual transitions into the average rock.

The third andesitic rock of importance occurs in a series of rounded hills and connecting ridges to the southward from Rosita. Its age relative to the Bunker andesite is assumed, for the two types do not come in contact. Both are later than the first, fragmental andesite, and both are cut by the succeeding eruption. This rock resembles the Bunker type in being fine-grained and porphyritic, but differs essentially in the relative amounts and characteristics of its constituents. It carries some free silica, as quartz or tridymite, and the silicates augite and hornblende are present in small and variable amount. The massive uniform structure shows that this rock was produced by a quiet welling out of a magma through vents whose exact locations are not known.

Following these two eruptions of andesite came a return to typical volcanic activity, manifested by violent explosive outbursts through numerous vents. Apparently the massive andesites had plugged the channel leading to the source of the molten magma, and the explosive force of the new period could only find relief by forming vents at various places all through the area occupied by the massive flows, in the centre and on the sides, and several miles away to the westward, near the present site of Silver Cliff. The product of this second violent outburst was very different from that of the first. The rock is a typical rhyolite. It was apparently produced in a large number of eruptions of small extent. The earliest were violent and covered the country for several miles about with volcanic ash and scoriæ. The first eruptions were followed by others producing more massive lava flows, but of no great extent, and an alternation of explosive with massive effusions seems probable. This is true at any rate of the region of the Rosita Hills.

The best illustration of a vent through which explosive action took place in this period is in Wakefield Hill, less than a mile south of Rosita. There is seen a mass of rhyolitic agglomerate, consisting chiefly of white pumiceous fragments, now much kaolinized, with irregular pieces of massive rhyolite and many rounded boulders of reddish granite and gneiss. Small pieces of charcoal are also found in this mixture. Through this agglomerate cut dikes of massive rhyolite.

Other prominent channels of the rhyolitic period are found as dikes in Mount Robinson, Democrat Hill and Knickerbocker Hill, while less important ones are numerous. From these vents the rhyolitic lavas spread over the low ridges surrounding the hills, and are found to-day in remnants much further from the source than any other rock of the series.

The rhyolite eruptions near the site of Silver Cliff, were on a much larger scale than those of the Rosita Hills. The lava flow to which the outcrop at the "Cliff" proper belongs, and in which the celebrated surface ore deposits of the "Racine Boy" and adjoining mines were found, was plainly of great extent. And while the surface exposures show that a complex of stratified rhyolitic beds dip under the massive flow, the magnitude of the earlier eruption was unsuspected until the deep shaft of the "Geyser" Mining Company penetrated several hundred feet of almost horizontally bedded breccia and tufa below the massive rhyolite sheet.* This shows that a lake must have existed at this point into which were gathered the fragmental materials from a vent near at hand. Round Mountain, situated on the eastern part of this rhyolite area, seems to represent the source of the Silver Cliff flow, and very possibly the explosive vent was at the same point.

* Note—March, 1891. The Geyser Shaft is now more than 1,100 feet deep, and all but the upper 270 feet has been in rhyolitic tufa and breccia.

Several of the mines near Silver Cliff have encountered a formation which has been almost a complete puzzle to superintendent and "experts," and has proved to be of great interest from a petrographical standpoint. Beneath the banded lithoidal rhyolite of the "cliff" is a zone of very round "boulders," varying in diameter from ten feet to less than one foot. At some surface outcrops of this zone some of the "boulders" were found to contain cavities in which ore occurred, and here quarries or open cuts were made, analogous to that of the "Racine Boy" Mine in the banded rhyolite. These round masses were most frequently found imbedded in a very soft white clay, but in other places glassy rhyolite or pitchstone was the matrix and the same glass was observed to commonly occur below the "boulder" zone. Investigation of the occurrences has shown that the "boulders" are huge compound spherulites, primary radiate crystallizations in the flow to which both the banded rhyolite above and the pitchstone beneath belong. The clay in which they are found is the decomposition product of the pitchstone, and consists of a mixture of kaolin and finely divided opaline silica. It is probable that these spherulites are the largest, as they certainly are among the most interesting, known illustrations of this curious development of crystallization from a molten magma. These spherulites, together with the wonderfully varied examples of similar growths in rhyolites of the Rosita Hills, have been carefully studied, and have yielded some interesting contributions to our knowledge of the character and origin of the group of bodies to which they belong.

Succeeding the rhyolite and apparently before any great erosion had taken place, came another andesitic eruption. This took place through long fissures which penetrated all of the older rocks. We now see the rhyolite cut by dikes of this andesite, and in two places there are surface flows of the same andesite resting upon rhyolite. The relationship is therefore perfectly clear. The larger surface mass of this andesite forms the upper part of Pringle Hill, west of Rosita, and the local name Pringle andesite is applied to the type. It is a mica-augite-andesite, and, though macroscopically much like the Bunker type, the two can be distinguished under the microscope by characteristics of mineral development. The principal dikes of this rock occur in the vicinity of Rattlesnake Hill, clearly cutting through rhyolite flows.

The last eruption of any consequence in the series produced a true trachyte. This magma also came up through fissures, even longer than those of any other eruption, and traversing all earlier eruptive types. The eruption consisted in the welling up of lavas through fissures, and was not attended, so far as the evidence shows, by any explosive action. Game Ridge, near Rosita, represents the largest surface mass of trachyte and the main dikes extend from Rosita to the western base of the hills.

Reviewing the series of eruptions which has been determined in the Rosita Hills, it is evident that the mountain built up by the lavas was at no time very much larger than the present group of the Rosita Hills, for almost all of the eruptive rocks are seen both in dikes and in surface flows. This is true at least of the last three eruptions. It thus appears that erosion in the periods between eruptions simply served to maintain the surface at about a constant position, and that deformation from the last of these periods up to the present time has not been very great.

These eruptions have been spoken of as belonging to practically one volcanic series, as constituting a volcano. The history of this volcano is then divided into two parts, each of which began by explosive action, and was followed by two more quiet eruptions from fissures. Further interesting evidence showing that the activity is to be compared with that of true volcanoes is afforded by the alteration products of some of the rocks. In two places rhyolite, occurring in channels at horizons very near the surface of the time of eruption, has been changed in a manner which is known to be characteristic of solfataric regions. This action took place immediately after the rhyolite eruption—that is, it was the closing phase of the rhyolite period of the volcano. The product to which reference is made is a hard, rough, porous mass, looking like a very coarse grained dolomite. It is composed of two minerals, quartz and alunite, the latter occurring in irregular grains showing a very good cleavage, while the quartz is developed only in minute grains abundantly included in the other mineral, and also forming a matrix in which the alunite is imbedded. As alunite has not been found in such development in this country before, it may be well to recall that this interesting mineral is a hydrous sulphate of alumina and alkali, closely allied in composition to ordinary alum, but very different from it in its physical characteristics. It is a mineral as hard as feldspar, practically insoluble in ordinary reagents, excepting sulphuric acid, and is thus adapted to form an enduring rock mass. Such masses are known in volcanic districts in Hungary, in Italy, on the Island of Milo, and elsewhere, and are the products of the action of sulphurous vapors upon rocks rich in alumina and the alkalies. The alunite rock of Tolfa, near Rome, has for centuries past been a commercial source of alum, which is extracted after slow roasting, by leaching with water.

The rough rock forming Democrat Hill, is composed of two-thirds quartz and one-third alunite, the original rock structure having been destroyed. In Mount Robinson, near Rosita, the rugged crest is due to a dike which has been altered in the same way, a large part of the product being rich in alunite. Apparently as a further product of alteration at this time, the alunite has been decomposed and extracted, a portion of its alumina remaining in crystals of diaspore—hydrous alumina. Certain parts of this rhyolite dike are thus replaced by a cellular quartzose mass, containing small amounts of glistening diaspore grains, with no other constituent of importance remaining.

That the solfataric action producing the alunite belonged to the rhyolitic period is indicated by the fact that only rhyolite is thus altered. The alunite rock of Democrat Hill is cut by two trachyte dikes which are almost completely kaolinized. As the trachyte is rich in the proper bases for alunite it would certainly have been acted upon by the solfataric vapors had they been of later date than that rock.

In the foregoing sketch no mention has been made of one of the most remarkable volcanic vents of the district, namely, that in which occurs the celebrated ore-deposit of the "Bassick" Mine. This vent is situated on the eastern edge of the eruptive area, and though its product was andesite, the observed facts do not justify its reference to any of the eruptive periods described. The shaft of the "Bassick" Mine is sunk 1,400 feet in a typical volcanic agglomerate whose surface distribution is very limited. This formation consists of boulders of several types of andesite mingled with various amounts of Archæan. The boulders have been rounded by attrition and are embedded in gravel and sand derived from the same action. Occasional fragments of charcoal have been found in the mass, from the surface to depths of 800 feet. The agglomerate is regarded as the filling of a typical "volcanic neck," or channel below the crater. Its walls have not been encountered in the mine workings, but they must descend quite abruptly as Archæan outcrops approach the shaft to within a few hundred feet on nearly every side.

It is beyond the scope of this article to speak of the ore-deposits of the district, but it may be briefly stated that the ore of the "Bassick" Mine appears as concentric zones about the boulders and as a replacement of the gravelly matrix. The entire mass has been permeated by thermal waters which have decomposed the rock fragments and deposited quartz, opaline silica, and kaolin, in abundance.

From the close of eruptive activity in the Rosita Hills down to the present time the only agencies at work seem to have been those of decomposition and erosion. The latter has not accomplished much, judged by the length of the period that must have elapsed. But rock decomposition has gone on very extensively and probably took place in the period representing the dying out of the volcanic action. Large areas of andesite are bleached and boundary lines between similar rocks are obliterated. The reference of this result to the action of thermal waters charged with various solvents is natural, and the further conclusion that the ore-deposits are intimately connected with that action is almost a necessity.

The chemical action of the circulating waters has not been so much a kaolinization as a muscovitization, that is to say, the bases, iron, lime and magnesia have been extracted but the alkalies have remained, and a silvery mica is more commonly the product than is kaolin.

When the great volcanic area of Southern Colorado and New Mexico has been carefully studied, it will no doubt appear that this local vent was an outlier, connected more or less directly with the vastly more important centres to the south and west, and a comparison of the sequences of events will be of much interest. So little is now known of even the immediately adjoining country to the southward, that it is possible that similar centres may exist unsuspected. However that may be, it does not seem probable that any other area of equal size will be found to contain so extensive and so complete a record of volcanic activity as is presented by the Rosita Hills.*

* Purely petrographical descriptions of rhyolite, trachyte, syenite, peridotite, augite-diorite, and andesite [Pringle type], from this district, were published in the Proceedings of this Society, Vol. II., pp. 228-250, 1887.

FULGURITE FROM THE SPANISH PEAKS.

BY R. C. HILLS.

At the meeting of October, 1888, the writer exhibited a number of specimens showing lightning tubes and blebs of fulgarite obtained near the summit of the westerly of the two lofty elevations, known as the Spanish Peaks. About six years ago J. S. Diller described certain interesting occurrences of this character on the summit of Mt. Thielson,* and more recently Mr. Frank Rutley has contributed the results of his study of similar occurrences from the summit of Monte Viso.† The material from West Peak is, in some respects, more satisfactory for the purpose of demonstrating the manner in which different rocks may be affected by lightning, together with the origin of the so-called lightning-tubes, than the material at the disposal of the above named writers—for which reason the following remarks may be of additional interest.

For a description of the unique, geological structure of the Spanish Peaks, the reader is referred to previous papers published in this volume ; it being merely necessary to explain here that they are mainly of eruptive origin, the higher ridges being made up almost entirely of eruptive rocks.

Topographically considered, they are two isolated peaks, lying some distance to the east of the Sangre de Cristo Range, and connected with one another by a low, saddle-shaped ridge. The culminating points of these mountains, known respectively, as the East and West Peaks, are about three miles distant from each other. The latter is the more lofty of the two, rising to an altitude of

* American Journal of Science, Oct. 1884.

† Quart. Jour. Geol. Soc., Vol. XLV., page 60.

13,700 feet above sea-level, the former being about 800 feet lower, yet still 5,000 feet higher than the low hills of the country near its base. These isolated mountains are, so to speak, natural lightning rods, and form the principal centers of attraction for the thunder storms that gather in that region during the summer months.

A very brief inspection of the rocks forming the apex of West Peak revealed abundant evidence of the effects of lightning. The triangulation monument, erected by Hayden's party, some 15 years ago, showed blebs of dark-colored fulgurite glass in a number of places; while a one-gallon tin can, at its base—containing the cards of adventurous cragsmen—had been twice visited by the electric current. Further search in the vicinity disclosed a number of places where the rock had been shattered by lightning, the fragments showing irregular, ramifying, hemi-tubular grooves, from the size of one's finger down to that of the smallest rootlet. They are substantially similar to those figured by Mr. Rutley, though in most cases the fulgurite has weathered out. Usually, the surfaces on which they appear, and to which they are generally confined, are the more or less irregular, ordinary fracture-planes of the rock, coated with a film of iron-oxide. In one place a large block, weighing several hundred pounds, had been divided into two parts, which were found lying within a few feet of each other. In this case the current had followed a plane of cleavage along which there was an appreciable thickness of iron-oxide which appears to have acted as a conductor. Upon striking the rock the current seems to have been split up into several minor currents distributed along the cleavage-plane, and these again suffered further sub-division as they advanced downward, so that toward the bottom the tubes become more numerous, but reduced in size to the diameter of a darning-needle. All the tubes, however, were formed along the cleavage-plane, and one-half of every tube in the system thus formed was found plainly exhibited on the opposing surfaces of the separated blocks.*

Another point which was clearly shown was, that independent of the splitting up of the current as it entered the rock, and the consequent decrease in the diameter of the tubes from this cause, there was also a rapid decrease in the size of the tubes due to diffusion of the current through the rock mass. Evidently the current was not strong enough to shatter the block but merely to sunder it along the plane of conduction and easy cleavage.

Tubes formed without the rock being split open by the operation are rare, and but one fragment could be found exhibiting a perfect tube. In this instance there is a main tube and a smaller ramification following, throughout, a capilliary veinlet corresponding to an old fracture-plane along which pyritous ore-particles had been deposited.

A number of places were noted where shallow basin-shaped holes had been formed in the talus near the apex, and an examination generally revealed blebs of fulgurite on the surface of fragments, either at the bottom of the hole or around the sides—such places having evidently been struck by lightning, which scattered the loose material and thus formed basin-shaped holes. It is noteworthy that lightning-tubes could not be found in these places. In a few instances the rusty, weathered surface of rock in place showed blebs of fulgurite, but in these cases also, lightning-tubes were not formed.

Such abundant proof of the effects of lightning on West Peak led to an examination of East Peak, under the impression that evidence of a similar character would be met with there. Yet, strange to say, nothing of the kind was discovered. Quite a number of the basin-shaped

* Two specimens, counterparts of each other, taken from these blocks, were exhibited in illustration. These, and the other specimens referred to are now in the Museum of the Society.

hollows were observed in the fragmental material near the summit, but not the slightest trace of fulgurite could be found in any of them. This apparent anomaly suggested an investigation of the rocks forming the summits of the two peaks, and especially of those containing fulgurite.

The material from West Peak consists of a coarsely-granular to crystalline aggregate of plagioclase, orthoclase, augite and biotite, with some apatite, and an abundance of magnetite. Chlorite also appears as a decomposition product of the augite. Hence, it is essentially a biotite-augite-diorite. This is the rock in which, with one exception, all the tubes and blebs of fulgurite were found. As a result of weathering, the basic silicates, in a rock of this composition, are partly or wholly decomposed and appreciable quantities of iron oxide deposited along planes of fracture or cleavage. From the same cause loose fragments, forming talus-like accumulations on precipitous exposures, are coated with a film of the same oxide.

A specimen, illustrating the exception just referred to, and already specified as the only fragment containing a lightning-tube intact, was also subjected to an examination. It was found to consist of rounded or irregular-shaped grains of quartz in a partly kaolinized granular-ground mass. A chloritic substance and some ore particles were also distinguishable. Quartz grains, however, make up the main body of the rock, which would appear to be metamorphosed material of sedimentary origin. It may, indeed, simply represent a detached block caught up and included by the diorite at the time of eruption since no considerable exposures of it were observed.

The ridge, connecting the saddle-shaped divide with the summit of East Peak shows several varieties of eruptive rocks, including porphyries, diorites, and thin sheets of basalt, but only the mass forming the summit was explored for fulgurite. This consists of a light colored eruptive rock in which are phenocrysts of plagioclase, imperfectly outlined, which may be bordered to some extent by orthoclase. Small scales of biotite are also discernible. Three sections under the microscope show well-developed polysynthetic plagioclase crystals whose optical behavior indicates nearness to andesine. Orthoclase is present, but in quantities subordinate to plagioclase. Quartz grains are rather numerous in the ground mass, although not noticeable as phenocrysts. Augite and biotite also appear, the former more or less altered to chlorite, but neither of these minerals are abundant. Grains of magnetite are also distinguishable in the ground mass which is throughout coarsely crystalline-granular. From the above composition it appears that this rock is essentially a quartz-bearing biotite-augite-porphyrite.

It is important to observe that not a trace of iron-oxide is discernible as a result of weathering, either on exposed surfaces or between the planes of fracture and cleavage.

The principal difference, therefore, between the eruptive rocks found at the summits of the two peaks, consists in the relatively greater abundance of augite, biotite, magnetite, and chlorite in the diorite of West Peak, and the marked absence of iron-oxide in the cleavage- and joint-planes of the porphyrite of East Peak.

This difference suggests that fulgurite is most likely to be formed along films or capillary veinlets of ore, producing according as these are superficial or confined to cleavage-planes, blebs of fulgurite glass, or lightning-tubes lined with the same substance. It also appears that there is a strong disposition on the part of the electric current to diffuse itself through the mass of the rock, and that under ordinary circumstances it is thus diffused and fulgurite is not formed. If, however, a better conducting substance is present, though it be a mere film of ore, the current becomes more intense along this conductor and fulgurite is produced. When the conducting substance occupies one of the capillary fractures, or joints, lightning-tubes are the result ; if the same substance is a film coating the surface of the rock, blebs of fulgurite are the result. In order that such conducting films may be formed it is necessary that the rock itself should contain minerals which, by decomposition, will produce the desired substance.*

The rock from Monte Viso, investigated by Mr. Rutley, is described by him as glaucophane-epidote schist containing garnet, sphene and occasionally diallage. The Mt. Thielson rock is described by Mr. Diller as hypersthene-basalt. Hence they have nothing in common with the West Peak rock, except that both contain an abundance of basic, iron-bearing silicates. The West Peak occurrences, however, tend to confirm the conclusion expressed by Mr. Rutley that lightning tubes are formed along planes of easy fission. They suggest, further, that only such planes or surfaces as contain appreciable quantities of some conducting substance develop sufficient conductivity, as compared with the mass of the rock, to concentrate the current in an intense form, and thus produce the occurrences described. It is often noticeable that the planes of jointing and lamination in epidote or amphibolite schists, exhibit a thin, nearly continuous sheet of the predominant mineral—sometimes scarcely more than a film—and it is conceivable that the conductivity would be greater along such planes than elsewhere. It would be interesting to know whether or not this was the case in the occurrences described by Mr. Rutley, a question suggested by his remark that a certain delicate banding of the rock was not distinctly visible on the furrowed surface. It is obvious that while planes containing iron-oxide, or some

* Since this paper was read Mr. Whitman Cross has very kindly informed me of his recent discovery of considerable fulgurite in the rusty-colored exposures of Mineral Point, in Gunnison County, and that the occurrence there tends to support the view above stated.

other ferruginous substance would possess greater conductivity than the mass of the rock, such substances would be very poor conductors as compared with metals, so that currents passing through them would meet with great resistance, and thus develop intense heat.

The basin-shaped hollows above mentioned are of very common occurrence on the high peaks and culminating ridges of the Rocky Mountains although, so far as the writer is concerned, their origin was not clearly understood previous to the observations on the similar hollows of West Peak. On the ridges connecting high mountain summits, as well as the summits themselves, these lightning holes are frequently met with, the ordinary effect of lightning upon rocks being, apparently, to rend and scatter the fragments without producing fulgurite—the latter being formed under exceptionally favorable conditions where, as Diller observes, the rock is rich in iron.

Prestwich, in his admirable text-book, calls attention to lightning as "a cause of disintegration occasionally occurring in mountainous and craggy districts."*

The occurrences just described are so much more frequent than is generally supposed, that it seems pertinent to suggest that lightning may be a more important geological agent than it has hitherto been considered.

In the operation of this agent the weak places, such as the high peaks, sharp ridges, and projecting pinnacles, are the points of attack. These are frequently riven and the fragments scattered down the mountain slopes. There can be little doubt, that in this manner a constant bombardment has been going on since early geological times, and during long periods when the climatic conditions were eminently favorable to electrical manifestations.

* Geology—Chemical and Physical, Vol. I., page 149.

MEETING OF AUGUST 4th, 1890.

(Boulder Meeting.)

THE NATURE OF THE CHEMICAL ELEMENTS.

BY CHARLES SKEELE PALMER.*

Introduction.

In his recent Faraday lecture before the Fellows of the Chemical Society (London, June 4th, 1889), "On the Periodic Law of the Chemical Elements," Prof. Mendeléeff having reviewed all the prominent efforts made up to date to explain the peculiar relations of the elements, as regards their ultimate nature, speaks thus:

"From the foregoing, as well as from the failures of so many attempts at finding in experiment and speculation a proof of the compound character of the elements, and of the existence of primordial matter, it is evident, in my opinion, that this theory must be classed amongst utopias. But utopias can only be combatted by freedom of opinion, by experiment and by new utopias. In the republic of scientific theories freedom of opinions is guaranteed. It is precisely that freedom which permits one to criticise openly the widely diffused idea as to the unity of matter in the elements."†

Certainly, no one is better fitted by profound scholarship, long experience, and bold prediction justly vindicated, to speak with authority on this subject, viz: the nature of the possible complexity of the chemical elements. But the free right of thought and its expression, freely

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* The second paper on this subject will appear in the Proceedings of the Society for 1891.

† Lond. Chemical Jour., Oct. 1889, page 647.

conceded by this veteran, justifies even the obscure student in approaching this subject; since moreover, Prof. Mendeléeff has done as much as any to put this question forward as a legitimate one for sober thinkers, a question, which hitherto has, in general, been characterized by wild but brilliant hypothesis worthy only of timidly whispered expression. But the promising nature of the problem leads us to follow on in the path indicated by the brilliant work of Prof. Mendeléeff, who has himself most abundantly given clues, which, if carefully traced up will bring us out into cleared ground; it is inconceivable that his own path should end in perplexity or confusion, or, indeed, in aught but rational explanation.

It is not within the scope of my wildest ambition to be able to reduce this subject at once to its finality; but it is my distinct purpose in these papers to draw attention to the more salient points, and to examine their significance as far as our present information shall allow, as well as to contribute something to the accepted atomic theory, which may be incorporated in, or serve as a foundation for, the work of others.

Historical and Directive.

It is not necessary, before proceeding directly to the main questions at issue, to explain in detail the history of all hypotheses on this subject. Prof. Mendeléeff has already ably passed judgment on these attempts. Moreover, I could not if I would; for in my isolated station I am not sufficiently provided with the chemical literature to go thoroughly into the subject from a historical standpoint. But this much I would do, viz: to observe the *nature* of the questions involved and the *method* which must be pursued.

A mistake here is a radical one. It is to the eternal credit of Lavoisier, that in all his work, he emphasized the principle that *matter* must be studied according to the *laws of matter;* it can be determined by the *balance*—it can be *weighed.* No progress can be looked for, in my opinion, which does not in a similar way and degree, consider what we *know* of the *actual chemical behavior* of the elements.

There would be no excuse for the reiteration of these commonplace truths, were it not that a large proportion of the ever-appearing new hypotheses on the subject ignore these self-evident principles of procedure, and look for light in some mere mathematical approximation to the atomic weights, regardless of the *chemical behavior and nature* of the elements corresponding to those atomic weights. Prout's hypothesis was a suggestion, but hardly a vestige remains of its original form. Such decimals as 35.37 : the atomic weight of chlorine, and the exact work of Stas and other investigators, demand a different interpretation. The observations of Lothar Meyer and Karl Seubert,* that nearly twenty of the elements have atomic weights, which are approximately multiples of 8 ; i. e., one-half the atomic weight of oxygen, is a remarkable one. Another observation of Prof. Meyer is that the atomic weights of the elements of the *fifth* series of the Periodic Law are approximately the arithmetical means of the respective members of the *third* and *seventh* series is equally striking. Other less successful and less intelligent attempts are not wanting. Thus A. M. Stapley,† suggests a set of formulæ carefully elaborated into a table which, though full of interesting coincidences, ignores chemical relations and is evidently based mainly on a mathematical conception of the subject.

L. Dulk in two articles‡ develops with great ingenuity formulæ for some of the elements in terms of mass and attraction in accordance with the direct ratio of the mass, and the inverse ratio of the square of the dis-

* Am. Chem. Jour. Vol. VII., p. 96.
† Nature, Nov. 21, 1889, p. 50.
‡ Berichte d. Deutschen Chem. Gesell. (Vol. XVIII., p. 432, and Vol. XIX., p. 932).

tance—thus practically reducing atomic weight to gravitation; and the particular error here in my judgment is, in regarding the *atonic mass* as consisting of the relative attraction of the atomic ingredients *for each other*. As Dulk interprets it we must reject his hypothesis; nevertheless, with a different interpretation, it is quite possible that his mode of calculation will prove of subsequent assistance.

The conception of Carnalley of an ingredient of negative weight must be criticised as involving conceptions highly fantastical, and not contributing to intellectual sobriety. These, and many other hypotheses might be mentioned, but they do not contribute to the development of our subject, and are only encouraging in so far as they show, and many of them do, genuine evidence of a true homology whose law of growth and variation, however, has not yet been found.

The Basis.

As already indicated, the *chemical relations* must be of prime importance in our speculations. It will probably not be gainsaid that the natural or Periodic classification of the chemical elements expresses most completely, most truly, and most concisely their relations. To be sure, there are many inconsistencies and anomalies. But when we consider our limitations, viz: that we do not have full knowledge of chemical relations; that we work usually at temperatures which are only 300 or 400° removed from "absolute zero;" that our chief solvent is a compound of hydrogen and oxygen; that we are usually governed by the ubiquitous oxygen; that we have possessed this invaluable classification as a working basis hardly a score of years—when we consider all this we may fairly conclude that, in so far as it speaks, the Periodic Law speaks truly. The fact that only *three* gaps were allowed between lithium 7 and molybdenum 96; that since the bold statement of the probable nature of ekaboron, ekaluminium, and ekasilicon, the history of chemical discovery has furnished only three new elements, viz: scandium, gallium, and germanium, whose chemistry has been proved up out of a score of rare elements for the most part prematurely announced; that these elements fitted into the gaps, not only in atomic weight but in *chemical relation;* all this clearly indicates that the Periodic Law may be followed with a large degree of safety as the *basis of comparison* of both atomic weight and *chemical relation*, including also physical relation.

I do not know that this needs to be so emphatically declared; but I wish to state it clearly, for if we accept this, in my judgment, the probability of the following views is assured.

I.—Briefly stated, the popular interpretation of the meaning of the Periodic Law is that the physical and chemical properties of the elements are functions of their atomic weights. The word *periodic* describes so concisely the recurring nature of the atomic relations that it is quite possible to overlook the fact that it *may* include more than is meant, and thus may cause us to forget the real nature of the periodicity of chemical relation; and let us notice among many interesting points, that the periodicity of chemical relation is only of one sort in that it is *direct* from the most *basiferous* to the most *acidiferous* elements, but *never retrograde.* Thus discarding hydrogen for the present, in passing from lithium 7, the most basiferous of its series, and the prototype of the alkali metals, we pass by well graduated steps through beryllium, 9; boron, 11; carbon, 12; nitrogen, 14; oxygen, 16, to fluorine, 18.3; which latter is the most intensely acidiferous element in its series. Here there is a gain of about 160 per cent. in atomic weight, and the change has been through the whole gamut of the chemical relations. Now, we would expect that the change back to an alkali metal, the chemical antipode of fluorine, would be gradual—say, by means of five or six intermediate elements. We find nothing of the sort: a feeble increment of about 25 per cent. (!) in atomic weight brings us with all the abruptness possible, to sodium 23, without a single intervening element to bridge over the chemical gap. We shall discuss more fully later the wonderful nature of this change from basiferous to acidiferous, and back again. Just now we would emphasize the fact that the *gradual* variation is *direct;* the *retrograde* is *abrupt.* This is paralelled fully in series (3) from sodium 23, to chlorine, 35.37, a gain of about 54 per cent., while in passing from chlorine 35.37 to potassium 39, we find only a paltry gain of about 10 per cent. and no intervening elements to soften the change from a halogen to an alkali metal. Similar disproportionate ratios of gain are found between the changes from any alkali metal to the halogen element of the same series and thence to the next alkali metal. The inference is direct, and incidentally it is two-fold, viz: that the different series are *independent* cycles, and that the change in chemical nature is attended, not only by an increase in weight, but by a *change* or *difference* in *make-up* or *ingredient.*

I do not desire to limit dogmatically the significance of the word ingredient; its possible meaning will be referred to later.

The *difference* in *chemical nature* between these chemical extremes, viz: an alkali metal and a halogen, must be largely due to *difference* in *nature* of *ingredient,* not simply to addition of the same ingredients.

The significance and probability of this will appear, I think, upon consideration. The probability will be emphasized by the later consideration of a variety of evidence.

It will be noticed that the extremes of chemical difference are the alkali metals on the one hand and the halogen corresponding (in the same series,) on the other. It is significant that we pass in the second series from one extreme to the other, in a compass of seven elements and similarly in the third series; but we must throw the fourth and fifth together in one long series of seventeen elements (!) to include these extremes, and similarly the sixth and seventh series in a long row of seventeen. Beyond this the gaps are too many to predict the true relation; it may take seventeen or more (!) gradations to compass the limit of chemical extreme. (See Table I, p. 294.) But we will state here in anticipation of the inferences to be drawn from the projection of the elements in series, in accordance with their absolute atomic gravities and volumes, that the cæsium series and the ekacæsium series, in which latter are included the platinum group, each probably includes about seventeen members. This remarkable attenuation of graduation, including a sub-variety of *direct* periodicity (but no retrograde) distinguishes the long series of which potassium and rubidium are the starting points, from which the short series, of which lithium and sodium are the respective starting points.

If one arranges the Periodic Law in this way, and it is by no means new, he will, of course, find difficulty in placing the members of the short series over the corresponding members of the long series; he would, of course, place lithium and sodium over potassium and rubidium, and probably magnesium over calcium and strontium; also fluorine and chlorine over bromine and iodine; and oxygen and sulphur over selenium and tellurium; and nitrogen and phosphorus probably, over arsenic and antimony. But he well may ponder over the correct location of beryllium, boron, and aluminium, carbon, and silicon. I have placed them for convenience at the right rather than at the left. (See Table I.) But the hypothetically correct place, and its significance, will be discussed later. Much harm may be done by forced

TABLE I. PERIODIC ARRANGEMENT OF THE ELEMENTS IN LONG AND SHORT SERIES.

Short Series	I	II										II	III	IV	V	VI	VII
1st											H.1.						
2d	Li.7											Be.9.1	B.10.9	C.11.97	N.14.01	O.15.96	F.18.27
3rd	Na22.99	Mg.24											Al 27.04	Si.28.1	P.30.96	S.31.98	Cl.35.37
Long Series	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**XIII**	**XIV**	**XV**	**XVI**	**XVII**
4th	K.39.03	Ca.39.91	Sc.44	Ti.48	V.51.2	Cr.52.4	Mn.54.8	Fe.55.9	Co.58.±	Ni.59.±	Cu.63.2	Zn.65.1	Ga.69.9	Ge.72.3	As.74.9	Se.78.9	Br.79.8
5th	Rb.85.2	Sr.87.3	Y.88.9	Zr.90.4	Cb.93.7	Mo.95.9	?	Ru.103.5	Rh.104.1	Pd.106.2	Ag.107.66	Cd.111.7	In.113.4	Sn.117.4	Sb.119.6	Te.125.±	I.126.5
6th	Cs.132.7	Ba.136.9	La.138	Ce.141	Di.142.	?	?	?	?	?	?	?	?	?	?	?	?
7th	?	?	Yb.172.6±	?	Ta.182	W.183.6	?	Os.191.	Ir.192.5	Pt.194.3	Au.196.7	Hg.199.8	Tl.203.7	Pb.206.4	Bi.207.3	?	?
8th	?	?	?	Th.232	?	U.239.8	?	?	?	?	?	?	?	?	?	?	?

classification. Probably, the terms of the short series can not be directly compared with the corresponding members of the long series, except in the case of the *end terms*, and possibly also, of some of the middle terms.

II.—If one proposes to himself the questions, what evidence do the elements in general give of complexity and what is the nature of the ultimate ingredient or ingredients? He will receive help by giving a reply couched in the form of another question, viz: What are the great *classes* of elements which are recognized universally? The answer is quite impressive. The new line of comparative chemistry emphasizes a very old distinction and assists us here as we ask yet another question, viz: What are the great classes of chemical compounds which are, and have been, and will always be recognized as of fundamental importance?

We are told that in the year 1744 Rouelle gave the name *base* to those bodies which react with *acids* to form *salts.** These three great classes of compounds, viz: acids, bases, and salts, defined a century and a half ago in terms of each other, are still so defined. Of these three, the classes *base* and *acid* are of especial importance; they represent among compounds the types which are most emphatically contrasted with each other. Now, how do the *elements* deport themselves with reference to these *types of compounds*, either in producing them, or in acting upon them? We will observe that, when thus compared, the elements fall into *three great natural chemical classes:* (1) Those elements which are by nature *basic;* (2) those elements which are by nature *acid;* (3) those elements which, in chemical relation, are midway between these extremes and, being to a large degree of themselves neutral or indifferent, are rendered acid or basic by the influence of some elements of either of the first two classes; notably however, by the *acid* elements. The fact that this third class is played upon and

* See Morley & Muir's edit. of Watts' Dic. of Chem. 1888, Vol. I., art. BASE.

varied in *chemical* nature chiefly by the acid elements is directly in line with the observation made above, that the gradual variation in a series is *direct only*, i. e., from alkali metal to halogen non-metal. These two observations: (1) the *direct* variation in chemical nature towards the halogen, and (2) that this acidiferous property of the third class is produced mainly by the *influence* of the halogen-like elements; these facts, coupled with observations to be made later, on the peculiar variation in atomic volume, with steady increase in atomic weight, indicate that the *variation is of the nature of addition or substitution*, a variation produced by *successive increments* or substitutions of the *same ingredient*. But this will be further discussed.

Let us notice some of the characteristics of the compounds included in these venerable titles, *bases* and *acids*. And here again I must apologize for venturing to repeat well-known truths which, in my judgment, are often obscured and that too, even by prominent teachers of chemistry. When Lavoisier named oxygen from ὀξύς sharp or acid, and γεννάω I produce, i. e., *acid maker*; he emphasized a peculiarity which has often been overlooked.

The subsequent history of the chemical discovery of hydrofluoric, hydrochloric, hydrobromic, hydriodic, hydrocyanic acids, and the acids, hydrogen sulphide, and hydrogen selenide, seemed to render the name *oxygen* almost a misnomer. It will probably not require a long disquisition to correct the incorrect statement frequently appearing from sources that should be trustworthy, that *hydrogen* is the acid maker (!). Hydrogen is certainly the figure-head of acids, but the figure-head is not the ship. Hydrogen is not the *principle* of acids. But we are dealing with the idea involved in the word *oxygen*. We have no desire to attach to Lavoisier's word any significance which he did not intend to give to it. But notice the parallel and almost identical idea which modern chemistry has developed in the word *oxidation* and its opposite *reduction*. From the first meaning of simply adding oxygen, the term oxidation passed on to include taking away the opposite, as hydrogen, as in the oxidation of alcohol to aldehyde, then to the addition of any element which resembles oxygen in chemical nature; as the oxidation of stannous to stannic chloride; then to the taking away of any element resembling hydrogen or opposed to oxygen or oxygen-like elements.

We notice that some writers object to this extended use of the term oxidation; but notice that otherwise we must have a particular verb and verbal noun to name the particular action of each oxidizer, and similarly in the case of reducers.

Now these terms oxidation and reduction in their fullest meanings are a part of the natural growth of modern chemistry; they emphasize and contrast the idea of acid and base. An acid, after all, is still essentially a compound of *oxygen*, or some *oxygen-like* element. The compounds CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_3, NO_2, though not acid yet illustrate the gradual replacement of basic hydrogen, by acid chlorine, and each can be transformed by the KOH reaction into the corresponding oxidized products, CH_3 (OH), CH_2O $(=CH_2.(OH)_2)$, CH.O.OH $(=CH\ (OH)_3)$, and CO_2, $(=C\ (OH)_4)$, or by the potassium alcoholates into *their etherial salts.*

The acid nature of $CH.(NO_2)_3$, $CH.Cl.(NO_2)_2$, $CH.Br.(NO_2)_2$; the increase in acid properties of $CH_2Cl.CO_2H$, $CHCl_2.CO_2H$, and CCl_3, CO_2H, as also of C_6H_4, $OH.NO_2$, C_6H_3, $OH.(NO_2)_2$, $C_6H_2.OH.(NO_2)_3$, lead on to this idea; as also the acid nature of uric acid, succinimide, phthalimide, isatin and the like. Indeed, so strangely do the acid properties of organic compounds develop that we learn to think of almost any *strong* oxygen-like element as contributing the chemical character requisite for an acid; and a sour taste, the displacement of hydrogen by a metal as such, the action on litmus or any similar dye-stuff, or even the effervescence with carbonates; each one finally gives way to the final test of acidity, viz: solubility in alkaline solutions.

As regards bases, I would also venture a word. Sodium, sodium oxide, sodium hydroxide and sodium carbonate, each reacts with acids to produce salts, and in each, sodium replaces the hydrogen of the acid concerned. Each contributes to the basic idea, though the quality is probably rightly regarded as reaching its maximum in the hydroxide. Now we observe that F, Cl, Br, I, O, S, Te, and N, may, and almost invariably do, exert an acidiferous action on their compounds. The halogens in their typical compounds, oxygen in all aërial and aqueous chemistry, sulphur and selenium in the sulpho- and selenio-salts, and nitrogen in the cyanogen compounds (and in the recently discovered hydrazoic acid HN_3) each and all show their nature These include the chief elementary oxidizers and acid makers; for economy of designation I call them the *oxygenoids*.

The elements Li, Na, Mg, K, Rb, Cs, Ca, Sr, and Ba, are almost invariably basic in their nature, and would be strong reducers in the elementary state. I call these elements the *kaligenoids*, the words alkaloid and alkaloidal being unfortunately appropriated for another use. We would again observe, in comparing acids and bases, that we are almost completely under the control of the chemistry of oxygen and particularly of water which serves as the almost universal bank of exchange or clearing house of oxidation and reduction.

Intermediate between these extremes, viz: the *kaligenoids* or *basiferous*, and the *oxygenoids* or the *acidiferous*, we find as a third class the great body of chemical elements. In the free state their physical properties are largely metallic and their chemical properties are usually those of reducers. They are also frequently basic enough to replace the hydrogen of acids; in this case they act as reducers. They may form low oxides which are basic enough to form salts with strong acids, but these salts are frequently acid in reaction—showing their *weak, basic* properties. Their lower oxides and hydroxides are not alkaline, but may be weakly acid. Their higher oxides are usually anhydrides of acids, and they can be oxidized at least, in alkaline solutions to acids.

Typical elements of this class are chromium, iron, molybdenum, manganese, carbon, sulphur and phosphorus. But here in particular no sharp line can be drawn, and only the class characteristics of forming nuclei for low or high oxides can be emphasized. They tend also to form double cyanides, chlorides, etc., in which the element forms the nucleus of the related acid, as H_3FeCu_6, H_3AlCl_6, etc. These elements of this intermediate class are conveniently designated as *nuclealoids*. Now, if we contemplate the chemical relations of these three great classes of elements, it will be noticed that though we can not draw a sharp, dividing line between them, and that although one and the same element may exhibit the properties of two or even three classes, yet the classes themselves, illustrate in their extremes, the great class tendencies of the elements. Thus carbon and nitrogen in their most reduced compounds, are basic, in their oxidized forms they are acid, and they are themselves slightly acidiferous. Yet this versatility does not obscure the tendency of the elements to develop the three grand properties of reducers, or base makers, oxidizers or acid makers, and passive nuclear foundations for acid or basic elements to play upon and stimulate to one extreme or the other, but notably towards the acid.

Now we observe types of these three great classes of elements in each series—both the short and the long. We observe that the gradation is direct, from the most basic to the inert and passive nuclealoidal, and thence to the acid elements. How shall we explain the regularity of variation and of chemical property? But one general hypothesis is suggested, viz: that *each of the typical classes* is mainly composed of a *typical sub-element* which imparts the *typical characteristics* to its containers. It would appear at first glance that each of these three classes is equally independent and fundamental, and that, therefore, we must have at least three sub-elements; but as subsequent discussion and calculation will show that the intermediate, nuclealoidal class is not a fundamental class, but a *mixed class*, characterized by varying combination of the characteristics of the kaligenoids and oxygenoids, therefore, only *two fundamental classes* need be recognized, viz: the *kaligenoids* and the *oxygenoids*, and hence only *two fundamental* sorts of ingredients, or sub-elements in each series. That the similar members of the different series are homologous with each other is well known, and preliminary calculation indicates that the homology between the respective sub-elements of the different series is equally simple. Therefore, we assume for the present, but two classes and but two sub-elements. Thus contained in large proportion in *all the stronger oxidizers* there is a typical sub-element or ingredient whose essential nature is illustrated in *oxidation* and *acidification*. Reiterating the old idea of Lavoisier, I would call this hypothetical ingredient *oxidium* (*ox*ygen + *id* generic + *ium*). Similarly entering into and characterizing the typical basiferous or kaligenoid elements, must be recognized a hypothetical sub-element, viz: *kalidium* (from *kal*ium, Arabic *alkali*, the *ash* + *id.* generic + *ium*). After my strictures on the useless multiplication of terms for special oxidation and reduction, it may not seem in good taste to coin new words in so cheap a mint, but here the necessity of the case demands economy of designation, and as I shall be obliged to refer repeatedly to these ideas I would suggest as abbreviations Oxidium = Od.; Kalidium = Kd.

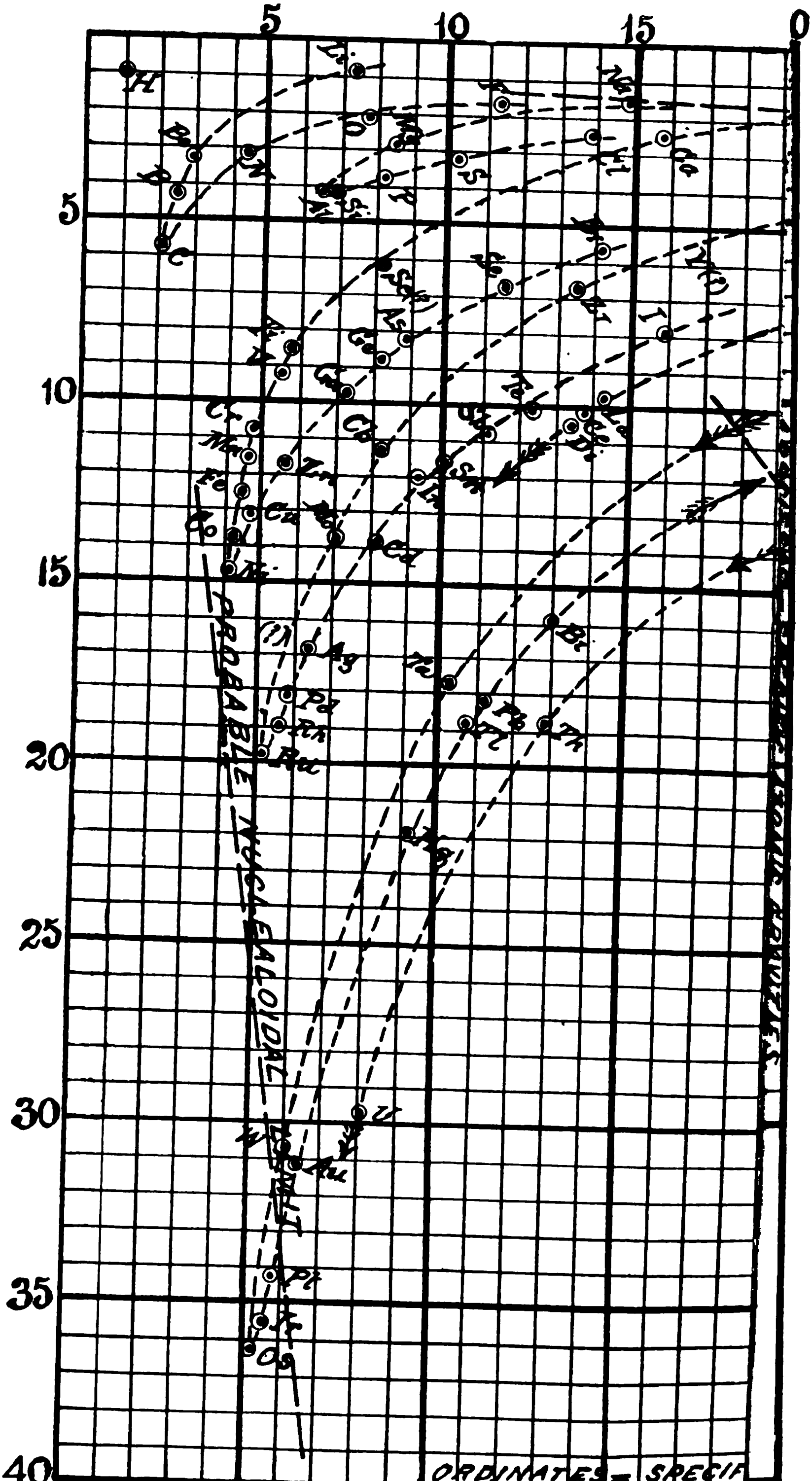
It will be pertinent at this point to indicate all that may be safely ventured at present as to the nature of these hypothetical sub-elements, whether they are condensations of the ether or of some similar substance; whether they are distinct modes of condensation of some lighter substance, say "protyle;" whether their structure is homogeneous like a jelly, or heterogeneous and of discrete particles, as "atomicules." As to these, or any similar questions, I have nothing to say at present. I regard the inference of these sub-elements as a legitimate sequence of the comparative study of the periodic arrangement of the atomic weights, and I do not care to involve, what I have considered in all seriousness, in any rash speculation, which can not be reduced to sober argumentation.

I realize the hazard involved in putting forth an hypothesis of this nature, but I have found it so valuable in emphasizing the distinctive properties of the great classes of elements, and that as a working hypothesis, not only in my own study, but also in teaching the elements of comparative chemistry, that I can not believe this idea to be wholly valueless. If there is anything of intrinsic worth in the hypothesis it can not be developed at once, and in the incomplete state of general inorganic and comparative chemistry. But I will offer what evidence is formed to support the view, and what interpretation I can to explain the probable modes of combination by which kalidium and oxidium have produced our chemical elements.

III.—The very remarkable projection, by Prof. Lothar Meyer, of the curves of the elements in terms of the atomic weights, and of the atomic volumes, is well known. Its remarkable continuity; its illustration of the accompanying variation in many physical properties; its comparison with the curves for melting points—these, and other points considered, render it one of the most valuable commentaries ever made on the nature of the chemical elements. But its very completeness obscures many important details. We need to dissect it to read its significance in certain respects. By a necessity of the method employed, natural similarity and dissimilarity in grouping are not observed. For instance, the sharp break between the halogen, the last of one series, and the alkali metal, the first of another independent series, is not clearly seen in its true light.

If we adopt any simple system of coördinates, and assume any figures co-related to those of atomic weights and atomic volumes, we will obtain regular curves, or branches of curves. If we assume, as units for Y and X, the atomic volumes (compared with that of hydrogen as unity), and the specific atomic gravities (obtained by dividing the atomic weights, by the respective specific volume), we obtain branches of curves, which emphasize the hypothesis of the sub-elements most *distinctly*. (See Projection.) Notice that the extremes, the basiferous and acidiferous elements are marked by high volume and low specific gravity, and the heavy, inert, nuclear elements of each series are at the end of each branch of the bifurcating curve, and have low volumes and high specific gravity. The figures for the calculation of the first curve are not complete, but the evidence is that carbon is the culmination of the nuclealoidal properties of that series.

The curves are not all regular. I append herewith a complete list of the figures employed for each element. (See Table II.) The chief difference of this projection from that of Lothar Meyer is that his curve regards the increase in atomic weight as one continuous process which ignores the vast difference between halogen and alkali elements. To be sure, these are contiguous in simple atomic weight considerations, but this is a matter which I hope to explain later.



PROC. C.S.S. VOL. III. PLATE. I.

TABLE II.

FIGURES USED IN PLOTTING THE PROJECTION.

	Symbols of Elements.	Atomic Weights.	Specific Gravities in Solid Form.	Atomic Volume. At. Wt. / Sp. G.	Absolute At. Vol. or At. Vol. Reduced to Units of H. by Dividing by 1.61.	Abs. At. Gr. Obtained by Dividing Each At. Wt. by its respective Abs. At. Vol.
1st Series....	H.	1.00	0.62(a)	1.61	1.00	1.00
2nd Series....	Li.	7.01	0.59	11.9	7.39	0.9485
	Be.	9.08	2.	4.51	2.8	3.24
	B.	10.9	2.68	4.06	2.52	4.32
	C.	11.97	3.52	3.4	2.11	5.67
	N.	14.01	1.4(b)	10.	6. } 4.5	3.1
		—	—	—	3.(c)	
	O.	15.96	1.3(d)	12.277	7.62	2.09
	F.	18.3	1.(e)	18.3	11.36	1.61
3rd Series....	Na.	23.	.97	23.7	14.72	1.562
	Mg.	23.94	1.75	13.68	8.497	2.81
	Al.	27.04	2.58	10.48	6.509	4.15
	Si.	28.	2.5	11.2	6.956	4.02
	P.	30.96	2.34(f)	13.23	8.21	3.77
	S.	31.98	1.96	16.31	10.13	3.157
	Cl.	35.37	1.60(g)	22.1	13.72	2.578
4th Series....	K.	39.03	.88	44.352	27.546	1.41
	Ca.	39.91	1.58	25.3	15.71	2.54
	Sc.	44.	?	?	?	?
	Ti.	48.	5.3±(h)	9.05	5.62	8.54
	V.	51.2	5.7	8.98	5.577	9.17
	Cr.	52.4	6.7	7.7	4.78	10.96
	Mn.	54.8	7.2	7.61	4.72	11.61
	Fe.	55.9	7.8	7.16	4.447	12.56
	Co.	58.±(i)	8.6	6.74	4.18	13.87
	Ni.	59.±(i)	9.1	6.48	4.02	14.67
	Cu.	63.2	8.18	7.72	4.795	13.166
	Zn.	65.1	7.2	9.04	5.61	11.60
	Ga.	69.9	5.96	11.728	7.28	9.60
	Ge.	72.3	5.5	13.1	8.136	8.88
	As.	74.9	5.2	14.40	8.94	8.37
	Se.	78.9	4.2	18.78	11.66	6.76
	Br.	79.8	3.5(j)	22.8	14.16	5.63

TABLE II. (*continued*).

	Symbol.	At. Wt.	Sp. G. as Solid.	At. Vol.	Abs. At. Vol.	Abs. At. Gr.
5th Series....	Rb.	85.2	1.52	56.1	34.84	2.45
	Sr.	87.3	2.5	34.9	21.67	4.03
	Y.	88.9	?	?	?	?
	Zr.	90.4	4.15	21.7	13.48	6.706
	Cb.	93.7	7.	13.4	8.32	11.26
	Mo.	95.9	8.5	11.28	7.	13.7
	?	99.±	?	?	?	?
	Ru.	103.5	12.1	8.55	5.28	19.60
	Rh.	104.1	11.8	8.82	5.48	18.996
	Pd.	106.2	11.3	9.4	5.838	18.18
	Ag.	107.66	10.5	10.3	6.39	16.82
	Cd.	111.7	8.6	12.988	8.06	13.86
	In.	113.4	7.5	15.2	9.44	12.01
	Sn.	117.4	7.3	16.1	10.	11.74
	Sb.	119.6	6.7	17.85	11.08	10.79
	Te.	125.±	6.25	20.	12.42	10.06
	I.	126.5	4.94	25.60	15.90	7.96
6th Series....	Cs.	132.7	1.88	90.6	56.27	2.36
	Ba.	136.9	3.75	36.5	22.67	6.04
	La.	138.	6. ±	23.	14.28	9.66
	Ce.	141.	6.3±	22.38	13.90	10.14
	Di.	142.	6.5±	21.84	13.56	10.47
7th Series....	Yb.	173.	?	?	?	?
	Ta.	182.	11. ±	16.5	10.24	17.77
	W.	183.6	18.5	9.7	6.02	30.49
	Os.	191.	22.5±	8.488	5.27	36.24
	Ir.	192.5	22. ±	8.75	5.43	35.45
	Pt.	194.3	21.2	9.16	5.689	34.14
	Au.	196.7.	19.3	10.19	6.329	31.07
	Hg.	199.8	13.6	14.7	9.13	21.88
	Tl.	203.7	11.8	17.3	10.74	18.97
	Pb.	206.4	11.4	18.1	11.24	18.36
	Bi.	207.3	9.9	20.939	13.	15.94
8th Series....	Th.	232.	11.23	20.659	12.83	18.08
	Ur.	239.8	18.7	12.9	8.01	29.93

NOTES.

Although the above figures may explain themselves, yet a word or two will be in order. The first four columns, except in particular cases, need no explanation. The figures in the fifth column are obtained by dividing the figures of the fourth column by 1.61, the atomic volume of solid H. The figures in the sixth column are obtained by dividing each atomic weight (second column) by its respective, absolute atomic weight (second column). The special points are

(a.) The figures .62 represent the specific gravity calculated from solid "hydrogenium" in the palladium alloy; it is quite remarkable that a calculation on this basis makes the Abs. At. Vol. of carbon (2.11) almost exactly twice that of H. (1.0) which ratio is approximately the same as that found for volumes of carbon (11.) and hydrogen (5.5), in organic compounds.

(b.) The figures 1.4 are assumed on the supposition that the density of solid nitrogen would be greater than that of liquid nitrogen (liq. N.—.885, Olzeswsky).

(c.) The figure 3, in the fifth column of N, is obtained thus: the molecular volume of CN in organic compounds equals 28.: subtracting 11 the atomic volume of C. leaves 17. an approximate atomic volume of N. in organic compounds; dividing 17 by 5.5 (the atomic volume of H. in organic compounds) gives us approximately 3; the mean of 6 and 3 gives us 4.5 for the fifth column of N.

(d). The value 1.3 is assumed similarly as in (b.) from the specific gravity of liquid O (—1.124 Olzeswsky).

(e.) The value 1. is assumed by comparison with the assumed values of O in (d.), and Cl. in (g). In this connection the atomic weight of Fl. 18.3 is from Moissan's earlier work, his recent figures of 19.± were not then available.

(f.) 2.34—The density of the red crystals.

(g.) 1.6 are figures assumed by comparison of corresponding figures for F. and Br.; also Faraday gave the figures 1.33 for liquid Cl.

(h.) The figures 5.3, the Sp. G. of Ti. are from p. 106 of Frankland's "Lecture Notes for Chemical Students," the only authority I found for each figures. F. W. Clarke's Tables make no mention of any determinations of the Sp. G. of this element.

(i.) The values of 58. and 59. were assumed respectively for Co. and Ni. in view of the present uncertainty respecting the purity of those elements and their exact At. Wts. Co. is evidently in chemical relation nearer to Fe, and Ni to Cu, than the reverse.

(j.) The value of 3.5 for solid Br. is assumed from 3.2 the Sp. G. of liq. Br.

Any other uncertainties or approximations in figures are indicated by the conventional (±). It is believed, that in all the assumptions mentioned above, the values are approximately correct, and that the variations from the true figures will not alter the projection curves materially, or affect the value of the argument.

It would require more space than I care to appropriate at this stage of the discussion to refer to all of the results of this projection. But I would emphasize a few:

(I.) The significance of this projection is that it gives the specific volume and the specific gravity relations of the elements of *each series* in a curve by itself. Each series consists of an open, two-branched, parabola-like curve, the two branches meeting in a sharp angle in the nuclealoidal maximum.

(II.) Each *short series* makes a complete curve by itself, which curve is of the same general form as those of the long series.

(III.) The termini of the branches vary, as do the chemical natures of the respective elements; thus, as regards their absolute specific volume, while fluorine is above lithium, and chlorine only a little below sodium, yet bromine and iodine are far below their respective antitheses potassium and rubidium.

(IV.) The alkali termini seem to form a straight line limit, shooting up toward high specific volume and low specific gravity; the halogen termini seem to form a straight line limit running off at an angle of about forty-five degrees (45°); with the exception of the third series, the nuclealoidal maxima seem to form an approximate straight line limit, running off toward low specific volume and high specific gravity. The second series, as plotted, is manifestly approximately correct, for carbon is emphatically the nuclealoidal element of that series, and it falls at that maximum.

The third series is anomalous, possibly from incorrect data. Silicon, in anticipation, would seem to be the maximum of nuclealoidal quality, yet it is lower in specific gravity than aluminium. This is possibly connected with the variation noted in (III.) viz: that while the alkali termini shoot higher and higher in the direction of strong, basic, chemical nature and light specific gravity, the halogen termini grow less acidiferous chemically, more strongly nuclealoidal and decidedly heavier in specific atomic gravity. These variations affect proportionately the chemical nature of each element of their respective series so that in ascending order in each series there is a chemical displacement toward the alkaline property.

In this projection it is possible that a continuation of the ascending halogen end of the retreating branch of each curve may intersect the next alkali element, which is the initial point of its curve, but this is not probable. This will be submitted to later calculation and discussion.

Much, indeed, if not all of the material of this preliminary paper is simply a reiteration of old and well-known fact and theory, but is indispensable in outlining the path to be pursued.

Department of Chemistry,
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Mar. 26, 1890.

NOTES ON THE GEOLOGY OF PERRY PARK, COLORADO.

BY PROF. GEORGE L. CANNON, JR.

Perry Park is one of the many districts in Colorado that possess features of considerable geological interest, yet owing to their remoteness from railways and wagon roads, and to the absence of important mineral resources, have received comparatively little attention from systematic observers.

This region was visited by A. C. Peale and others, of the Hayden Survey, and some of the more prominent features of the geology were noted in the reports of that exploration for 1873, 1874, and 1876. The most important of these notices are Dr. Peale's section of the Park, pages 197 and 198 of the report for 1873, and Holmes' panoramic view of the same, published in the report for 1874. In these reports, the Park is designated by the name of Pleasant Park, but this has now been replaced by that of Perry Park, the latter name being in honor of a prominent St. Louis capitalist, Mr. John D. Perry, the former owner of the large tract of land now in the hands of the Perry Park Land Co.

This company has spent large sums in rendering the beauties of the place accessible to visitors, and has opened a summer resort that is reached by a stage line from Larkspur, on the D. & R. G. R. R. A number of Denver's prominent citizens are erecting summer residences along the shores of Lake Waconda, a large artificial pond recently constructed. To the lover of picturesque, as well as to the geologist, the locality presents attractions of more than ordinary interest, and in common with Manitou and Palmer Lake seems as if especially designed by the Creator as a summer home for the citizens of the heated cities of the plains.

The term Perry Park, as a geographical designation, should be used to include all of the belt of uplifted sedimentary formations inclosed in the crescentic curve of the margin of the foothills west of Dawson's Butte.

During a few days recently spent in this locality, the writer noted some features in the geology of the district that do not seem to have been described, and a description of the same may have a temporary value as a contribution to our present knowledge of the sedimentary formations abutting against the front of the Colorado Range.

Archæan Rocks.

The red biotitic granite, that forms the edge of the foothills, from Manitou to the Platte River, is found forming only the lower portion of the mountains, and becomes a less conspicuous feature in passing northward, and the feldspars of the upper portions of the mountain are of lighter colors.

Indications of hematite are quite common, and in the mountains, a few miles north of the hotel, prospecting has been done on some silver claims that are said to have yielded assays as high as $160 per ton. Smoky quartz crystals, some of remarkable size, have been secured in the neighborhood. Microcline (Amazon stone) does not seem to be as abundant as it is to the southward.

Paleozoic Formations.

This locality is notable for affording the only exposures of Paleozoic measures that are known to exist between those near the Garden of the Gods and those near the Wyoming State line. The writer was unable to make a detailed examination of these beds, but would call attention to a few features noticed at the beautiful section at the mouth of the Muaga Canon. The pink and white hues of the Paleozoic rocks, the vermillion of the Triassic ledges, and the orange and white colors of Nanichant

Cliff make a color display not frequently noticed. The 114 feet of cherty blue and white limestone, mentioned by Dr. Endlich as occurring at Pleasant Park, was not so prominent at this point as to have attracted the attention of either Dr. Holmes or the writer. About midway in the formations of this age occur numerous chert concretions that are interesting, both for their beauty of coloring and possible economic value for ornamental purposes, but also for the remains of brachiopod shells, found on weathered surfaces of the nodules, the shells in the interior of the rock being less easily observable. Dr. Peale mentions the occurrence of *Spiriferina* and *Terebratula* in this vicinity. The writer's observation would indicate that these are the most common of the few species here represented, the former being the most abundant. In the cherts that have been brought down to Denver, and are so common in the river-drift and glacio-natant drift in that vicinity, the writer has found specimens of crinoids and corals and the tubes of tubicoloid annelids resembling *Spirorbis*. But few of the radiate and molluscan casts are sufficiently well preserved to permit of specific identification, and it is questionable, even if they were identified, whether they would present sufficient evidence to warrant the reference of the beds to a definite horizon, until a more complete study shall have been made of the lithological character of the formation.

Two poorly preserved impressions of possible vegetable forms, one perhaps a stigmaria, were noticed.

The writers of the Hayden Survey regarded these beds as of Sub-carboniferous or lower Carboniferous age, with possible traces of Silurian beds near the contact with the Archæan granite.

Triassic Formations.

The 'Red Beds,' have an estimated thickness of 1,500 feet, and are separated from the Carboniferous beds by a shallow valley, from a quarter to half a mile wide. The texture of the rock is generally fine, and in the absence of that excess of cross-bedded structure found in other localities, the beds would appear to have been formed in comparatively quiet waters, some distance from a shore-line. The Vermilion (Unkartum) Cliffs, south of the Echo House, will afford quarries of a beautiful, light red sandstone, similar to that from the Manitou quarries, used so extensively in Denver. About half a mile north of this hotel the dip of the beds suddenly rises from an inclination of about 25° to verticality and for a short distance an overthrow of some 10° is noticeable, but at the Naguntuwep Rocks, half a mile beyond, the normal inclination of the beds is regained. The removal of the softer portions of the vertical beds has given origin to numbers of isolated monuments and castellated forms of marked beauty. Were the Cathedral spires and the Gateway of the Garden of the Gods to be removed, that world-renowned locality would suffer by comparison with this weird wildness of monuments.

A valley, averaging a quarter of a mile wide, separates the Red Rock cliffs from those of the Dakota sandstone. The formations that generally rise above the level of this valley, in isolated ridges, are but poorly represented here and the only bed that stands out above the grass-grown slopes of the depression is the gypsum ridge, with its protecting cap of limestone.

The greater portion of this ridge, twenty feet or more, is composed of a valuable deposit of gypsum of pure white, or delicate pink color, that is excellently well-adapted for the manufacture of plaster of paris or for some architectural purposes. Good specimens of satin-spar are obtainable in seams of the gypsum. The limestone forming the cap-rock of this minor hogback, a layer three or four feet thick, possesses a curious structure, resembling indurated thinolite. Some fragments of the tubular bodies show faint traces of a radiate structure, and it is possible that the rock is a mass of very poorly preserved fragments of coral. The fossil shells, said to occur in this limestone, could not be found. Between the gypsum and the lime is a thin bed of calcareous material, fitted with reddish fragments of siliceous material, that show traces of coraline structure.

The red earth on the edge of the lake indicates the presence of the reddish shales usually found at this point in the typical section, but the valley and the west slopes of the Jura-Dakota Hogback is well grassed over or strewn with debris from the crests of the Hogback, so that neither the upper Trias or the Jurassic beds can be readily observed.

Cretaceous Formations.

The Jura-Dakota Hogback does not attain a prominence exceeding that of the red rocks, and the protecting strata of sandstone, instead of forming one main crest are divided into several minor ridges, one of which is the 'Walls of Jericho,' seen from the hotel, in the water-gap between cliffs, at the rear of the house. Excellent stone, resembling that of the Fort Collins stone, can be secured from these ledges.

A feature of some possible economic value is the occurrence of layers of beautiful purple, yellow and other shades of colored quartzite. It is probable that this is one of the unknown sources from which the quartzite used by the Indians of the plains was obtained, the extensive use of this stone being proved by the large amount of chipped fragments found on the ridge south of the lake.

Exposures of the Benton and Niobrara beds are not conspicuous. The shales of the former group give indications of petroleum. The Niobrara limestone thickens in passing northward, and contains numerous poorly preserved fragments of *Ostreæ* and *Inocerami*. The *Inoceramus* *problematicus* and *I. deformis*, usually so common in these beds, were not observed. A thin layer contains numerous shark's teeth of several Selachian and Cestraciont genera, *Lamna*, *Galeocerdo*, *Oxmrhina* (?) and *Ptychodus*, represented by perhaps more than one species in some of the genera of these characteristic Colorado group fossils.

Laramie and Post-Cretaceous Beds. A considerable belt of Montana shales is crossed before the Laramie and Arapahoe strata, forming the base of Dawson's Butte, are reached. The writer's observations, made in a rapid reconnoissance about the mountain, would seem to indicate that the Monument Creek beds have, in that vicinity, a greater extent than is indicated on the map of the Colorado atlas, and are probably continuous with the Raspberry Butte mass and with that to the west of Castle Rock, and thereby hindering the examination of the coal-bearing horizon.

The Overlapping of Beds.

The foregoing observations apply principally to the sections made along the banks of Wahlumpa Creek (Bear Creek, Hayden). In passing northward towards Jackson Creek marked changes in the stratigraphy occur ; formation after formation disappearing by the overlap of formations, until the Montana beds rest directly on the granite. The Paleozoic beds, the Jura-Dakota Hogback and the 'Red Beds,' disappear before reaching the northern end of the Park in about the order named, leaving the gypsum ridge and the Niobrara limestone for a short distance in isolated companionship. On the divide, between Jackson and Jug Creeks, the Niobrara at last vanishes, and the Montana shales appear to cover all earlier deposits. The representation of Monument Creek beds, or of a wide belt of Triassic exposures abutting against the granite in this vicinity, noticeable on some maps, are erroneous. Great difficulty attends the observation of the contact of the sedimentary and the Archæan formations, owing to the large amount of fine debris spread over the country on the western side of West Plum Creek. So thick did the debris become on the terraces between Jug and Indian Creeks as to prevent the deciphering of the stratigraphy without the devotion of more time than was at the writer's disposal.

The "Red Beds" reappear shortly after reaching the north of Jug Creek, but the flat slopes of the terraces for some distance render it improbable that the formations regain anything like their normal development before the region of the headwaters of Willow and Indian Creeks is reached.

Lœssial Formations.

Typical lœss occurs in this region at elevations considerably above the highest known deposits of the lœss on the hills west of Denver, perhaps above 6,000 feet. The lœss probably blends with granitic debris above mentioned, and the coarse drift (upland drift) at Palmer Lake, probably has some connection with the phenomena of the upper level of the lœssial sea, which it now seems, probably covered a large portion, if not all of the divide region.

Glacio-natant Drift.

Some possible glacio-natant deposits were noticed, but but were not investigated.

This reconnoissance has been of great value to the writer's study of the Quaternary of the Denver Basin in demonstrating the suspected fact that a large portion of the ice-drift, found on the hill south of the Platte River, near Denver, was derived from the valley of West Plum Creek. Among the stones derived from this locality may be mentioned quartzites of every shade (except the black, vitreous variety, whose source has yet to be ascertained,) red and cream-colored siliceous rock, cherts, jasper, hornstone, agate, chalcedony and iron-stone. Similar material in the river-drift of .both the ancient and modern beds of the Platte River has had a like origin. The jasperized and agatized woods, the rhyolite and the Monument Creek sandstone, found in the three deposits just mentioned, have been derived from the eastern branch of Plum Creek. An interesting discovery in the drift from that source was a fragment of silicified wood showing the endogenous structure of palm tree.

The writer contemplates the commencement of a systematic study of the Arkansas-Platte divide region, believing that a patient investigation of that obscure and somewhat uninteresting district may yield results of as great importance as have been developed in the study of equally obscure and supposed exhausted fields about Denver; nor is it improbable that this study may attain practical results; the few days spent in this reconnoissance showing that deposits of considerable future value exist in this neighborhood, the importance of which is but little known or appreciated.

Reports of the progress of the work will be presented to the Society from time to time, and published in the annual Proceedings of the Society.

A BOULDER COUNTY MINE.

BY JOHN B. FARISH.

At one of our meetings, held some time ago, Professor Van Diest suggested that if members would report observed facts in regard to mines which they examine, such facts might, in the hands of Professor Emmons, and other eminent geologists, be turned to practical account. In accordance with that suggestion, I wish to present for your consideration, some interesting occurrences, recently observed during an examination of the Golden Age Mine, in Boulder County.

Leaving the little village of Jamestown—or, as it is more generally known, "Jimtown"—located in the cañon of James Creek, the road winds up a steep mountain composed of coarse gray granite, with occasional belts of gneiss, common to all the mineral-bearing sections of Boulder County, to the summit of the Front Range. Here are located the Golden Age and Sentinel mines, the relative locations of which are shown in Fig. 1.

The Golden Age location covers the outcrop of a quartz-porphyry dike, which cuts through the granite country rock with a strike of about N. 70° E. This dyke varies in width from a few feet, as at a point between the Main Shaft and the Hill Shaft, to about fifty, and dips to the southward at an angle of about 45°, as shown in Fig. 2. The outcrop of the main ore-chute thus far explored on the Golden Age vein, is marked by a line of surface works extending along the contact on the lower side of the porphyry dike, from the Line shaft on the east to the main shaft on the west. At a depth of about 100 feet the Main shaft discloses a split in the vein. The upper or hanging wall streak, called the hanging-wall vein, continues into

Fig. 1.

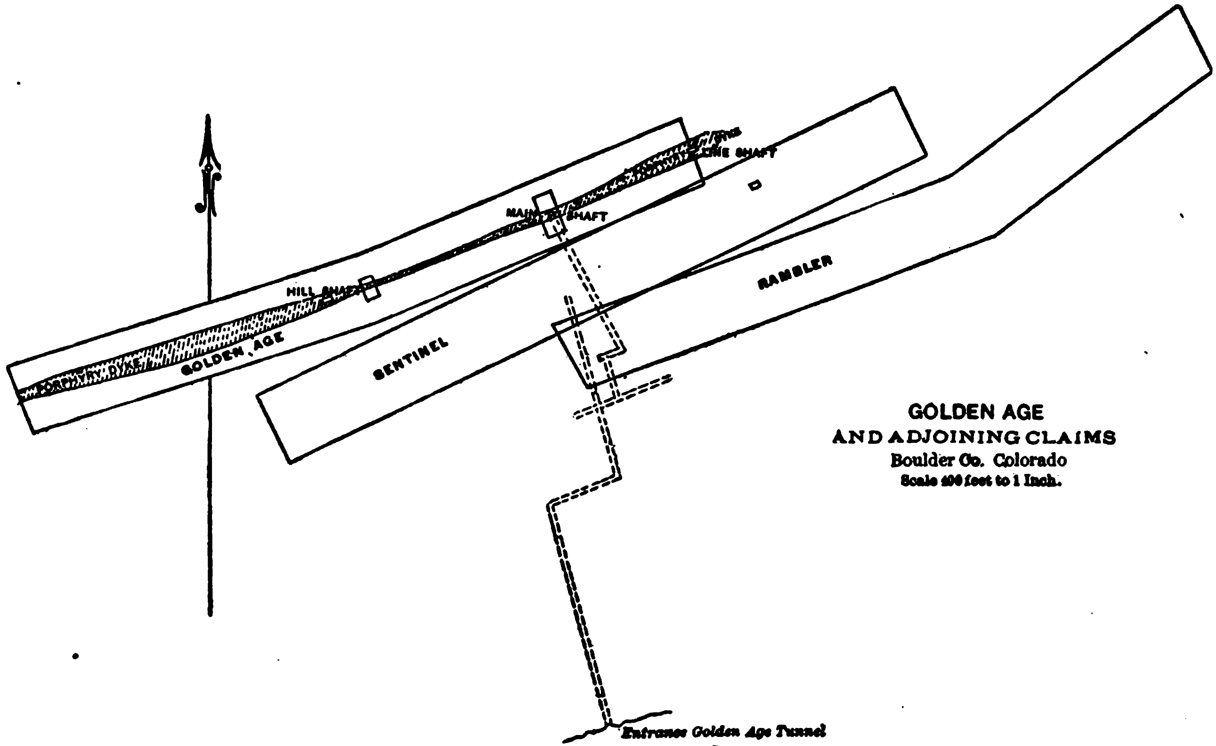
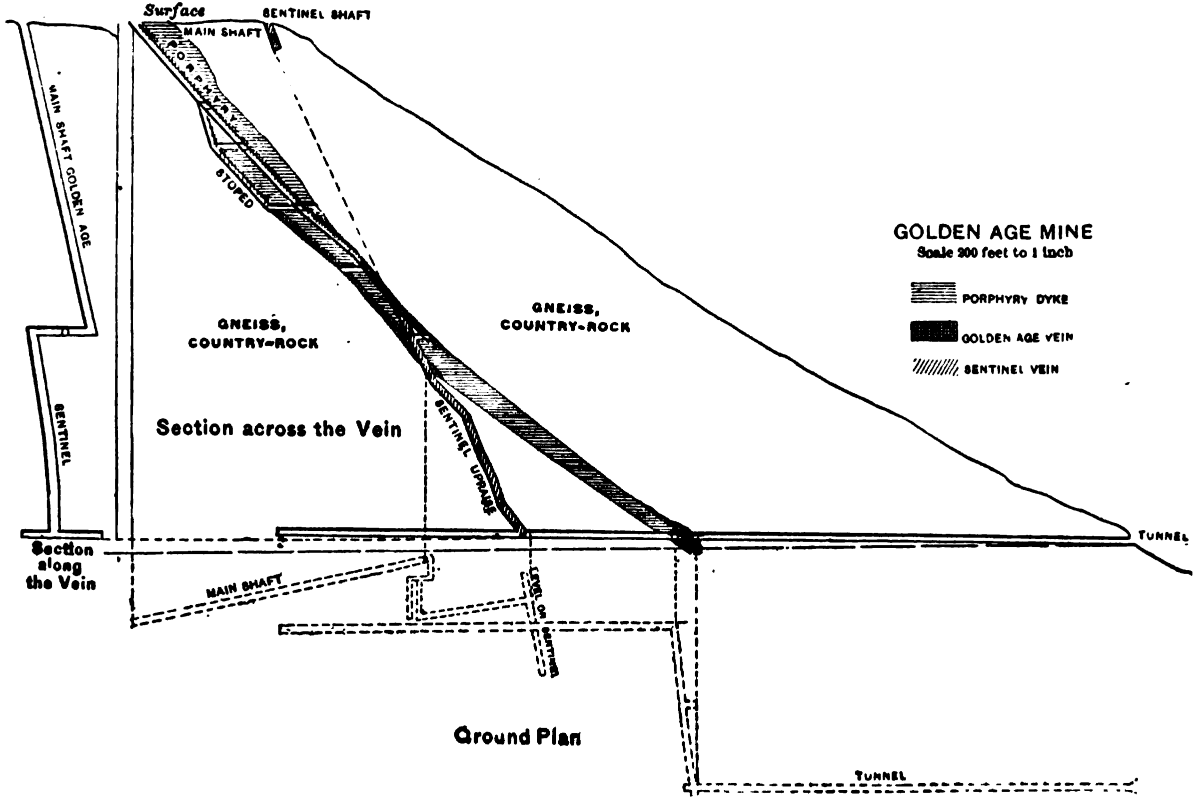

GOLDEN AGE
AND ADJOINING CLAIMS
Boulder Co. Colorado
Scale 400 feet to 1 Inch.
GOLDEN AGE
PORPHYRY DYKE
HILL SHAFT
MAIN SHAFT
SENTINEL
RAMBLER
Entrance Golden Age Tunnel

FIG. 2.


GOLDEN AGE MINE
Scale 200 feet to 1 inch
PORPHYRY DYKE
GOLDEN AGE VEIN
SENTINEL VEIN
Surface
MAIN SHAFT
SENTINEL SHAFT
PORPHYRY
STOPED
GNEISS, COUNTRY-ROCK
GNEISS, COUNTRY-ROCK
Section across the Vein
SENTINEL UPRAISE
TUNNEL
MAIN SHAFT GOLDEN AGE
SENTINEL
Section along the Vein
MAIN SHAFT
LEVEL ON SENTINEL
Ground Plan
TUNNEL

the dike on approximately the same dip, but with porphyry hanging- and foot-walls, until a depth of 330 feet is reached, where it enters the upper contact between the porphyry and granite, and remains in it to the bottom of the Main shaft, 470 feet on the incline below the apex. The Adit tunnel cuts the porphyry dike about 250 feet below the bottom of the shaft, and shows this streak in the same contact.

Below the split the lower, or foot-wall streak, called the foot-wall vein, stands a little straighter, and at the second level, 180 feet below the surface, is found in the contact between the under side of the porphyry dike and the granite foot-wall. It remains approximately in this contact, though occasionally found wholly in the granite, to the lowest explorations in the shaft.

The porphyry dike varies in width on its dip as well as on its strike. On the third level a cross-cut 47 feet long, reaches the granite on both sides of the dike, while in the Adit tunnel it is passed through in 8 feet. It has been considerably acted upon by the vein-forming agencies in the upper workings, and in none of these openings was I able to secure a specimen that was not more or less decomposed. Where it is cut by the Adit tunnel it is less acted upon, and shows considerable pyrites.

The Golden Age veins are well defined, often presenting banded structure. They are inclosed in distinct walls, with selvages, which at times show slickensides. So far as my observation went—and this was confirmed by Mr. Amsden, who has been foreman on the mine for ten years—the seams and feeders that have enriched both veins, come in from the porphyry dike.

The ore from the Golden Age veins is somewhat remarkable, and the rich and magnificent gold specimens from it are familiar to all the miners of Boulder County. It is a typical free milling gold ore. A good percentage is saved by simple amalgamation on copper plates; the resulting bullion being over 900 fine; and the tailings yield iron concentrates of fair grade. As a rule it is, especially when rich, a hard, often flinty or vitreous appearing white quartz. The gold, especially in the hanging-wall vein, is seldom accompanied by pyrite, chalcopyrite, or any of the baser minerals. It is generally imbedded in the white quartz, as bright yellow gold, in size from coarse grains to nuggets often several ounces in weight. One specimen, found by a former owner, contained 70 ounces of gold, nearly all in one piece. The foot-wall vein contains more of the base minerals than the hanging-wall. After it reaches the lower contact between the porphyry and granite, there is a marked increase in the quantity, which is still further increased when it leaves the contact and enters the granite. In such places, blende, and galena appear in small quantities, with pyrite and considerable chalcopyrite; but the ore retains its value in free gold. One small stope on the foot-wall contact is said to have produced besides the mill ore, specimens which, amalgamated by hand in a mortar yielded gold bullion to the value of $25,000, leaving tailings sufficiently rich to ship to the smelters. In none of the openings were any tellurium minerals found, and Mr. Amsden says they are unknown in the Golden Age vein.

Returning to the surface, the Sentinel location covers the apex of a vein which there appears enclosed in a belt of schistose, or gneissic rock. It lies nearly parallel to, and about 100 feet south of the apex of the Golden Age vein. Only two shallow openings have been made on this vein on the surface; the deeper, a shaft sunk about 30 feet. In driving the Adit tunnel the first vein encountered was the Golden Age, on the hanging-wall contact of the dike, and about 175 feet further to the north the Sentinel vein was reached in granite. An upraise was made on this vein to the lowest (No. 5) level, from the Main shaft, thus demonstrating that this vein dips south at an angle of about 70°, passing through the Golden Age vein on its course.

The Sentinel vein produces an ore entirely distinct from that of the Golden Age. It is the characteristic bluish quartz of the tellurium veins of Boulder County, with the characteristic chalcedony, quartz crystals, and finely disseminated pyrites. The value is in metallic gold, petzite and sylvanite. While most of the gold was deposited as native gold, a certain portion has evidently been rendered free by the partial decomposition of the sylvanite. This ore is very rich. One specimen recently found, weighing a little over two pounds, is valued at $228.00; while shipments of first class ore are made to the smelters which return from ten to as much as seventeen dollars per pound. It is the practice, however, in handling this high grade tellurium ore, to amalgamate as much as possible in a mortar by hand, and ship the remaining tailings. As illustrating this, I will cite one lot, selected at random, of 17⅜ pounds, which yielded $200.00 in bullion, and then netted at the smelter's $80.60, the assay on the tailings being 435 ozs. gold and 84 ozs silver per ton.

The richest ore usually occurs in two narrow seams or streaks, often from a foot to, at times, as much as ten feet apart; the intervening space being more or less mineralized country rock. The miners leasing on this vein consider it richest when in the schistose rock, and poorest when it is in the porphyry on its course through the dike. Though the openings on the vein, in the dike, are limited, this opinion appears to be, and doubtless is, correct.

So distinct are the characteristics of these veins, that the crossing of the Sentinel through the Golden Age is plainly marked, being exposed in the Main shaft and workings connected with it. The dip of the former, as stated, is about 70° to the southward, and is quite regular as far as has been explored, though, at the points where it comes in contact with the quartz streaks of the Golden Age veins, it often follows along, without a break in its continuity, either above or below them for short distances before finally passing through and assuming its regular dip. Nor does the dip of the Golden Age veins appear to be much disturbed, the greatest vertical displacement noticed being only about 30 inches, at a point where it is broken by the passage through it of the Sentinel vein.

It is possible that the facts observed here confirm the opinion that the gold mines of Boulder County belong to at least two distinct periods of vein formation. To a first, or earlier, can be assigned the Golden Age, the mines of Ward, and other districts producing similar ores, free from tellurium minerals. To a second, or later, the tellurium gold veins for which Boulder County is particularly noted. That the ores from the Sentinel, or tellurium vein, are lower grade where the vein passes through the porphyry dike than elsewhere, is probably due to the formation of the Golden Age vein first. This vein drained the dike of its disseminated mineral values. The Sentinel doubtless received its mineral from the schistose or gneissic rocks, and is consequently richer where enclosed in those rocks, than when in the dike.

Prospectors, as a rule, look for richer or larger bodies of ore when veins unite, or cross each other. In this property we have two interesting occurrences of this kind. The two Golden Age veins unite at a point 100 ft. below the surface. These are similar veins of the same age. The result was, the large and rich ore bodies, mined in the stopes near the Main shaft and adjacent to the junction of the veins. The other case,—the crossing of the Sentinel tellurium vein through the Golden Age veins, the passing of a later through earlier veins,—produced no local enlargement or enrichment of the ore bodies. It is evident that, to form such ore bodies, except in rare cases, the veins should be of contemporaneous origin.

COLUMBITE AND TANTALITE FROM THE BLACK HILLS OF SOUTH DAKOTA.

BY DR. W. P. HEADDEN.

COLUMBITE.

In the year 1885 Prof. W. P. Blake published in the *American Journal of Science* an account of the occurrence of columbite in the Etta and Bob Ingersoll mines, both situated in Pennington Co., S. D., and within a short distance of each other. Since that time this mineral has been found at a number of localities in the same district and also in the northern portion of the Hills, in what is known as Nigger Hill district. It occurs in all of the stream tin, very sparingly however, in that from Two Bit and Mace gulches in the northern section. The presence of the columbite in all of the stream tin suggests its possible association with cassiterite in the veins, which, by their disintegration have furnished the stream tin. Columbite is not always associated with cassiterite, but I have found no columbite where cassiterite did not occur in the same vein and sometimes, but not usually intimately associated with it.

The chief occurrence of columbite in the Hills is at the Etta mine. It is abundant in the upper portions of the open-work on the southwestern and southern sides of the hill, where it occurs in a zone of beryl, one end of the crystals of columbite rests upon or even penetrates the tin ore while the crystal itself is enclosed in the massive beryl.* In other parts of the workings it occurs associated with spodumene, feldspar and sometimes quartz.

* The identification of this mineral rests upon the following data, hardness, 7.; Specific Gravity, 2.71; Al_2O_3 with trace of Fe_2O_3, 19.12; BeO, 13.00; SiO_2, 63.56 (!) 95.68. Alkalies were not examined for, SnO_2 and CaO absent MgO, trace.

The line of demarcation between the beryl and the tin ore, which in this case is composed of albite and muscovite carrying a very dark, almost black, cassiterite, is sharply defined and there is usually no intervening mineral. But sometimes there is a zone of pink feldspar, the mass of which is formed of radiating plates with a well-defined but undulating and jagged upper boundary. This feldspar is probably the product of an alteration, indicated by its mode of occurrence and also by the fact that where decomposition has taken place about the crystals, as is shown by the staining of the adjacent mineral, the ends of the feldspar crystals penetrate the softened area and lap up on the edges of the columbite crystals. I have failed to observe any crystals with stained borders in the massive beryl, except in the presence of the feldspar. Where smaller spodumene crystals occur in this association they have undergone a complete alteration. The crystals of columbite in this portion of the mine are comparatively small, crowded together, and often penetrate one another. In other portions of the mine, they occur as isolated individuals, sometimes in groups, of larger size. The largest fragment of a single individual which I have been able to obtain weighs fourteen pounds; and the largest group, consisting of two and a part of a third crystal, weighs thirty and one-quarter pounds.

The Peerless mine, about half a mile north of the Etta, has furnished but one or two larger aggregates of crystals and a few thin plates, which occur in the interstices of the quartz masses. One of the larger specimens furnished by this locality was found on the surface, it probably had weathered out and otherwise remained in its original position.

In the Sarah, about one-quarter of a mile north-west from the Etta, occurs the largest mass of which I have personal knowledge. The diameters of the mass as it is exposed are 8 in. x 14 in. I could not obtain any estimate of how much has been broken off, and there is no exposure showing how far the remnant extends into the enclosing rock mass. This is the only specimen which I could find in the mine; there is, however, not much work done at this point.

On the Newton lode it occurs sparingly in thin plates. At this locality beryls are very plentiful but entirely different from the beryl at the Etta, as it is disseminated through the rock mass in individual crystals from an inch to one and one half inches through and several inches long.

Prof. W. P. Blake described, as before stated, the only specimen found in the Bob Ingersoll; he estimated its weight at 2,000 pounds. At the time of my visit to this locality only a small portion of this mass remained, it having been broken to pieces and carried away or "cached." However, I obtained some smaller pieces varying in weight up to thirty pounds; one such piece is now in the cabinet of the Dakota School of Mines. The mineral occurs in small crystals and only sparingly at other localities which I have visited in this district.

No measurements have been made on any of the crystals found, and the description here given may need subsequent alterations. Well terminated crystals are rare and usually small. The best, and indeed almost the only good crystals obtained by me are from the beryl which occurs in the Etta mine, but I have in one specimen, from an unknown locality, two clusters of three crystals each imbedded in quartz.

The crystals occurring in the Etta mine vary greatly in lustre and also in their modifications. The usual form is tabular, the crystals being sometimes two inches wide, two or more inches long, with a thicknes of not more than one-quarter of an inch. The terminations of such crystals are always poor. The surfaces recognized on such are: 010, 110, 130, 100, 132, 102, 001, 01⅓. These forms are not recognizable on all of the crystals; sometimes the prism

130, and sometimes both prisms are wanting. The crystals are often thinner at one edge than at the other, and are otherwise distorted; they are sometimes vertically, again irregularly, and even horizontally striated. The striæ on the Etta crystals do not appear to be due to polysynthetic crystallization. The lustre on the different surfaces is not equally bright; that of the macropinacoid is almost always shining, while the basal pinacoid is seldom so, being often etched. In color the duller crystals are of a grayish black; the brighter ones of a pure black. The streak is, where not otherwise stated, a dark brown, which in the mass of loose powder appears grayish black. The mineral from the Hills differs from specimens obtained from other sources in two respects: in the fine grained texture of the fractured surfaces; sub-conchoidal fracture being almost wholly absent; and the lustre of the fractured surfaces is quite dull and no iridescence has been observed.

The smaller crystals are more highly modified than the larger ones, as the following readings serve to indicate: 001, 01⅙, 01⅓, 01⅔, 010, 110, 130, 100, 122, 132, 102, 133, 101(?), 111(?). A fragment of a small and very bright crystal furnished the following reading: 001, 01⅓, 01⅔, 010, one prism, probably 130, a brachypyramid 122(?), 102, 113. The larger crystals are much simpler, the usual forms being: 001, 01⅓, 010 and 100. The crystals from the unknown locality have a brilliant lustre on all surfaces, and 010 is strongly striated; due to polysynthetic crystallization. The macrodomes are wanting, and the other surfaces are 110, 100, 162, 102, 131, 001. The crystals from the Advance claim, one of the Dixie group, have a very different habit.

The form of this mineral from the northern Hills is often stout columnar with 010, 100, 001, and a macrodome; most of the crystals have been found in the placers and the angles are somewhat rounded, but not obliterated. Two minute crystals from the Yolo vein show the three pinacoids without the dome. The crystals from the Centennial are tabular and resemble those described from the Etta.

The occurrence of columbite in the Nigger Hill district is confined, so far as we at present know, to the stream tin and to the following three claims, the Centennial, the Uncle Sam and the Yolo; in these it occurs very sparingly. The Uncle Sam has furnished one larger piece, said to have been about the size of a man's head. The Yolo has furnished but a few pounds. In the Centennial it occurs in an intimate mixture of albite and quartz ; in the Yolo with muscovite, albite and quartz. I have not succeeded in obtaining a specimen from the Uncle Sam (the occurrence of the one piece, however, is corroborated by the statement of several persons who are familiar with the history of the mine.)

My specimens from the stream tin came from Mallory and Upper Bear gulches : for the former I am indebted to Mr. Mark Hydliff, for the latter to Capt. St. John, both of Bear Gulch. The columbite from Mallory Gulch, where it is found associated with rutile, and from the Yolo claim is different from the columbite of the southern Hills and also from that found on the Centennial claim.

Method of Analysis.—The method of analysis was a modification of Rose's. The decomposition of the mineral was effected by fusion with potassic hydric sulphate, the fused mass powdered and boiled out with water, at least twice, the mixed acids digested with yellow ammonic sulphide, to remove any stannic and tungstic oxides. I found Bloomstand's objection to fusion with sodic carbonate and sulphur, i. e., that some of the acids go into solution fully justified. The ferrous sulphide was dissolved out with dilute sulphuric acid, the mixed acids were thoroughly washed and dissolved in hydrofluoric acid. This solution after the addition of a sufficient quantity (8- to 9-tenths gram) of potassic fluoride, was evaporated on a water bath until the residual mass was simply moist—not wet and also not perfectly dry; for if evaporated to perfect dryness, even at the temperature of a water bath, the subsequent solution in water is apt to be turbid, due to decomposition of the double fluorid. The moist mass was dissolved in the least possible quantity of boiling water, the solution concentrated a little and allowed to crystallize. The tantalic potassic fluorid will have separated, almost completely, by the time the solution has become cold. It is advisable to let it stand for an hour or so; the double salt is then filtered off and washed with water acidulated with hydrofluoric acid and containing also a little potassic fluorid. This process is repeated with the filtrate, including the wash-water, which seldom yields more than a little of the potassic tantalic fluorid; if it should a third evaporation is rendered necessary. I find this method preferable to that proposed by Prof. Rammelsberg, i. e., to fuse the mixed acids with potassic fluorid.

The method as described yields perfectly clear solutions and the volume is always small; platinum vessels are, of course, necessary. The complete but not over-washing of the potassic tantalic fluorid is the most delicate manipulation in the process. The filtrate containing the columbic acid is evaporated on a water bath, after the addition of 25–30 drops of concentrated sulphuric acid, so long as aqueous vapor is given off, when it is transferred to the sand bath and a portion of the sulphuric acid expelled. The columbic acid is subsequently thrown down by addition of a sufficient quantity of water and boiling. If, however, the quantity of columbic acid present is large, it is better to add less sulphuric acid, about half as much, and a sufficient quantity of potassic hydric sulphate, evaporate to dryness and fuse—the columbic acid obtained by subsequent boiling of the fused mass with water is granular and less bulky. The tantalic acid was invariably weighed as Ta_2O_5 after ignition in an atmosphere of ammonic carbonate. The analysis of the specimens in hand presented no other difficulties.

The composition and specific gravity of the Columbite from these localities vary not only with the localities, but with the individual crystals from the same locality to such an extent that an analysis of one piece cannot be taken as even the approximate composition of an adjacent crystal. A general description of the occurrences has been given. The hardness of the mineral varies but little from 6; and the fracture, as already stated is uneven with a tendency to fine granular rather than to sub-conchoidal.

Analyses I, *Etta Mine.*—The original large piece from which this specimen was taken is now in the cabinet of the Univ. of New York. This is an older analysis, and the columbic and tantalic acids were separated by fusion with caustic soda and subsequent treatment with carbonic dioxide, and is given here because it is the only specimen which I have found from this locality having so low a specific gravity.

Sp. grav. 5.8900.

		Atom. equiv.		Atom. R.
Columbic acid	64.09	47.82	56.01	2.19
Tantalic "	18.20	8.19		
Stannic "	.10			
Ferrous oxide	11.21	15.57	25.53	1.
Manganous "	7.07	9.96		
Calcic "	.21			
	100.88			

Ratio columbic to tantalic=6 : 1 and the formula becomes $6RCb_2O_6+RTa_2O_6$ where $R=Fe_{8\cdot13}Mn_{5\cdot13}$.

II. *Etta mine.*—Small shining crystals from the beryl. Sp. grav. 6.1809 at 21° C.

		Atom. equiv.		Atom. R.
Columbic acid	47.05	35.15	50.66	1.92
Tantalic "	34.04	15.33		
Stannic "	.30	.21		
Ferrous oxide	11.15	15.48	26.44	1.
Manganous "	7.80	10.96		
	100.33			

Ratio, Cb : Ta=7 : 3. Fe : Mn=3 : 2.

Formula, $7RCb_2O_6+3RTa_2O_6$. $R=Fe_{3\text{-}5}Mn_{2\text{-}5}$.

III. *Etta mine*:—

Sp. grav. 6.2453 at 19° C.

		Atom. equiv.		Atom. R.
Columbic acid	46.59	34.80		
Tantalic "	35.14	15.83	50.76	1.97
Stannic "	.18	.13		
Ferrous oxide	7.44	10.3	25.7	1.
Manganous "	10.94	15.4		
	100.29			

Ratio, Cb : Ta = 7 : 3. Fe : Mn = 2 : 3.

Formula, $7RCb_2O_6 + 3RTa_2O_6$. $R = Fe_{2-4}Mn_{3-5}$.

IV. *Etta mine*:—One of the group of three weighing 30¼ pounds.

Sp. gravity 6.3758 at 21° C.

		Atom. Equiv.		Atom. R.
Columbic acid	40.37	30.12		
Tantalic "	41.14	18.53	48.74	2.
Stannic "	.13	.09		
Ferrous oxide	8.28	11.50	24.31	1.
Manganous "	9.07	12.80		
Calcic "	.78	1.39		
Magnesic "	.10	.25		
	99.89			

Ratio, Cb : Ta = 5 : 3. Fe : Mn = 1 : 1.1.

Formula, $5RCb_2O_6 + 3RTa_2O_6$. $R = Fe_{1-2}Mn_{1-2}$.

V. *Etta mine*:—This is a large individual crystal weighing 14 pounds.

Sp. gravity 6.51506 at 19° C.

		Atom. equiv.		Atom. R.
Columbic acid	39.94	29.80	49.15	2.02
Tantalic "	42.96	19.35		
Stannic "	trace			
Ferrous oxide	8.59	11.93	24.26	1.
Manganous "	8.82	12.33		
	100.31			

Ratio, Cb : Ta = 2.98 : 1.93 or 3 : 2. Fe : Mn = 1 : 1.

Formula, $3RCb_2O_6 + 2RTa_2O_6$. $R = Fe_{1-2}Mn_{1-2}$.

VI(a). *Etta mine*:—

Sp. gravity 6.6116 at 27° C.

		Atom. equiv.		Atom. R.
Columbic acid	35.11	26.16	47.88	1.93
Tantalic "	47.11	21.62		
Stannic "	.35	.20		
Ferrous oxide	8.37	11.62	24.82	1.
Manganous "	9.26	13.20		
	100.20			
(b) Columbic acid	35.17	26.25	47.65	1.96
Tantalic "	47.08	21.20		
Stannic "	.37	.2		
Ferrous oxide	8.38	11.64	24.34	1.
Manganous "	9.02	12.70		
	100.02			

Ratio, Cb : Ta=5 : 4, very nearly. Fe : Mn=1 : 1.

Formula, $5RCb_2O_6+4RTa_2O_6$. $R=Fe_{1-2}Mn_{1-2}$.

These analyses are not duplicate of the same piece but of what I supposed to be different specimens. One was made about a year later than the other.

VII(a). *Etta mine*:—Crystal weighing about a pound, the smallest of the crystals forming the group weighing 30¼ pounds. (Compare with analysis IV.) These crystals seem to be intergrown at the base.

Sp. gravity 6.6936 at 20° C.

		Atom. equiv.		Atom. R.
Columbic acid	31.80	23.73	47.27	2.01
Tantalic "	52.14	23.48		
Stannic "	.10	.06		
Ferrous oxide	6.00	8.33	23.41	1.
Manganous "	10.71	15.08		
Calcic "	trace			
Magnesic "	trace			
	100.75			

(b) This specimen was found in the collection of the late Prof. Jansen and was a fragment of a large crystal showing characteristics of the Etta crystals.

Sp. gravity 6.7072 at 21° C.

			Atom. equiv.		Atom. R.
Columbic acid	31.31	31.45	23.37		
Tantalic "	52.49	52.25	23.64	47.07	2.
Stannic "	.09		.06		
Ferrous oxide	6.10		8.47		
Manganous "	10.71		15.08	23.55	1.
	100.70				

Ratio, Cb : Ta=1 : 1. Fe : Mn=2.8 : 5 or 3 : 5 nearly.

Formula, $RCbO+RTa_2O_6$. $R=Fe_{3-8}Mn_{5-8}$.

(c) *Etta mine* :—Sp. gravity not determined.

		Atom. equiv.		Atom. R.
Columbic acid	32.73	24.85		
Tantalic "	50.53	22.78	47.69	1.98
Stannic "	.10	.06		
Ferrous oxide	7.81	10.84		
Manganous "	9.37	13.20	24.04	1.
	100.54			

Ratio, Cb : Ta=1.09 : 1. Fe : Mn 4 : 5 nearly.

Formula, $RCb_2O_6+RTa_2O_6$. $R=Fe_{4\ 9}Mn_{5-9}$.

VIII. *Etta mine* :—This specimen is a fragment of a large crystal showing only the two pinacoids 010 and 100, it is nearly square in section and is the third one in the cluster of three, (compare with analyses IV and VII[a]).

Sp. gravity 6.75003 at 20° C.

		Atom. equiv.		Atom. R.
Columbic acid	29.78	22.22		
Tantalic "	53.28	24.00	46.31	2.
Stannic "	.13	.09		
Ferrous oxide	6.11	8.48		
Manganous "	10.40	14.75	23.23	1.
	99.78			

Ratio, Cb : Ta=1 : 1.08. Fe : Mn=1 : 1.74 or 4 : 7.

Formula, $RCb_2O_6+RTa_2O_6$. $R=Fe_{4-11}Mn_{7-11}$.

The analyses so far are all of specimens from the Etta mine and with the exception of VII (c) have been given in the order of their specific gravities. The formulæ deduced from these analyses show the increase of the tantalate in these isomorphous mixtures up to an equal number of molecules, and emphasizes the fact that these various mixtures occur not only in the same locality, but may form the individual crystals of groups, where these occur.

IX. *Peerless mine*:—Small crystals or fragments of a larger complex crystal found on the surface. This occurrence was similar to that at the Bob Ingersoll mine.

Sp. gravity 6.3734 at 19° C.

		Atom. equiv.		Atom. R.
Columbic acid	37.29	27.83		
Tantalic "	44.87	20.21	48.10	1.92
Stannic "	.09	.06		
Ferrous oxide	6.87	9.54	25.06	1.
Manganous "	11.02	15.52		
	100.14			

Ratio, Cb : Ta=2.78 : 2. Fe : Mn=3 : 5. This does not give a simple molecular ratio and is only a remote approximation to the formula, $3RCb_2O_6 + 2RTa_2O_6$. $R=Fe_{3-8}Mn_{5-8}$.

X. *Cora mine*:—This was a large massive piece entirely free from any of the originally enclosing, or any penetrating rock. It had the appearance of having been broken out of a larger piece, as only fracture surfaces were shown. It was obtained from Mrs. Wm. Franklyn. Though differing greatly from the preceding, in physical appearance, it has the same molecular ratio.

Sp. gravity 6.3934 at 18° C.

		Atom. equiv.		Atom. R.
Columbic acid	37.91	28.30		
Tantalic "	44.55	20.07	48.43	1.94
Stannic "	.09	.06		
Ferrous oxide	6.70	9.30	24.86	1.
Manganous "	11.05	15.56		
Calcic "	trace			
	100.30			

Ratio, Cb : Ta=2.83 : 2. Fe : Mn=3 : 5.

Formula, $3RCb_2O_6+2RTa_2O_6$. $R=Fe_{3-8}Mn_{5-8}$.

XI. *Peerless mine:*—This was a large fragment found at the foot of the dump and formed a part of a second mass found in this mine; analysis IX was from the first mass found. The two specimens resemble each other less in physical properties than they do in composition.

Sp. gravity 6.4447 at 20° C.

		Atom. equiv.		Atom. R.
Columbic acid	40.28	30.06		
Tantalic "	42.09	19.00	49.19	1.96
Stannic "	.19	.13		
Ferrous oxide	6.70	9.30	25.15	1.
Manganous "	11.23	15.85		
	100.49			

Ratio, Cb : Ta=3 : 1.9 or 3 : 2. Fe : Mn=3 : 5.
Formula, $3RCb_2O_6+2RTa_2O_6$. $R=Fe_{3-8}Mn_{5-8}$.

XII. *Bob Ingersoll mine:*—This is a part of the mass originally described by Prof. W. P. Blake. The fragments show that it was a large aggregate of crystals; one piece showed a crystal with fair terminations.

Sp. gravity 5.9005 at 20° C.

	(a)	(b)	Atom. equiv.		Atom. R.
Columbic acid	80.98	57.32	42.80		
Tantalic "		23.43	12.89	55.66	2.
Stannic "	.09	.09	.06		
Ferrous oxide	6.18	6.29	8.80	27.80	1.
Manganous "	13.42	13.55	19.00		
	100.67	100.68			

Ratio, Cb : Ta=7 : 2. Fe : Mn=1 : 2.11.
Formula, $7RCb_2O_6+2RTa_2O_6$. $R=Fe_{1-3}Mn_{2-3}$.

XIII. *Sarah mine:*—This is quite different from the preceding in its lack of lustre, and is the only specimen of the mineral that I have seen which is not unquestionably crystallized. The section of this mass is not very regular, still it may be a very large individual crystal; it does not appear to be an aggregate of crystals as did the Bob Ingersoll mass. Its composition is quite close to that given in analysis I.

Sp. gravity 5.8038 at 27° C.

		Atom. equiv.		Atom. R.
Columbic acid	61.72	46.07		
Tantalic "	18.93	8.53	54.77	1.99
Stannic "	.25	.17		
Ferrous oxide	11.21	15.57	27.49	1.
Manganous "	8.67	11.92		
	100.79			

Ratio, Cb : Ta=5.4 : 1 or 11 : 2. Fe : Mn=1.4 : 1 or 3: 2.
Formula, $11RCb_2O_6+2RTa_2O_6$. $R=Fe_{3\text{-}5}Mn_{2\text{-}5}$.

XIV. *Locality unknown* :—This crystal was black, shining, vertically striated, tabular in habit, with 010 somewhat curved, apparently due to the deposition of thin plate-like individuals, each a little narrower than the preceding one. This cause will also explain the striation in this particular case.

Sp. gravity 6.5649 at 28° C.

		Atom. equiv.		Atom. R.
Columbic acid	40.07	29.90		
Tantalic "	41.92	19.34	49.37	2.08
Stannic "	.20	.13		
Ferrous oxide	9.73	13.50	23.70	1.
Manganous "	7.24	10.20		
	100.16			

Ratio, Cb : Ta=3 : 2. Fe : Mn=2.64 : 2 or 3 : 2 nearly.
Formula, $3RCb_2O_6+2RTa_2O_6$. $R=Fe_{3\text{-}5}Mn_{2\text{-}5}$.

XV. *Mallory Gulch* : — Nigger Hill District. This specimen was furnished me by Mr. Mark Hydliff; its color, streak and powder were light brown; hardness quite inferior to that of the columbite from the veins. The mass was traversed by checks in every direction and these were filled with mica (muscovite). It was very difficult to obtain pure material for analysis except at the sacrifice of a large amount of material. The specimen was worn smooth and was roughly egg-shaped.

Sp. gravity 6.2324.

		Deducting lime and magnesia.	Atom. equiv.		Atom. R.
(a) Columbic acid	40.85	41.69	31.11		
Tantalic "	39.38	40.19	18.10	49.27	1.88
Stannic "	.11	.11	.06		
Ferrous oxide	9.68	9.88	13.72	26.16	1.
Manganous "	8.53	8.70	12.44		
Calcic "	1.41				
Magnesic "	.61	100.67			
Titanic acid	trace				
	100.55				

(b) The same after having been treated with hot dilute hydrochloric acid.

		Atom. equiv.		Atom. R.
Columbic acid	40.48	30.20		
Tantalic "	40.97	18.46	48.76	1.83
Stannic "	.15	.10		
Ferrous oxide	9.95	13.82	26.54	1.
Manganous "	9.03	12.72		
	100.58			

XVI. From same source. This is more compact but otherwise the same as the preceding specimen.

Sp. gravity 6.4687.

		Atom. equiv.		Atom. R.
Columbic acid	37.28	27.82		
Tantalic "	44.48	20.00	47.92	1.9
Stannic "	.16	.10		
Ferrous oxide	9.29	12.90	25.12	1.
Manganous "	8.68	12.22		
	99.89			

These three analyses give approximately the following formula: $3RCb_2O_6+2RTa_2O_6$. $R=Fe_{1-2}Mn_{1-2}$.

These specimens have already undergone partial decomposition indicated by the presence of lime, magnesia and ferric oxide removable by dilute hydrochloric acid.

XVII. *Yolo claim :*—Nigger Hill District. This specimen was obtained from Capt. St. John, owner of the property. It is different in every respect from any sample heretofore given; it is fine grained, gray black in color, penetrated by seams of muscovite and the small irregular masses are coated with fine scales of the same mica. It is the only specimen in which I detected any admixed cassiterite. The material used for the analysis was carefully selected and showed no extraneous minerals after deducting the cassiterite.

Sp. gravity 6.5919 at 28° C.

		After deducting Cassiterite.	Atom. equiv.		Atom. R.
(a) Columbic acid	23.40	24.40	18.34		
Tantalic "	55.05	57.60	25.95	44.62	1.86
Stannic "	.40	.41	.31		
Ferrous oxide	13.82	14.46	20.30	23.90	1.
Manganous "	2.44	2.55	3.60		
Calcic "	.70	.73			
Cassiterite	4.46				
		100.15			
	100.27				

Ratio, Cb : Ta=4 : 5. Fe : Mn=5 : 1.

(b) Columbic acid	23.86	25.01	18.88		
Tantalic "	54.18	56.82	25.60	44.68	1.96
Stannic "	.30	.31	.20		
Ferrous oxide	13.38	14.03	19.46	23.11	1.
Manganous "	2.46	2.58	3.65		
Calcic "	.78	.79			
Cassiterite	4.64				
		99.54			
	99.60				

Ratio, Cb : Ta=4 : 5. Fe : Mn=5 : 1.

Formula, $4RCb_2O_6+5RTa_2O_6$. $R=Fe_{5-6}Mn_{1-6}$.

The physical properties of this specimen and the high percentage of tantalic acid indicate that it is rather a tantalite than a columbite; on the other hand the few small and imperfect crystals from this locality have the form and habit of columbite, and if this observation is correct the mineral should be classified as such.

The following analyses are introduced here, partly for their own sake and partly for comparison.

XVIII. *Turkey Creek*, near Morrison, Colorado. This specimen was kindly furnished me by Mr. Richard Pearce, of Denver. The specimen inclosed some pinkish feldspar, and both the columbite and feldspar were somewhat decomposed. The columbite occurred as plates packed closely together, the surfaces of which were coated with a thin yellow ochreous incrustation.

Sp. gravity 5.3830, also 5.3880 at 19° C.

		Atom. equiv.		Atom. R.
Columbic acid	73.45	55.00	55.94	1.92
Tantalic "	2.74	.30		
Tungstic "	1.41	.50		
Stannic "	.21	.14		
Ferrous oxide	11.32	15.70	29.10	1.
Manganous "	9.70	13.40		
Calcic "	.61			
Magnesic "	trace			
Loss on ignition	.28			
	99.45			

Ratio, Cb : Ta = 183⅓ : 1. Fe : Mn = 8 : 7.

Formula, RCb_2O_6. $R = Fe_{8-15}Mn_{7-15}$.

XIX. *Haddam, Conn.:* — Specimen obtained through Geo. C. English & Co., Phila. Color black, lustre shining metallic with iridescence on fractured surfaces, fracture somewhat sub-conchoidal. The physical properties of this specimen are quite different from those of the Black Hills mineral.

Sp. gravity 5.7803 at 28° C.

		Atom. equiv.		Atom. R.
Columbic acid	60.52	45.16		
Tantalic "	19.71	8.88	54.10	1.92
Stannic "	.09	.06		
Ferrous oxide	12.64	17.55	28.12	1.
Manganous "	7.51	10.57		
Magnesic "	trace			
	100.47			

Ratio, Cb : Ta=5 : 1. Fe : Mn=1.75 : 1 or 2 : 1 nearly.
Formula, $5RCb_2O_6+RTa_2O_6$. $R=Fe_{2/3}Mn_{1/3}$.

XX. *Mitchell Co., N. C.:*—Specimen obtained from Dr. A. E. Foote, of Phila. It resembled the Haddam specimen quite closely and differs as that does, from the Hills specimens.

		Atom. equiv.		Atom. R.
Columbic acid	70.98	52.97		
Tantalic "	9.27	4.17	57.25	2.
Stannic "	.17	.11		
Ferrous oxide	12.21	16.96		
Manganous "	7.30	10.30	28.61	1.
Calcic "	.80(?)	1.35		
	100.87			

Ratio, Cb : Ta=12.7 : 1 or 13 : 1. Fe : Mn=1.64 : 1 or 8 : 5.

These results corroborate the observation of Marignac that the specific gravity increases with the contents of tantalic acid. The Yolo mineral forms the only exception in the whole series.

The first eight specimens are all from the Etta mine and have the form of columbite, but the ratio of Cb : Ta gradually falls from 6 : 1 to 1 : 1, and it does not fall below this except in the case of the Yolo mineral where it reaches 1 : 1¼. If we examine the ratio of Cb : Ta in the tantalites from Sweden and elsewhere, afforded by the analyses of this mineral by Prof. Rammelsberg, we find that it exceeds that obtained here for columbite. In the case of the

Broddbo mineral, of which he gives two analyses, we find the ratio in one case to be Cb : Ta = 1 : 1, in the other analysis it is as 3 : 2, while Marignac's analysis of the Braddbo tantalite, quoted by Rammelsberg, gives, if we reject the Sn the ratio of Cb : Ta = 1 : 3.64. Prof. Dana says of the columbite from Northfield, Mass., analyzed by W. J. Comstock (appendix III, page 30), "The Northfield mineral had the form and habit of ordinary columbite though it is essentially a tantalite. This was also true of the Branchville (Conn.), mineral * * *." The analysis of the Northfield mineral gives 1 : 1¼ for the ratio of Cb : Ta, while that of the Branchville mineral, by the same analyst, gives 1 : 1 for this ratio. It will be noticed that of the twenty specimens from the hills which I have analyzed, seven of them contain the Cb and Ta in the ratio 3 : 2, four contain them in the ratio of 1 : 1, and one contains them in the ratio of 1 : 1¼. There is no doubt as to the form of these specimens, unless it be in regard to the last one, but in the case of the Northfield mineral, which gives the same ratio for Cb and Ta, i. e., 1 : 1¼, Prof. Dana expresses no doubt. The tantalite from Yancey Co., N. C., analyzed by Comstock (appendix III, p. 118) gives the formula $6RTa_2O_6+4\ RCb_2O_6$, while the columbites from Northfield, Mass., and the Yolo claim, Lawrence Co., S. D., gave the formula $5RTa_2O_6+4RCb_2O_6$. If the Broddbo specimens be tantalites then we have an overlapping of specific gravity and composition which destroys their value as guides in determining these minerals when the molecules of the columbate and tantalate are nearly equal in number. It was my intention to carry this investigation further and show that there is really no sharp line between them, but that these minerals merge one into the other. I have found that the specific gravity of the specimens, especially from the stream tin, increases continuously from 5.8 to 7.72 with the maximum of 8.2. In form too, the columbite is not always tabular in habit, but sometimes the pinacoids, to which the tabular habit is due, are very subordinate, and the crystal assumes a very prismatic habit. I have so far been unable to determine the superior limit of tantalic acid compatible with the columbite form.

The Turkey Creek (Colorado) mineral deserves mention as being an almost typical columbite, but, like the greater number of the Hills columbites, is rich in manganese. It is also rather remarkable that it is the only one which contains tungstic acid. I have not yet found a pure ferriferous columbite in the Hills, the only specimen which approaches it is that from the Yolo mine, which gives the atomic ratio for Fe : Mn=5 : 1 ; by far the larger number of all the rest are rather manganiferous than ferriferous columbites. This fact becomes interesting when we compare the columbites with the tantalites, so far examined.

TANTALITE.

In the transactions of the American Institute of Mining Engineers, vol. xiii, p. 233, Prof. Schaeffer publishes the identification of a mineral from the Etta mine as tantalite and gives the following analysis.

Sp. gravity 7.72.

Tantalic acid	79.01
Stannic "	.39
Ferrous oxide	8.33
Manganous "	12.13
	99.86

The locality given is probably correct, as I have found several persons who state that some of the Etta mineral was sent to Cornell University, where Prof. Schaeffer was at the time engaged. I have been unable to find any tantalite at this locality and there are some things about the analysis which are difficult to account for. Prof. Schaeffer states that he was unable to find the least trace of columbic acid. If we calculate the atomic equivalents on this basis we obtain the following results:

		Atom. equiv.		Atom. R.
Tantalic acid	79.01	35.60	35.86	1¼
Stannic "	.39	.26		
Ferrous oxide	8.33	11.57	28.66	1.
Manganous "	12.13	17.09		

or Fe+Mn : Ta=1 : 1¼ instead of 1 : 2. The oxygen ratio on the same basis is 1 : 3.1 instead of 1 : 5; whereas if we consider that there is no tantalic acid present but that the 79.01% is all columbic acid, the atomic ratio of Fe+Mn : Cb=1 : 2.06 and the oxygen ratio becomes 1 : 5.1, which are exceedingly close approximations to the true ratios for columbite. A comparison of Prof. Schaeffer's analysis with XII*a* will make it evident that his specimen was essentially the same mineral.

	Prof. Schaeffer's.	XII *a*.	*b*.
Columbic acid	79.01	80.98	57.32
Tantalic "			23.43
Stannic "	.39	.09	
Ferrous oxide	8.33	6.18	
Manganous "	12.13	13.45	
	99.86	100.67	

The assumption that there is no tantalic acid in a specimen from the Etta mine is altogether contrary to the results of my tests and analyses; still, the fact remains, that on this assumption the analysis gives a correct ratio, and the mineral is a columbite, but a very exceptional one for the locality.

In the year 1887 Mr. Frank Herbert brought some stream tin to the Dakota School of Mines to have it smelted and the tin run into bars. The yield was exceedingly unsatisfactory and a portion of it was not smelted but was, by accident or otherwise mixed with some stream tin from Bear Gulch, a locality in the Northern Hills. A little over a year ago I examined some of the material, and was lead to believe it to be tantalite. The preceding facts were, at that time, not fully known to me so I supposed the tantalite to be from the Northern Hills. This was not the case; as I have succeeded in finding more of the tantalite in the stream tin from Grizzly Bear Gulch, Pennington Co., S. D., but have found none in the stream tin from Bear Gulch, Lawrence Co. The stream tin in which I found the tantalite was also from Mr. Herbert's placer ground near the Tin Queen Mine. The largest piece which I have found weighs 5 grams and has a specific gravity of 8.2 at 28° C. The mineral has not yet been found in place, but these fragments have unquestionably been derived from the Tin Queen lode which lies immediately above the placer ground. The tantalite is perceptibly harder than the columbite and the streak and powder are dark brown. The method of analysis was the same as for the analysis of columbite.

I. *Herbert's placer*, Grizzly Bear Gulch, Pennington Co., S. D. Piece weighed 2.5 grams.

Sp. gravity 7.7727 at 28° C. (Jolly balance).

		Atom. equiv.		Atom. R.
Tantalic acid	78.20	35.23		
Columbic "	6.23	4.65	40.33	1.96
Stannic "	.68	.45		
Ferrous oxide	14.00	19.44	20.58	1.
Manganous "	.81	1.14		
	99.92			

Ratio, Ta : Cb = 8 : 1.

Formula, $8FeTa_2O_6 + FeCb_2O_6$.

II. Same locality.

Sp. gravity 7.7893 at 28° C. (Jolly balance).

		Atom. equiv.		Atom. R.
Tantalic acid	78.35	35.29		
Columbic "	6.24	4.66	40.33	1.913
Stannic "	.58	.38		
Ferrous oxide	14.05	19.48	21.08	1.
Manganous "	1.14	1.60		
	100.36			

III. Same locality, weight of fragment 2 grams.

Sp. gravity 8.2 at 28° C. (Jolly balance).

		Atom. equiv.		Atom. R.
Tantalic acid	82.23	37.85	39.92	2.06
Columbic "	3.57	2.66		
Stannic "	.32	.21		
Ferrous oxide	12.67	17.79	19.38	1.
Manganous "	1.33	1.59		
	100.12			

Ratio, Ta : Cb = 14 : 1.

Formula, $14FeTa_2O_6 + FeCb_2O_6$.

IV. *Coosa Co., Ala.* Specimen obtained from Ward and Howell, Rochester, N. Y. Weight of fragment 3 grams. This piece was deeply pitted, color black; powder brown.

Sp. gravity 7.3559 at 28° C. (Jolly balance).

		Atom. equiv.		Atom. R.
Tantalic acid	71.37	32.15	42.28	2.19
Columbic "	8.78	6.55		
Stannic "	5.38	3.58		
Ferrous oxide	8.44	11.71	19.27	1.
Manganous "	5.37	7.56		
Ignition	.20			
	99.54			

The columbic acid from I, II and III, was yellow while hot and that from I was tested with metallic zinc and sulphuric acid, and gave the deep blue color characteristic of this acid. The analyses of these tantalites show that they are isomorphous mixtures in which the tantalate predominates.

I have found but one crystal of tantalite which shows unmistakable planes; these belong to a prism, the basal pinacoid, strongly etched, and two pyramids which are not well developed; its specific gravity is 7.212.

The most characteristic thing in these analyses is the small amount of manganous oxide present, while its large amount seems to be almost characteristic of the columbites.

I have also found two fragments of tantalite in the stream tin from Mitchell's Bar, a locality about one and a half miles north by east from the Etta mine, but no analyses have yet been made of these specimens.

MANGANESE COLUMBITE.*

The mineral here described occurs on the Advance Claim, one of the Dixie group of tin mines, on Elk Creek about one and a half miles south of the Etta mine, Pennington Co., S. D. It occurs in a vein of granite which apparently folds over the crest of the hill; its thickness was not measured but did not exceed two feet. The columbite was found at only one point; the under side of the granite is here very even and smooth and consists, for about two inches, wholly of mica crystals whose cleavage planes stand at right angles to the wall. The inner edge of this band of mica is also sharply defined but irregular. The outer surface, that is the under surface as the granite lies, is filled with minute crystals of columbite lying in all directions as though a crop of small crystals had separated first, forming a swarm of them which adhered to the wall, and the larger crystals seem to be extensions of these points into the mass; only a few points, however, have developed into larger crystals. If there were two periods of growth, this would account for the peculiar pointed appendages to many of the crystals. Many of these crystals are short, doubly terminated but much distorted, and attached at the side as the more perfect ones indicate.

The band of mica varies in thickness up to two inches and seldom incloses any other mineral than the columbite; the quartz and feldspar, (mono and triclinic) rests upon the mica while an occasional beryl penetrates its mass. The columbite crystals do not enter the beryl as they do in the Etta mine, but are sometimes found in the feldspar, immediately adjacent to the mica, they are often

* This portion of the article was read before the Society by title and appeared in the Am. Jour. Science, Feb., 1891.

rusty, and some of them thickly coated with oxide of iron, and the most of them are not at all or only fainted striated.

The crystals have a habit often observed in ordinary columbite, and such approximate angles as can be obtained correspond with those usually accepted. The planes present are: 100, 001, 010, 110, 530, 133, 021. The development of the prisms 530, 110, especially the former, gives the crystals a flattened form in the direction of the macrodiagonal axis.

I. One of the largest crystals, weighing one and a half grams, was used for this analysis; the crystal was rusty, and had to be cleaned by boiling in dilute hydrochloric acid, its color after cleaning was black, luster submetallic, a little shining, fracture uneven, streak brown, powder grayish-brown.

Specific gravity=6.170.

		Atom. equiv.		Atom. R.
Columbic acid	47.22	35.25		
Tantalic "	34.27	15.44	50.90	2.07
Stannic "	.32	.21		
Ferrous oxide	1.89	2.62	24.59	1.
Manganous "	16.25	21.97		
	99.98			

Ratio, Cb : Ta=7 : 3. Fe : Mn=2 : 17.

II. Three small crystals.

Specific gravity not determined.

		Atom. equiv.		Atom. R.
Columbic acid	45.66	34.07		
Tantalic "	35.53	16.00	50.32	2.01
Stannic "	.38	.25		
Ferrous oxide	2.29	3.04	25.01	1.
Manganous "	16.25	21.47		
	100.00			

The results of I and II agree as closely as could be expected when we consider that each of the three different crystals of II may have, and probably did, represent different molecular mixtures.

MEETING OF NOVEMBER 3d, 1890.

NOTES UPON THE HISTORY OF THE DISCOVERY AND OCCURRENCE OF TIN ORE IN THE BLACK HILLS, SOUTH DAKOTA.

BY DR. WM. P. HEADDEN.

The earliest identification of tin from this district was made in 1876, by Mr. Richard Pearce, of Denver, who detected cassiterite as stream tin in gold dust received from the northern section of the Hills. Mr. Pearce, subsequently, but during the same year, obtained larger quantities from the same source. The second discovery was made on Elk Gulch, southern section, April, 1877. The material was assayed by Theodore Vosburg, but the true nature of the bullion was first recognized by Fred J. Cross. The material assayed by Mr. Vosburg was float, but granite carrying cassiterite has since been found in place at or near the same localities. The next discovery was made by Mr. Fred J. Cross in the summer of 1879, who found stanniferous quartz, probably on what is known as the Bismark Lode. It was found in Peerless Mine (then being worked for mica), by Sam Bippus, a laborer, on November 5, again on December 14, 1882, and in the Etta Mine on May 2, 1883, by I. W. McDonald, "Doc." Ferguson, and one, possibly two, other men who were working the Etta for mica. Prof. McCullough, of Madison, Wisconsin, who was in the Hills at that time to investigate the Peerless, a property in the immediate neighborhood, and A. J. Simmons, of Rapid City, took some of the ore to Deadwood, where the first assay of it is said to have been made. In the following month, June, 1883, Mr. W. P. Blake investigated the matter in the interest of some California capitalists, and published the results of his observations together with those of a subsequent visit in the same year in the *American Journal of Science*, September, 1883, *Eng. and Mining Journal*, September 8, 1883, *Mining Resources*, 1884.

The first company to work the mines for tin was formed in 1884, and since that time a large portion of the Hills, both in the northern and southern sections, has been prospected and located as tin-bearing.

The cassiterite occurs, as a rule, in granite in the Bismark district, however, in quartz veins. The two occurrences are of different origin. The former is an original accessory of the granite, the latter is, probably, the result of segregation.

The granites appear interstratified with the schists, and have a common strike throughout the northern and southern granite-bearing areas, *i. e.*, north 25–30° west, but in the vicinity of Haywood their strike is almost at right angles to this, and again north and a little east of Custer, there are considerable deviations from it. The parallelism with the schists, however, remains apparent. Granite south of Custer is an orthoclastic granite in which the orthoclase is nearly all pink. In the vicinity of Haywood a little pink orthoclase is found, but north of Custer the prevailing color is white, and the feldspar is not exclusively or even principally monoclinic. In the northern hills the granites resemble those of the central hills, but there is a greater variety in texture, and, in the extremes, greater variety in character. The continuity of these masses in depth is very doubtful. But it must be admitted to be an exceedingly perplexing question to any student who has no theory to establish or preconceived notion to confirm. On the eastern margin of the schist area, sections of unmistakable lenses are often shown. Some of them are very small, others are quite large. Their longer axes are parallel, and they are often found succeeding one another in the same line of outcrop. In some instances there are intervening masses whose sides are not curved, and so give a more or less rectilinear section as of a small sheet. Many of these granites are to be considered as intrusive, the intrusions having taken place before the folding of the slates. The following points are worthy of notice: First, that a series of lenses and sheet-like masses may be seen following the same line, presumably corresponding to the bedding plane of the original slate. Second, that these smaller masses often have stringer-like terminations. Third, that lateral intrusions into the schists are never, or very rarely, found. Fourth, that portions of crumpled schists are sometimes to be observed penetrating the granite.

The granites of the South with pink feldspar contain, as a rule, more tourmaline than the granites of the western, central and northern sections, and also less cassiterite. The cassiterite in the granite is not often associated with arsenopyrite, or wolfram, but in the few quartz veins in which it has been found, arsenopyrite is of quite frequent occurrence; and it is not wholly absent in the granite. The cassiterite occurs, usually, in rather large crystals and grains, not evenly disseminated through the mass of granite, but in rather sparingly occurring bunches; in the quartz veins the cassiterite seems to be more nearly continuous. This tendency of the tin ore to occur in bunches is beautifully shown in some of the small lenses already referred to. But one small lens of ore, consisting of cassiterite, feldspar and tourmaline, has been observed by the writer. This was probably a true secondary formation, the country rock was not mineralized, and no case of such mineralization has yet been observed.

There are no porphyries in the southern section of the Hills. The granites are scarcely at all decomposed; both selvages and cases of freezing are absent, and but little stream tin. This is very noticeably the case in the southern Hills.

These considerations must be acknowledged to be weighty when we consider the age of these rocks, on which point our testimony is very positive; for the Cambrian lies unconformably upon them, and they have furnished material forming its basal conglomerate, for the feldspar, mica and tourmaline derived from the granite are still recognizable in it. We cannot escape the conclusion that these schists and granites have been exposed to erosion for immense periods of time, and have contributed material for later formations; and it is very suggestive that neither stream tin nor concentration by segregation has been produced on any considerable scale.

MEETING OF DECEMBER 1st, 1890.

THE QUARTZ-PORPHYRY OF FLAG-STAFF HILL, BOULDER, COL.

CHAS. S. PALMER and HENRY FULTON.

*(Communicated by Chas. S. Palmer.)**

This paper is a continuation of a preliminary paper on the Eruptive Rocks of Boulder Co., Colo.,† and is especially devoted to the examination of a quartz-porphyry found in dykes, beds, etc., quite generally in the foot hills near Boulder, and named from the locality Flag-staff Hill, where its occurrence was first observed. A short description of its more obvious characteristics is given in the same paper above referred to (p. 234.)

MACROSCOPIC APPEARANCE.

The rock is light gray in color, with much fresh dark mica which is unusually well crystallized. The first effect on the eye is that of coarse biotite granite; but a careful examination shows that the gray cast of the rock is due to the unindividualized ground mass, and discloses its real nature. Held in the hand one notices also the abundant quartz and the fairly abundant feldspar, the crystals of both of which are usually much larger and more decomposed than the dark mica provisionally called biotite. Thus the rock consists of good sized crystals of quartz, feldspar, and dark mica, in a light gray homogeneous ground mass, which ground mass is a felsite.

(a) The Macroscopic Quartz.—In the preliminary sketch, the quartz was described as poorly crystallized; but this appears to have been a hasty generalization. To be sure

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* The third paper of this series will be published later on.

† See ante, p. 230.

in most of the outcrops the impression is gained of poorly crystallized forms for the quartz; but in the course of excavations made during the summer of 1890, near the south side of Sunshine Cañon for the construction of a new reservoir, the quartz-porphyry was found intercalating beds of (Triassic ?) sandstone. Here the rock was badly weathered, and with little trouble one could crumble up the rock and pick out the quartz crystals. They were of the common di-hexagonal pyramid, a form of quartz characteristic of quartz-porphyries. Yet these crystals were themselves quite weathered, and frequently fell apart in getting them out. The reason why the fresh rock does not furnish these di-hexagonal crystals, or at any rate show them, is not apparent, unless it may be that the crystals are so firmly imbedded in the ground mass that when the rock is broken, they suffer fracture, (rather than break away, leaving a clean mould), and hence their real form is much obscured. The crystals extracted from the reservoir site, vary from two to four or five millimeters in diameter; none are glassy, but are of a uniform semi-transparent or translucent gray tint and luster.

(b) The Macroscopic Feldspar.—This mineral is badly weathered; fresh cleavage surfaces are rare; one twin, Carlsbad apparently, was noticed; the color is light gray or light flesh color, the fresher the feldspar the deeper the pink tint. The original crystals were from four to eight millimeters in their greatest diameters. The weathering has evidently been in the line of ordinary kaolinization. In one case a small crystal of weathered pyrites was observed imbedded in a weathered feldspar. It will be shown later in the paper that the decomposed feldspars contain a notable amount of carbonic acid, probably chiefly as sodium carbonate, and the presence of sodium in greater quantity than potassium in the rock indicates that the feldspar was originally a sanidine.

(c) The Macroscopic Micà.—This mineral which is decidedly the most striking feature of a hand specimen,

deserves some especial examination; no especial chemical analysis of the mineral has yet been made, but some evidence is found that the mineral is not as fresh as it appears. In the optical examination the biaxial figure in converging polarized light comes out sharply. The plane of the optic axes is at right angles to the plane of symmetry $\infty P \dot{8}$ · Tschermak has classified the micas in respect to the position of the plane of the optic axes (see Groth's *Zeitschrift für Min. u. Geol.*, 1877–8, d. Glimmer Gruppe), and according to this classification, our mica must be related to *anomite* in optical properties. On attempting to get the stroke or percussion figure, and the pressure figure of Reusch, very peculiar results were obtained. Many crystal laminæ and the sharpest and finest needles were tried; yet the percussion star barely appeared, but the pressure figure appeared as a clear terraced pit. Now, it is rather strange that the percussion figure should be almost wanting, and the pressure figure prominent. It indicates that the mica has become soft and lost its brittleness, and it implies a decomposition analogous to and contemporaneous with that affecting the quartz and feldspar, and the rock itself. In anticipation it may be said, that though the microscope indicates no decided change in the chemical and physical texture of the mica (some of the micas have well pronounced *iron rims*, but this has not destroyed the clear texture of the mineral in most instances), yet the position of the optic axes and the behavior of the percussion and pressure figures, warrant the view that the mineral should not be pronounced true "anomite" until it shall have had a special examination with chemical analysis and search for the possible unchanged original, if so be that it is as we believe at present an alteration. The anomite of Tschermak was found in a gneiss near Krems in Nieder-ästerreich. It may be that the mica we are dealing with had its plane of optic axes distorted by heat, pressure, weathering, or other agency, being evidently the first mineral to crystallize in the original magma. Meanwhile we leave it for a special consideration later. The rock has in places a gneissoid habit, and the mica may be a true anomite.

THE MICROSCOPIC EXAMINATION.

In the preliminary paper (p. 236) three points were adduced as evidence that the rock is a true eruptive rock, viz: 1st, its porphyritic character; 2d, its intrusive nature as seen in the field work; 3d, the development of a true fluidal and schistose structure locally; reference was also made to the base as being a microfelsite. It is the certain determination of the latter point, *i. e.* the nature and condition of the ground mass, which will fix the rock. The microscopic examination of the macroscopic ingredients will absorb but a little space.

(a) The Quartz.—This is in sections, clear with a few glassy inclusions and in several cases has the corroded edges characteristic of the quartz in quartz-porphyries and similar acid rocks.

No case was observed of a distinct *globulaire* rim though traces may be present. No case was observed of any pegmatitic or micro-pegmatitic structure; the quartz crystals are all well individualized. No case was observed of any quartz crystal giving support to any radiating projection of granophyre or other secondary crystallization. In short the quartz is a simple crystalline quartz, with corroded edges, and in a few cases with "negative crystals," internal cavities of a perfect di-hexagonal pyramidal shape. Apatites are common as inclusions, and zircon needles are not rare.

(b) The Feldspar.—The feldspar has no marked microscopic features; most of it is highly kaolinized; the extinction angle is not always sharp, but several approximately parallel extinctions were observed.

(c) The Mica.—This occurs in the characteristic dichroic brown fibres, extinguishing with one Nicol at right angles to the cleavage. The basal sections show a dark greenish-brown color, and gives the interference figures of a biaxial crystal.

(d) The Ground mass: Mineral Morphology. — The groundmass polarizes feebly between crossed Nicols, though the first impression is of almost total extinction; the brightest particles appear to be quartz; little if any mica can be observed in the ground mass as a rule; with a good power rectangular particles can be observed which seem to be remnants of a kaolinized feldspar (orthoclase or sanidine); these are dark in transmitted light, and opaque, yellowish-white in reflected light. Beyond the recognition of these ingredients little can be positively stated. As the macroscopic ingredients have weathered, one should look for a similar change in the ingredients of the base. But just what this may be can not be positively stated. How shall we determine the real nature of the ground mass? Here we find ourselves in what is confessedly one of the most difficult of petrographical problems. In the last edition of his Massige Gesteine, Rosenbusch reviews the whole subject of the porphyritic base and (p. 374) defines the three landmarks, crystalline, micro-crystalline, and crypto-crystalline. With this in mind it is not difficult to pronounce our ground mass as consisting essentially of micro-crystalline quartz and weathered feldspar in a finer base which is, in part at least, crypto-crystalline. A little assistance may be gained here by observing that the quartz contains glassy inclusions which are partly devitrified. This glass has perhaps been better preserved from being enclosed within the quartz, and was probably originally identical with an original glassy base which is now the crypto-crystalline substratum of the ground mass. We have been only fairly successful in making these sections of the ground mass which are by no means fully resolved with a good $\frac{1}{8}$ inch objective. Rosenbusch lays stress on both these points, viz: the section and the lenses in studying the ground mass, and it must be confessed that all has not been done in this case that is desired. There is no perceptible mosaic of micro-pegmatite, nor radiating granophyre in the ground mass. Only in one case with the

highest powers have we observed a tendency of the quartz to be grouped in fine parallel fibres of similar extinction and illumination between crossed Nicols. No drawing of which we are capable can do justice to the delicate yet bewildering confusion of this ground mass, and none has been attempted. The ground mass shows here and there a few accessory minerals, as apatites, zircons, and a little iron stain, but these do not call for special remarks.

(d) The Ground mass : rock morphology.—The porphyritic structure of the ground mass just referred to might be alone regarded as sufficient evidence for the eruptive nature of the rock. But further evidence is found in the flow-structure. This is shown not only in certain hand-specimens where portions of the neighboring sandstones have been surrounded and enfolded by the once plastic rock, but also thin sections of these hand specimens show clearly under the microscope the flow-lines in the fine ground mass. Here the finer particles are clearly arranged in flow-structure about the larger crystals. This evidence is peculiarly satisfactory in the classification of the rocks.

ANALYSIS.

	1.	2.	3.
SiO_2	67.20	76.92	66.45
Al_2O_3	14.95	12.89	15.84
Fe_2O_3 } FeO }	5.19	1.15	2.59 / 1.43
CaO	0.30	0.68	2.90
MgO	2.39	0.98	1.21
K_2O	0.89	4.27	2.89
Na_2O	4.00	0.68	3.92
H_2O	2.13	1.97	0.84
CO_2	0.40		1.35
	97.45	99.54	99.42
Sp. Gr.	2.43	2.49	2.67

No. 1 is the Flag-staff Hill Quartz Porphyry: the SiO_2, Al_2O_3, Fe oxides, CaO and MgO were determined by H. Fulton. No. 2 is an average quartz porphyry, quoted from Geikie. No. 3 is the Lincoln porphyry quoted from Emmons' report on Leadville.

In discussing the analyses we would note : *First*—the low percentage of silica in such an acid rock. The comparison with the other figures is significant. Roth* says "the silica varies from 70 to 75 per cent. and may fall to 65 per cent. in felsite porphyries *poor in quartz*" (the italics are mine). Is the inference to be drawn that the felsite base is poor in silica to compensate for the macroscopic quartz? The biotite is probably a basic mineral, and certainly is found in basic rocks frequently and the orthoclase is fairly acid. Biotite usually contains about 40 per cent. of silica, and sanidine about 65 per cent. The biotite crystallized first, probably, and why such a rock which is not acid to excess should have precipitated so much free quartz is not clear.

Secondly—The iron is largely ferrous: the pulverized rock is gray but takes on a *decided* red tinge on heating. The iron is contained almost entirely in the mica.

Thirdly—The calcium oxide is small in amount and indicates a small amount of the anorthite molecule, and therefore of plagioclase feldspar.

Fourthly—The magnesia, 2.4, indicates that the mica is a true magnesia mica, but partly replaced by ferrous iron : this explains why so small a percentage of magnesia was obtained from a rock apparently so rich in dark mica.

Fifthly—The low percentage of potash as compared with soda is significant and indicates that the feldspar was probably a sanidine.

Sixthly—The water present may be in the base, or in the mica which has already begun to suffer decomposition. Before the blow-pipe the mica expands in the vermiculite manner. Biotites have been known to contain as high as 4.4 per cent. of water (see Roth, *Chem. Geol.*, Vol. I, p. 19).

Seventhly—On treating the powdered rock with hydrochloric acid a fairly copious effervescence is seen, 0.4 per

* Chem. Geol., Vol. II., p. 107.

cent. is probably a low figure for the average rock. On treating the hand specimen with acid it was noticed that the fresher feldspar effervesced only slightly, but the weathered one strongly; also the ground mass did in spots where there seemed to be kaolinized feldspar. As the lime is small, part at least of the carbonic acid must be held as sodium carbonate in the weathered feldspar, a natural mode of decomposition, but one which I have not seen in the literature.

THE FIELD WORK.

A list of outcrops observed up to date has been prepared and will at some time be incorporated in a complete geological map of the county. As announced in the preliminary paper, the region is furnished with a great abundance and variety of eruptive rocks and it would be premature at this stage to offer more than the most general remarks on the age and relation to other rocks, sedimentary and massive. I have found no rock in Zirkel's report which matches this, nor do I find any close resemblance to any of the Leadville or Ten Mile rocks. Two years ago I came to Denver and carefully went over the collections of rocks belonging to the Society, but found no specimens liable to be confounded, at least in macroscopic appearance, with the Boulder rock. When the Geol. Survey was packing up to move from Denver, Mr. Cross gave me a boulder taken from Clear Creek near Georgetown which was a white quartz porphyry with well developed *di-hexagonal* crystals but with no mica, and hence not liable to be confounded with this.

I always think of the rock as being comparatively recent, but would not state a positive opinion as to its age. In one or two clear cases the rock seems to intercalate Triassic (?) beds.

Chemical Department, University of Colorado,
Boulder, Colo., Dec. 1, 1890.

ADDRESS OF THE RETIRING PRESIDENT.

R. C. HILLS.

Before taking up the subject I shall present to you this evening, permit me to occupy your attention for a short time with a brief review of the progress of the Society.

The year now drawing to a close will rank as a prosperous one in the history of our organization. The increase in the volume of our annual proceedings is most gratifying, while the several papers that have been submitted to you testify, in themselves, to the importance of the work performed. Meanwhile, our collections have been enriched by a large number of rare and valuable specimens, and the additions to our library include many publications that are new to our list of exchanges. Such results are certainly encouraging, whether we regard them as an evidence of growth, or as a stimulant to the further development in our midst of that true spirit of investigation so essential to the advancement of pure science.

Scarcely less gratifying, is the promising outcome to the experiment made last summer of holding two or more meetings each year somewhere outside of Denver. This is simply the partial application of a plan which has long been in vogue with national scientific bodies, both in this country and in Europe, but has not, so far as I am aware, been adopted by state or metropolitan organizations.

The benefits which may result from the successful carrying out of this plan, are (1) the opportunity afforded non-residents of taking an active part in the deliberations of the Society. (2) Exchange of ideas in the field in presence of facts bearing on geological and other questions. (3) The collection of material for the museum ; and (4) the tendency to popularize the organization.

There can be no doubt of the desirability of encouraging non-resident members to interest themselves in the affairs of the Society; nor can the advantage of mutual observation and counsel in the field be overestimated. The building up of a natural history museum is one of the principal objects we have in view, and whatever tends to increase the scope and value of the different departments will be an important aid to our future development. I firmly believe that the possession of a large and well-appointed museum will be one of the surest means of perpetuating the existence of the Society and of increasing its effectiveness by attracting to its ranks not only the students of science but many among the more intelligent and well-disposed who are capable of appreciating its objects and fostering its growth.

The tendency to popularize our institution, and keep it prominently before the public, is a commendable feature of the proposed plan. Popularity of the right kind is something we are always ready to welcome, and at the present time, more than ever before, it is advisable that we should cultivate the good-will of the educated public. It is evident that, if we are to accomplish in the fullest sense the purpose that binds us together, we must be unremitting in our endeavors to strengthen the Society financially, so as to meet the increased expense contingent upon expansion. To my mind the most practicable way to achieve this result will be to largely increase our associate membership by enlisting the services of all right-minded men in the undertaking. I have no doubt that a great many persons could be found who would be quite willing as associates to rally around the scientific nucleus, and give the Society financial support, if they could only be made acquainted with the objects of the organization. Hence the first step must necessarily be to make these objects well and favorably known.

In carrying out this idea it is not in my opinion advisable that we should, as popular lecturers, become teachers of elementary science—as some have suggested. As an organization our province is to discover and record, and popular teaching falls naturally within the province of educational institutions. With us the field for investigation is so large that there is an abundance of material for all who possess the leisure and inclination to undertake original research, and if time were given to popular work it would often be at the expense of research work. On the other hand we may with propriety, even as a scientific body, publicly announce the papers to be read at the regular monthly meetings and invite the attendance of all persons specially or generally interested in the subjects discussed. I believe that a great many residents of Denver would gladly avail themselves of the opportunity to attend our meetings, and it would doubtless be to our interest to afford them this opportunity whenever important papers are presented. The adoption of this plan at our provincial meetings would generally insure a large attendance, since mine superintendents, engineers and assayers are all more or less interested in the majority of the subjects brought before the Society.

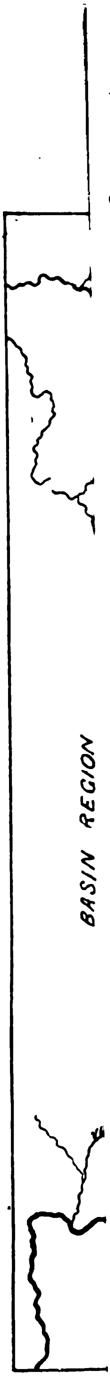
I have therefore to urge, (1) that whenever important papers are to be communicated, the same shall be publicly announced, accompanied by an invitation to those interested in the special subject to attend the meeting; and (2) that the holding of two or more provincial meetings during the summer months, be made a permanent feature of the annual programme.

OROGRAPHIC AND STRUCTURAL FEATURES OF ROCKY MOUNTAIN GEOLOGY.

During the past year, two important memoirs have appeared relating to Rocky Mountain geological dynamics. The first, by Prof. J. D. Dana on "The Rocky Mountain Protaxis," treats largely of the post-Cretaceous movement; while the second, by S. F. Emmons on "Orographic Movements in the Rocky Mountains," treats of the several movements up to and including that of the post-Cretaceous. These memoirs cover the ground pretty thoroughly as regards Palæozoic and Mesozoic times. The present contribution will refer mainly to movements in Cenozoic time, and more especially to the orographic and structural effects of post-Bridger and later disturbances, and attendant eruptions, as exemplified in the geology of the south-central Rocky Mountains. It will be necessary, however, to refer briefly to disturbances of early geological times in order to call attention to certain points not previously noted by workers in this field, and to render more intelligible the subsequent discussion of the Cenozoic movements.

ARCHÆAN DISTURBANCES.

The principal lines along which flexing has taken place no doubt were, as King maintains, already determined by the post-Laurentian movement, which inaugurated the pre-Cambrian land conditions of central Colorado and of the Basin Region west of the Wasatch Range. The uplift of the Unita Mountains may be cited as a possible exception to what may otherwise be considered as an established fact. But the unconformity of the Red Creek quartzite with the Unita sandstone, observed by Powell and Emmons, may be regarded, even in this case, as evidence of coincidence with a post-Archæan elevation—an



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inference which derives some support from my own observations on the White River Plateau. This uplift is directly connected with the Unita by a continuous line of flexure—the Axial Basin fold—produced by contemporaneous movement along a common axis, as I will explain beyond. On the summit of the plateau the Unita sandstone (Cambrian ?) containing worm tubes like the *Scolithus* of the Potsdam, rests immediately on the granite mass of the uplift; thus indicating the existence of a land area in pre-Cambrian and early Cambrian times. It seems probable, therefore, that a post-Laurentian ridge extended through that locality in a direction corresponding approximately with the line of post-Cretaceous uplifting passing through the Unita Mountains to the Wasatch Range.

The lines of post-Laurentian flexures correspond, in a general way, to the trend of the existing mountain ranges. Those which were portions of pre-Cambrian land-masses, or submerged ridges, include the Medicine Bow, Front, Wet Mountain, Park, Mosquito, Sawatch, Sangre de Cristo, Toas and Conejos ranges; the plateaus of the Uncom pahgre, White River and Unita; the Vernal Mesa and the San Juan and La Plata Mountains. In northern New Mexico the Moreno Range, east of the Moreno Valley, lies between the southern prolongation of the Wet Mountain axis and the Toas Range. The absence there of sediments older than the Cretaceous indicates an Archæan ridge that was not submerged until about the time of the movement supposed to have occurred at the close of the Jurassic.

In central and southern New Mexico, and in the corresponding regions of Arizona, there are Archæan areas which evidently remained unsubmerged until the Carboniferous; while others do not appear to have been submerged at all.

Through Colorado to the Wyoming line the course of the Front Range is nearly north-and-south. In southern Wyoming, the Archæan body of the Laramie Hills forms the northern extension of the Front Range in the direction of its axis; the more elevated Medicine Bow Range curving northwesterly away from this axis. The range of the Laramie Hills also curves northwesterly as it approaches central Wyoming. In the Sweetwater region, there is a broad Archæan area which may have formed part of a pre-Cambrian land-mass with its southern border near the present east-and-west uplifts of the Sweetwater, Ferris and Seminoe Mountains. The Park Range fold is essentially parallel with the Medicine Bow fold, but extends further to the northwest. The Wet Mountains may be considered as the continuation, *en èchelon*, of the Front Range. The Unita-Sawatch fold pursues a nearly meridional course from the Conejos Range of northern New Mexico to central Colorado where it curves northwesterly through the White River Plateau and passes into Utah on an east-and-west line. The Vernal Mesa, Uncompahgre Plateau and La Plata uplifts are essentially east-and-west folds, parallel with each other and with the Unita-Sawatch fold with which they apparently consolidate in the eruptive area of the San Juan Mountains, and thence extend southward as the Conejos Range. The Mosquito and Sangre de Cristo ranges are mainly post-Mesozoic uplifts formed along the eastern border of the Sawatch-San Juan land-mass.

Previous to the Cambrian the areas of the Medicine Bow, Front, Park and Wet Mountain ranges formed the main part of the Colorado Island of Emmons; while the areas of the Sawatch, Mosquito, Sangre de Cristo, Conejos and Toas ranges, the San Juan Mountains and Vernal Mesa formed a land-mass which included the Sawatch Island of the same author. The area of the White River Plateau may have existed for a time as an independent island but was submerged early in the Palæozoic. Another small independent island may have existed in the vicinity of the La Plata Mountains, but was consolidated with the main San Juan peninsula before the beginning of the Silurian. The area of the Conejos Range of northern

New Mexico was probably connected with the Toas Range area to the east across the present valley of the Rio Grande, and so remained up to the time of the post-Carboniferous movement if not later. During the Algonkian Period the region of the Uncompahgre Plateau probably formed a peninsula connected with the San Juan area, but may have been entirely cut off from this area previous to its complete submergence at about the time of the post-Carboniferous movement.

There can be little doubt, as Emmons maintains,* that the principal land-masses existed as such, though with gradually diminishing areas, throughout the Palæozoic and Mesozoic up to the time of the post-Laramie revolution, and that they were never more than partly submerged.

PALÆOZOIC DISTURBANCES.

The post-Archæan movement consisted in a slight elevation of the southern end of the Sawatch Island, and probably of the northern end of the Colorado Island, sufficient to lift certain areas of pre-Cambrian deposits above the level of early Palæozoic sedimentation. At the same time the northern shore-borders of the Sawatch Island, together with the southern shores of the Colorado Island, slightly subsided and a limited thickness of Cambrian sediments was deposited in the adjacent seas. This movement also effected the complete submergence of the area of the White River Plateau, though, even here, subsidence was much less than in the adjoining Uinta region and in the Wasatch.

The slight movement at the end of the Cambrian was one of subsidence around the main Sawatch body and western part of the San Juan peninsula, and probably of elevation around the Colorado Island and eastern San Juan border.

* Orographic Movements in the Rocky Mountains. Bulletin of the Geological Society of America. Vol. I, p. 252.

The movement which terminated the Silurian seems to have been one of general elevation, since no recognizable Devonian sediments appear between the Silurian and Carboniferous. Nevertheless, our present limited stratigraphical knowledge of the beds referred respectively to these ages does not warrant the assumption that Devonian strata are wholly wanting in this part of the Rocky Mountains. Nor is it strictly true as generally maintained that the Carboniferous is everywhere conformable with the Silurian when broadly considered.

The first important subsidence of the land initiated the Lower Carboniferous Period. By this movement large portions of New Mexico and Arizona, the regions bordering the Sawatch and San Juan, together with the western and Wyoming borders of the Colorado Island, were depressed, and a considerable thickness of calcareous sediments accumulated in the surrounding seas. This subsidence appears to have continued with but little interruption up to the beginning of the Upper Carboniferous. The Middle Carboniferous beds bordering the northern portion of the Sawatch consist mainly of soft, light-colored gypsiferous deposits with bituminous shales sometimes containing a little coal. The strata are more or less variegated in color as they approach the base of the "Red Beds." Whether the whole belongs to the Middle Carboniferous, or the upper portion to the Upper Carboniferous is uncertain. These soft beds are scarcely noticeable in southern Colorado. In the San Juan region they are represented by sandstones and conglomerates,* and along the eastern flank of the Sangre de Cristo by limestones, sandstones, clays and shales sometimes containing beds of coal.

Post-Carboniferous Movement.—During the Upper Car-

* Mr. Chas. D. Walcott, who kindly examined a few shells from this horizon, expressed the opinion that they indicated the lower part of the Carboniferous. If a more complete collection should substantiate this view, it will tend to show that the Upper Carboniferous is absent in San Juan, and possibly the upper part of the Middle Carboniferous also.

boniferous there was a marked change in the character of the sediments deposited in the Elk Mountains and Sangre de Cristo. This change was evidently related to the post-Carboniferous movement recognized by Stevenson and discussed at some length by S. F. Emmons in his memoir already cited. The views there advanced are confirmed by my own observations in the same regions. By this movement the Toas-Sangre de Cristo border was greatly depressed, so that this portion of the San Juan area may have been separated for a time from the Sawatch land-mass to the north. On the other hand the eastern border of the Wet Mountain area, the margin of the Colorado Island and the northern border of the Sawatch Island, were to some extent elevated ; while the Uncompahgre Island was nearly if not completely submerged, and so remained until the time of the post-Laramie movement.

In the Elk Mountains and Sangre de Cristo the presumably Upper Carboniferous beds consist of very coarse conglomerate from 3,000 to 6,000 feet in thickness. In the former locality Emmons observed pebbles containing Carboniferous fossils—indicating that by previous movement Carboniferous beds had been elevated into areas of erosion. At the same time the enormous thickness of the conglomerate points to long-continued, steady subsidence of the areas receiving sediments. In the western San Juan region the strata between the Lower Carboniferous and the "Red Beds" are quite limited in thickness, and apparently graduate into the "Red Beds," so that the western border of the San Juan peninsula underwent but little if any subsidence. One of the most remarkable features connected with this epoch, and one that has yet to be explained, was the superabundant deposition of sediments in strong shore currents. Both in the Elk Mountains and Sangre de Cristo the source of the material is equally uncertain. From his study of the former region Emmons expressed the belief that the material there deposited was probably derived from some area south of the Elk Mountains near the head of the Gunnison Valley and north end of San Luis Park. It may be noted in this connection that only strong ocean currents could transport such coarse material and distribute it so far along the Sangre de Cristo and Elk Mountain borders of the land-mass. There seems to be some basis for the belief that the San Juan and Sawatch areas were for a time entirely separated from one another and that during this interval there was a strong northwesterly current or tidal flow across the depressed area and present continental divide—thus effecting the distribution of the material of the Sangre de Cristo and Elk Mountain conglomerate. In this manner it may be possible to trace the local occurrence and enormous thickness of the conglomerate to the force and direction of the new ocean currents set up by the temporary separation of the San Juan peninsula from the Sawatch body to the north. According to this view the source of the Elk Mountain beds would be the eastern and northeastern portions of the San Juan Island, from which we may suppose the greater part of the Sangre de Cristo conglomerate was derived ; although some of it may have been transported from the region of the Moreno Mountains to the south.

It is evident that a movement which would permit the deposition of conglomerate to the depth of a mile or more, within comparatively narrow limits, must have been associated with important orographic changes ; and whether or not ocean waters at that time connected the two localities, their position with reference to each other indicates a connecting depression, transverse to the axis of upheaval, at what was evidently the weakest point between the two uplifts. The post-Carboniferous movement of the Colorado archipelago was apparently synchronous with the elevation of broad areas in the western continental region and in the Appalachians, so that this part of the Rocky Mountains was clearly in sympathy with the general disturbances then in progress.

Post-Palæozoic Movement.—The effects of the succeeding movement—that of the post-Palæozoic—was a rise of the eastern border of the San Juan land-mass and a depression of the western. At the same time the entire borders of the Sawatch and Colorado bodies were evenly depressed. The Wet Mountain body was also in a measure a subsiding area as regards its eastern border. If any portions of the Uncompahgre Island still remained above ocean level there is no question but they were completely submerged by this movement. Assuming that the San Juan area was separated from that of the Sawatch during the epoch of the conglomerate, the two were again connected by post-Palæozoic elevation. It seems probable that at about this time a connection was formed between the Colorado and Sawatch islands by way of the northern Wet Mountain region, so that throughout the Mesozoic they were no longer independent land-masses but were consolidated into one long island extending from southern Wyoming into northern New Mexico. The park depressions, which appear to have received sediments throughout the Palæozoic, were still connected with the western ocean by means of the depression between the Park Range and Gore Mountain uplifts. In central Wyoming, the Palæozoic strata on the southern border of the Archæan body—which since the Cambrian was probably separated from the Colorado Island by a submerged area in the region of the Laramie Hills—have about the same development as observed in western and southwestern Colorado, so that as regards limited subsidence and sedimentation the two regions are nearly related and in strong contrast with the Wasatch region, which was one of profound subsidence and great depth of sediments. A similar contrast is afforded between the Palæozoic areas of New Mexico, or even eastern Arizona, and the Plateau Province, also a region of abundant sedimentation, apparently, in the southern extension of the Wasatch Palæozoic trough.

East and west of the consolidated Colorado land-mass the character of the "Red Beds" which were deposited after the post-Palæozoic movement, indicate shallow-water conditions throughout. It may be well to remark here that up to the present time no Permian beds have been recognized in the Rocky Mountains, although there is a probability that certain beds in the Uinta Mountains may be the equivalent of Permian beds elsewhere. The beds referred to this age in Texas, as shown by C. A. White* are by no means the equivalent, palæontologically, of the Permian of Europe; while Dr. Newberry† has expressed the same opinion with regard to the American Permian as a whole.

In the "Red Beds" near Fairplay, Colorado, Prof. Lakes found remains of plants and insects which, according to the determinations of Lesquereux‡ and Scudder,§ render it uncertain whether the beds containing them are Triassic or Permian. As I shall presently show the stratigraphical evidence likewise suggests uncertainty as to the age of the "Red Beds."

MESOZOIC DISTURBANCES.

These beds have by common consent been referred to the Trias, though to what portion has not been determined since, except at Fairplay, no fossils have been found in them. The term "Red Beds" as here understood applies to the formation of dark-red or bright-red, sometimes pinkish, heavy-bedded sandstone immediately succeeding the Upper Carboniferous when the latter is present. It is, therefore, not applied to the remaining beds of the Trias such as occur in the western San Juan region, nor to the Upper Trias recognized by Eldridge along the eastern

* Proc. A. A. A. S., Vol. XXXVIII, Toronto Meeting, 1889.
† Intern. Cong. Geol., Berlin Meeting.
‡ Am. Jour. Sci., Vol. XXV, page 157.
§ Am. Jour. Sci., Vol. XXVIII, page 199.

base of the Front Range.* East of the Sangre de Cristo the Upper Carboniferous conglomerate is in places capped by about 50 feet of red sandstone lithologically identical with the "Red Beds" and underlying the fresh-water Jura exposed there. In many localities, for instance the Morino Range, Wet Mountains, Vernal Mesa, Treasury Mountain and near Gunnison City, the Cretaceous overlaps the older Mesozoic beds, as may have been the case in other localities previous to erosion. Elsewhere around the margin of the Mesozoic land-mass there is a nearly continuous outcrop of the "Red Beds" constant in character and for considerable distances evenly developed. Along the Front Range the red sandstone is succeeded by a bed of cream-colored sandstone included by Eldridge in the "Red Beds" formation. This sandstone is prominent as far south as the Garden of the Gods but has not been observed west of the range. Of the 600 feet of sediments in the Denver Basin, termed Upper Trias by Eldridge, the upper pink sandstone layer has its lithological equivalent at the top of the Trias on the upper White, and is no doubt represented in the exposures of the upper Grand, the Eagle and elsewhere along the northwestern border of the Triassic body. It is also quite prominent in the Wind River Range of Wyoming.

Inter-Triassic Movement.—In the southwestern portion of the San Juan region the "Red Beds" are succeeded by an entirely different series of sediments. Beds of limestone conglomerate a few feet thick alternate with fine-grained light-colored sandstones, aggregating about 300 feet in thickness. These beds are exposed on the Animas, Dolores and San Miguel, but thin out and disappear to the northward and are not present on the Uncompahgre, though the underlying "Red Beds" are throughout very evenly developed. The "Red Beds" proper are non-fossiliferous. The overlying group contains, in the conglomerate, teeth

* Bull. Philo. Soc. Wash., Vol. XI.

and bones of saurians; and in the sandstones leaf impressions, and remains of fishes regarded by Dr. Newberry as allied to *Catopterus* of the Atlantic Coast Trias if not of that genus. With but one exception I have been unable to detect the remotest resemblance to the San Juan fossiliferous Trias in any of the central or northern Colorado exposures. On the edge of the platform southeast of Red Dirt Creek, and a few miles north of Grand River, there is a thin layer of the highly characteristic bone conglomerate exposed near the top of the Trias. It seems probable that a study of the beds in that vicinity might throw some light on the relation of the northern Colorado series to that of the San Juan Mountains. On the Animas and Dolores the fossiliferous beds are succeeded by about 200 feet of brick-red, somewhat shaly sandstone which does not extend as far north as the San Miguel. The increase in thickness of this sandstone to the southward suggests that it may be identical with the uppermost Trias of northern New Mexico, which was no doubt deposited in the neighboring waters of the southern shore-border of the same land-mass. There is, consequently, above the normally developed "Red Beds" of the southwestern San Juan region, 500 feet of strata not observed in the northern and eastern portions of that region—indicating 500 feet of additional local subsidence. While the physical conditions along the eastern border of the Front Range were evidently not altogether identical with the physical conditions then existing in southwestern San Juan, yet the local extent of the cream-colored sandstone and the succeeding Upper Trias points to a corresponding subsidence of about the same amount in the Denver Basin. Whether or not this subsidence affected the western shore-borders of the Colorado peninsula can only be determined by a more complete examination of the exposures west of the Gore Mountains.

From a study of the flora obtained from the northern New Mexico series at Abiquiu—the yellow sandstone overlying the "Red Beds"—Newberry decided that it indicated the horizon of the Rhetic or upper Trias of Europe. He intimates, however, that the "Red Beds" may represent the Lower Trias of Europe. There is a possibility that the uppermost beds of Abiquiu, San Juan and the Denver Basin may belong to the same horizon. However this may be the evidence afforded by the San Juan fossiliferous Trias, and the absence of Triassic sediments above the "Red Beds" elsewhere around this peninsula, is in itself conclusive proof of decidedly uneven subsidence following the epoch of the "Red Beds." The result of this subsidence was the depression of the San Juan region already referred to, and probably the eastern border of the Colorado peninsula. The region between these two borders, as well as the northern portion of the Sawatch and the floor of the shallow seas of northwestern Colorado and northern New Mexico suffered little if any depression. Hence, there was an inter-Triassic movement whereby along the western border of the San Juan peninsula the southern extremity subsided 500 feet more than the northern, and the same movement probably effected a like amount of subsidence along the eastern border of the Colorado peninsula. If this movement was not inter-Triassic, then the "Red Beds" are more nearly related to the Permian than is generally supposed—a possibility which is also suggested by the conflicting evidence presented by the fauna and flora of the South Park "Red Beds."*

There is one other point in connection with the San Juan Trias that is worthy of note, especially when viewed

* The small collection of fossils already referred to in a foot-note as having been examined by C. D. Walcott, and which indicate the lower part of the Carboniferous, were obtained from a pinkish conglomerate underlying the "Red Beds" on the Animas River. The two formations appear to graduate into one another. The palæontological and stratigraphical evidence taken together would certainly lead one, not familiar with current views as to the age of the "Red Beds," to regard them as Upper Carboniferous, or possibly Permian. Assuming that they are of Triassic age and that the Upper Carboniferous is wholly wanting in that region, post-Carboniferous elevation must be admitted.

in relation with the physical conditions of the Jurassic Period, and that is, the probable existence of fresh- or brackish-water areas of sedimentation. This is indicated by the remains of land-plants, and in the similarity of the saurian teeth to those figured from the Atlantic coast Trias where such conditions prevailed. The upper beds of the Abiquiu series, in which land plants abound, are evidently not of marine origin. Of the Triassic beds elsewhere little can be said other than that they are, throughout, shallow water deposits.

In central Wyoming the "Red Beds" and possibly others corresponding to the Upper Trias of Colorado and New Mexico, outcrop along the Sweetwater, Ferris and Seminoe mountains, and no doubt extend in a continuous sheet beneath the broad Cretaceous area lying between these ranges and the northern extension of the Colorado peninsula. Prof. White places the southern limit of Triassic sediments at about lat. 34°* which is not far from the truth. According to my own observations they are not present south of the Black Range exposures of New Mexico. Nor have I observed them anywhere in southern Arizona, though Dutton reports them present in the Zuni Plateau. Hence, there probably existed a large land area in southern New Mexico and Arizona, which separated the Triassic waters of the north from similar areas in Sonora where, according to the identification of fossil plants by Dr. Newberry, Upper Triassic beds undoubtedly exist.

Jurassic Movement.—The movement at the close of the Trias consisted of a general elevation of the entire area south of the Wyoming line. The upward tendency of the movement is indicated by the absence in Colorado of Jurassic beds characteristically marine, such as are present in Wyoming and elsewhere north and west.† This elevation

* Am. Jour. Sci., Vol. XXXVIII, pp. 440–445.

† The Jurassic beds east of the Wind River Range are lithologically identical or nearly so with the fresh-water beds of Colorado.

may have extended far beyond the borders of the Triassic land-mass, and have included the larger part of the area now occupied by Upper Jurassic sediments—a point which it will be necessary to consider in connection with the succeeding disturbance, that which followed the laying down of the marine, Lower Jurassic beds. The structural effects of this movement are not entirely separable from those produced by the previous one—that is, in the interval between the deposition of the uppermost beds of the Trias and the lowest of the fresh-water Jurassic, there were two distinct movements, separated by a considerable lapse of time, whose independent effects are more or less combined. These two movements have been ably discussed by S. F. Emmons* who includes them both under the general designation "Jurassic movement." During his careful investigations in the important districts of the Elk Mountains and Mosquito Range he recognized the fact that following the Trias there had been a period of elevation, erosion and subsequent depression accompanied by folding, faulting and uplifting previous to the deposition of the Upper Jurassic beds. It is a question, however, whether the greatest amount of disturbance was associated with the post-Triassic elevation or with the inter-Jurassic subsidence. The even distribution of the Upper Jurassic beds certainly indicates equality in the subsiding movement, while the deposition of these beds unconformably upon a floor previously elevated and planed down by erosion would lead one to infer that the greatest amount of disturbance was really associated with the post-Triassic elevation. This question must, however, like many others of the kind, await the result of more extended investigations before it can be fully answered.

The absence of Lower Jurassic beds in Colorado and New Mexico seems to be fairly well established. In the

* Bull. Geol. Soc. Am., Vol. I, p. 267.

region west of the range, especially in southwestern Colorado, there are countless exposures of Lower Mesozoic beds in localities far removed from the old shore-borders and where if Lower Jurassic beds were deposited remnants should be found to-day. So far as I am aware they have not been identified. The hornstone and bituminous limestone strata observed on the San Miguel between the fossiliferous Trias and the Dakota requires further study before it can be classed with the marine Jura. Moreover, it is extremely local being nowhere present in the exposures further west. The recognized Jura of the San Miguel and Uncompahgre valleys consists of indurated bluish-green shales, sometimes showing minute worm burrows, some variegated clays and a prominent bed of highly characteristic cherty conglomerate. Away from the shore line these give place to variegated clays, shales and sandstones so that such beds are characteristic of the Jurassic exposures along the Grand and Gunnison.

East of the range, along the mountain border, thin beds of limestone are generally present in addition to clays, shales and sandstones. Along the base of the Sangre de Cristo the Upper Jurassic sediments rest partly on Upper Carboniferous conglomerate and partly on thin remnants of the "Red Beds" which, apparently, graduate into the conglomerate. Along the Front Range the same beds are found resting on the upper of the two subdivisions of the Trias already noted. In the Elk Mountains, as shown by Emmons, along the Grand and Yampa the Upper Jura is found resting upon rocks of all horizons from the Archæan to the Upper Trias inclusive. In his remarks on the Mosquito Range, Emmons attributes the uplifting of this range, in part at least, to the Jurassic movement, whence he deduces a somewhat earlier age for the intrusive eruptives (porphyries and diorites) folded and faulted by it, or by the disturbances terminating it. The Mosquito fault which he has traced northward to within 20 miles of Grand River appears to have been produced by the same movement. To what distance northward this fault extends, remains to be shown. My own hasty reconnoissance work in the Park Range would not lead me to suppose that it extended as far north as Grand River, where the Mesozoic beds, upturned on the flanks of the range, lie at about the same elevation, as can be seen from the exposures at the upper and lower ends of Gore's Cañon. How far east the country was affected by the combined movements is mere speculation owing to the absence of Jurassic exposures in the Plains Region. Yet there can be little doubt from the great north-and-south geographical range of the fresh-water Jura that the disturbances were not confined to the immediate vicinity of the Front Range border.

In a general way the effects of the post-Triassic and inter-Jurassic movements may be briefly summed up as follows. During the latter part of the Trias, fresh-water conditions prevailed in southwestern Colorado, northwestern New Mexico and probably around the margin of the Colorado peninsula where sediments were being deposited. At the close of the Trias a wide-spread upward movement occurred, and extensive areas in Colorado and in the adjacent regions north and south were elevated, and subjected to erosion during the epoch of the marine Jura; after which the entire region again subsided, with faulting and probably folding, to near its previous level and fresh-water conditions again prevailed.

Early Cretaceous Movement. — The succeeding movements, as affecting the Rocky Mountains, involve a series of disturbances beginning with the close of the Jura and extending through early Cretaceous times to the epoch of the Dakota sandstone. For the sake of convenience it will be referred to here as the early Cretaceous movement, to distinguish it from the post-Jurassic movement of King which probably corresponds in time to the inter-Jurassic subsidence of the Rocky Mountain Region. Orographically considered, the Lower Cretaceous disturbances were of less importance than those of the Jurassic, though their effects were yet more wide-spread and prolonged. Elevation seems to have taken place over the greater part of the region lying between the eastern and western continental masses, sufficient to exclude ocean waters from the area previously occupied by the Mediterranean sea; so that, excepting the lacustrine beds of the Kootanie group, no sediments are known to have been deposited from the close of the Jura to the beginning of the Upper Cretaceous represented by the Dakota sandstone. That this period of land conditions corresponded to a considerable lapse of time, is indicated by the great thickness of Lower Cretaceous beds which accumulated in Texas. These beds, (Comanche group) have not yet been identified in the Rocky Mountains, although there is a possibility that certain beds of undetermined age and local extent may belong here. Where the Cimarron cuts through the Moreno Range there is exposed, below what is usually regarded as the Dakota, a considerable thickness of light-colored massive sandstone which may be the equivalent of the Texas Neocomian. There are also certain shales and sandstones in the Dolores region which Holmes, 14 years ago, regarded as Lower Dakota. It is probable that these beds are either Jurassic or else Neocomian.

Judging from the limited amount of erosion to which the Upper Jurassic beds were subjected previous to the Dakota Epoch, the Lower Cretaceous elevation was nearly equal throughout and unaccompanied by great disturbances even in regions of former violent dynamic movement. The absence of pronounced erosional effects after so long a period as that indicated by the whole of the Texas Neocomian shows conclusively that while the region in question was undoubtedly elevated beyond the reach of ocean waters, it was, nevertheless, not sufficiently elevated to admit of more than incipient denudation. This, of course, only applies to that extensive portion of the region not included by the body of early Cretaceous highlands. There can be no question that around the pre-existing grand uplifts the Lower Mesozoic and older sediments were partly upturned and in places deeply eroded, so that they were overlapped by the succeeding Dakota which may be observed to-day resting directly on Lower Palæozoic rocks and even on the Archæan. Nor is the unconformity merely confined to simple transgression and divergence of strike, for there is in places a perceptible angular unconformity, for instance in the San Juan region and especially below Dallas on the Uncompahgre. It is, therefore, quite evident that this movement was not altogether wanting in orographic effects. The subsidence which inaugurated the Dakota Epoch was probably one of progressive advancement from the southeast, permitting the even deposition of a comparatively thin bed of sandstone over a vast area. West of the principal uplifts the Dakota is less a distinctively sandstone formation, and shale beds, and even coal of workable thickness, become characteristic of it. This subsidence was the initial stage of the great depression of the region which followed the Dakota Epoch and gave rise to marine conditions more wide-spread and complete than had hitherto existed since the close of the Carboniferous.

Late Cretaceous Movement.—Of the two principal groups of the marine Cretaceous of the Rocky Mountains, the Colorado group is the most constant in lithological definition and development, indicating a fairly regular subsidence which, judging from the usual occurrence in the Niobrara or upper sub-division of the Colorado, of limestones abounding in foraminifera, may have been sufficiently profound to establish pelagic conditions.

The variations observed in the thickness of the marine Cretaceous are generally due to expansion or contraction of the beds of the Montana group. In this part of the

Rocky Mountains there is no record of a time of brackish-water sedimentation in the interval between the Colorado and Montana, such as existed in the Belly River country to the north, though in the Sweetwater region shallow-water conditions at about this time are indicated by the occurrence, at or near the same horizon, of as much as 200 feet of rather coarse sandstone containing an abundant marine fauna. Elsewhere there was simply an abrupt change from the calcareous deposits of the Niobrara to the mainly argillaceous deposits at the base of the Fort Pierre. We have yet to discover positive evidence of the erosion of the Montana beds preceding the Laramie even where the line of separation can be clearly made out, for example, in the Raton region; while in northwestern Colorado the gradual lithological transition of this group into the Laramie renders it very doubtful if any reduction in thickness can be attributed to erosion of the Montana beds. In some cases the variation in thickness can be explained on the ground of irregular post-Niobrara movement as noted by Eldridge in the Denver basin. At the same time part of this variation must be credited to the inequalities of a subsidence measured by from 3,000 to 10,000 feet of strata.

Towards the close of the marine Cretaceous the subsidence was evidently very gradual and not equal to the thickness of sediments deposited. As a consequence there was a steady shallowing of the waters and an increased deposition of sandstones. The movement which occurred during the Laramie, and continued up to the end of the Cretaceous, was of the same character as the preceding and may be regarded as a continuance of it, with like irregularity and gradual decrease in rate of subsidence.

The Laramie Movement.—As just intimated, the subsidence during the Laramie Epoch was not equal throughout the region affected by it, though the relative amount in different parts of the Rocky Mountains is not easy to approximate owing to the difficulty of defining the vertical range of the formation itself. Considered as a whole, it is the uppermost of American Cretaceous terranes, of brackish-water origin at the base and fresh-water origin near the top; with a prevalence of light-colored, often massive, sandstones and important beds of coal. The upper and lower members are, nevertheless, but seldom clearly distinguishable from the beds of the nearest related horizons, and in some localities the transition from one to the other takes place through several hundred feet of strata. This is noticeably the case in northwestern Colorado where, as the Laramie merges into the Montana, the successive beds of sandstone become further and further removed by the constantly increasing thickness of the intervening shales until finally the former disappear entirely. Where the line should be drawn under such circumstances is generally a difficult question since fossils are only abundant in a few localities and lithological characters are usually the only aid in identification. In the Raton coal field the Laramie, with its coal beds and strata abounding in plant remains, is readily distinguishable from the marine Cretaceous below, the light-colored massive sandstone underlying the lower coal bed changing within a vertical distance of 90 feet into thin-bedded sandstone containing *Baculites*. In the Grand River coal field the lithological distinction between the coal measures and the Montana beds may in many places be sufficiently complete for practical purposes, as it is in Coal Basin for example. Yet in strata above the great workable beds we find marine shells such as *Inoceramus*, and below these again a bed containing great numbers of brackish-water shells, not as a mere local occurrence but as a characteristic of that particular horizon for a distance of over 50 miles along the outcrop. Again, on the North Fork of the Gunnison, the same coal beds are overlaid by sandstone containing remains of land plants. It seems that we have here evidence of an alternation of marine and brackish-water conditions, such as might be possible during the period of transition from the Montana to the Laramie, wherever the inequalities of the subsiding movement were pronounced; and in this connection it should be stated that where the marine shells occur there is evidence in the convergence of the coal beds as they leave the old shore-line, of a synclinal depression along the latter, to the amount of about 100 feet, formed while the lower portion of the coal measures was being deposited.

East of the continental divide the entire series of coal-bearing strata was by Hayden referred to the Laramie, an assignment the correctness of which no one will question; but in the Grand River and La Plata coal fields the whole of the coal-bearing series was by the same authority referred to the Pierre-Fox Hills (Montana) presumably on the evidence of marine shells which, as I have shown, are not entirely wanting, while the evidence afforded by the remains of Laramie plants seems to have been overlooked. There can be no doubt of the Laramie age of the coal-bearing formation both east and west of the continental divide, yet just where the line should be drawn between the Montana and Laramie on the west side of the main range is still an open question. If this line is to be determined on the basis of faunal remains the result may be that in places we shall have a theoretical separation into two groups, of what is practically a continuous series of measures. For economic reasons we could wish that the base of the Laramie were made to coincide with the base of the productive coal measures, or, what amounts to the same thing, with the lowest strata containing land plants. It may be well to explain, however, that the base of the productive measures does not always include the lowest coal seams exposed. In the Coal Basin section, which probably affords the best lithological definition of the Laramie in western Colorado, the shales of the Montana group, containing some thin layers of fine-grained sandstone, graduate rapidly into heavy-bedded light-colored sandstone which becomes massive toward the top and forms the base of the measures at that point. The thickest workable coal beds are found in the lower half of the measures, those near the base being better developed than others higher up. According to my own observations this is generally true of the Laramie of western Colorado. But in the region north of Grand River; relatively thin beds of sandstone, are often seen to alternate with shales for some distance below the base of the productive measures, and in such cases thin seams of coal are usually present. In these beds no land plants appear, but marine shells are abundant in a few places, so that in all probability they belong to the upper or Fox Hills portion of the Montana group. The presence of thin seams of coal is consistent with the shallow-water conditions of the times, when the formation of limited areas of marsh land might follow an excessive accumulation of sediments at points along the shore-borders. But such an operation has little in common with that required for the production of a great thickness of continuous workable measures. For the present, therefore, as in a former discussion of this question.* I shall regard the base of the Laramie as limited by the base of the productive measures, or by the bed of massive sandstone usually found immediately below the lowest workable coal bed.

In defining the upper limit of the Laramie group, if we accept the view now current that it is the uppermost of the Cretaceous terranes, and not in the ordinary sense transitional, we meet with the difficulty of distinguishing between that portion which is undoubtedly Laramie, and that portion which may be in part transitional or even early Tertiary. This difficulty has been recognized by Prof. C. A. White who, as late as 1888, in discussing the

* Coal Fields of Colorado. Proc. Colo. Sci. Soc. To appear in a future publication.

relations of this group to other formations, says: "Judging from my own investigations, it is regarded as impossible to draw either a palæontological or stratigraphical dividing line between the Cretaceous and Tertiary portions of the Laramie group."* No doubt, the Laramie has been more fully explored than any other group of equal geographical extent in the Rocky Mountains. Yet most of the work performed has been in the nature of geological reconnoissance, and I am strongly of the belief that in many localities a careful study of the composition of the sediments will show that at least a stratigraphical dividing line can be drawn.

Theoretically, the Laramie Epoch terminated with the beginning of the upward movement which ushered in the Eocene Epoch. This movement was wide-spread, and not only greatly emphasized the pre-existing orographic features, but created others, so that entirely new areas were exposed to erosion and a change in the composition of the sediments was among the earliest results. Local flexures, tending to produce recognizable angular unconformity, were not developed in a marked degree by this movement. Hence, the composition of the sediments deposited after it must be mainly depended upon to distinguish them from others which were deposited before it. I do not doubt, that as systematic studies are extended it will appear less difficult than formerly to separate the true Laramie from beds now included with it which are either transitional or early Tertiary. Further on I shall endeavor to point out certain facts bearing on the identification of the beds in question, and for the present I shall regard the base of these beds as the upper limit of the Laramie group.

The strata referred to this group are known to occur in northern Mexico, and through the Rocky Mountain region far north into British America it is the principal

* Am. Jour. Sci., Third Series, Vol. XXXV. p. 438.

coal-bearing formation. In Colorado the Laramie originally occupied two great basins separated from one another by the broad body of the old consolidated land-mass. West of the continental divide the strata appear to have extended continuously from northern New Mexico and Arizona to central Wyoming. South of the Gunnison a broad area of erosion separates the Grand River and La Plata coal fields which were doubtless once connected, for at the present time the coal measures cap the elevated table land of Mesa Verde, as far north as Sierra El Late, and a long, narrow remnant is still preserved by the protecting eruptive cover of Tongue Mesa in the San Juan Mountains. In North Park, the coal-bearing strata outcrop near the base of the Medicine Bow Range and have been reported, on trustworthy authority, from the opposite side of the basin at the foot of the Park Range, near the divide separating the Grand and North Platte drainage. If Laramie beds were ever deposited in Middle Park they have since been removed by erosion, the beds assigned by Hayden to this epoch are not only not coal-bearing, but, as S. F. Emmons has pointed out, were probably deposited after the post-Cretaceous or, more properly, post-Laramie movement. Yet a narrow strip of Laramie beds may at one time have extended along the western, or Park Range, border of Middle Park ; and so have connected the North Park and South Park areas. Westward, the Laramie can be traced, with but slight break in continuity, from the borders of the Sawatch and Park Range uplifts to the eastern base of the Wasatch Range. East of the continental divide, the persistency of the Montana strata, and the fact that a remnant of the Laramie is still preserved near Cañon City, indicates the probability that the Raton and northern Colorado coal fields once formed a continuous series of measures, covering the eastern half of the State and extending as far south as the Cimarron in New Mexico. The area of erosion in the region of the Laramie

Hills now separates the northern Colorado field from the nearest Wyoming field, that of Carbon County—though previous to the post-Cretaceous movement the two fields were probably connected. In San Luis Valley, Laramie beds have not been discovered ; nor have other Cretaceous beds been recognized, so that the Sangre de Cristo Range was probably the eastern border of the San Juan peninsula up to the close of the Mesozoic Era.

In the Raton field, where the base of the Laramie is well defined, the total thickness below the succeeding beds of the Poison Cañon group is, roughly measured, nearly 5,000 feet both on the Cuchara and in the country between Rouse and the Spanish Peaks. In the Raton Mountains, where the basaltic overflow covers a broad plateau of Laramie beds, the thickness is about 3,000 feet. At Cañon City—near Alkali Gap—there is but 1,300 feet of Laramie strata between the marine Cretaceous and certain beds containing eruptive debris which are thought to be of post-Laramie age. In the Denver Basin, Eldridge reports only 1,200 feet of measures below the Arapahoe beds. West of the main range the greatest development is along the Great Hogback on Grand River, where, according to rough measurements, there is from 3,000 to 3,500 feet of measures below the Ruby beds. This decreases to about 2,000 feet in Coal Basin, and scarcely more than 1,000 feet is exposed underlying the Ruby beds in the Anthracite Range. On the Yampa River, and in Twenty-Mile Park, the thickness may approach 2,000 feet. On the southern margin of the Grand River field, from Grand Mesa across Green River to Castle Gate in Utah, the variation in thickness is not noticeable, this region being somewhat remote from the principal centers of disturbance.

The difference in thickness of over 3,000 feet observed between the Laramie of the Spanish Peaks region and the same group in northern Colorado and the Anthracite Range for example, cannot be due wholly to post-Cretaceous elevation and erosion in the last named districts. There is no question but that elevation and erosion preceded the laying down of post-Cretaceous sediments, and it is possible that the areas receiving these sediments were previously deeply eroded; though it is evident that they were relatively areas of depression rather than elevation, and that part of the difference may be attributed to unequal Laramie subsidence. Such, indeed, can alone explain the variation in the distance between continuous beds of coal, as I have had occasion to note in the Raton field, and in Coal Basin where the distance between the three lower seams varies as much as 75 feet in about three miles; the greatest variation being at the points nearest to the old shore line—indicating that gradual flexing was in progress along the border of the Sawatch body, probably accompanied by elevation of the latter, during the Laramie Epoch. With this exception, there is no proof of dynamic disturbances of orographic importance, and so far as can be discerned the Laramie movement was simply one of uneven subsidence possibly accompanied by slight flexing.

The orographic events of early geological times may be briefly summed up as follows. The post-Carboniferous and inter-Jurassic movements—which were to some extent associated with lateral compression, folding and displacement—being excepted, there is little evidence of crumpling and linear diminution from pre-Cambrian time to the close of the Mesozoic. Yet, during this long interval, an average of not less than 20,000 feet of sediments, derived, directly or indirectly, from the Archæan bodies was deposited in the surrounding seas. We cannot believe that the sediments of the Colorado area were derived from any other source, or that the beds of western Kansas, Nebraska and Texas were wholly derived from more remote regions since, even as late as the Pliocene, eruptive debris from the Rocky Mountains was transported as far east as western Nebraska. But, when we consider that the Archæan area subjected to denudation, and which furnished the material of 20,000 feet of strata, was never more than one-sixth the area of sedimentation, it is evident that, from the beginning of the Palæozoic to the close of the Laramie, a quantity of material equal in the aggregate to a mass 20 miles high over the entire area of erosion was converted into sediments. One cannot suppose for a moment that, in the early Palæozoic, the islands of the Colorado archipelago had a mean elevation of 20 miles. Hence the conclusion that since the beginning of the Cambrian, there has been a gradual, sometimes intermittent, upwelling of Archæan material along the granite axes of the ranges, responsive to a varying rate of subsidence of the areas of sedimentation. This view of the gradual squeezing up of the Archæan bodies of the Rocky Mountains—an operation which I do not hold was wholly unaccompanied by compressive stress—postulates a degree of plasticity in the crystalline basement rocks not easy to comprehend. Yet the conditions which are supposed to exist at but a few miles below the earth's surface might, under the constant pressure of accumulating deposits, develop sufficient viscosity in masses of such magnitude as to admit of a slow upwelling, essentially imperceptible and no greater in the aggregate than the rate of erosion.

Cenozoic Disturbances.

Post-Laramie Beds.—The fact has been very generally recognized that during the latter part of the Laramie purely fresh-water conditions prevailed in the Rocky Mountain Region. The effects of physical changes following dynamic movement, would be less noticeable after the cessation of marine conditions than before ; consequently, when the evidence of such changes seems unquestionable it is entitled to more than ordinary consideration. Evidence of this character, indicating great disturbance, is not wanting in the upper portion of the beds in Colorado previously assigned on palæontological grounds to the Laramie group, or at least to the Upper Laramie. On both sides of the main range, the sections of the Laramie measures show a gradual transition from base to summit. The lower members are shales and sandstones, in nearly equal proportions, always associated with thick beds of coal. In ascending order the proportion of shales to sandstones gradually decreases until, finally, the latter largely predominate; so that firm, and often coarse-grained sandstones are everywhere the lithological feature of the upper part of the measures. This decrease in the thickness of successive shale-beds is associated, in a general way, with a marked decrease in the aggregate thickness of the successive groups of coal beds, and toward the top of the measures it is only in a few localities that seams of economic value exist. West of the continental divide, we usually find the massive sandstones overlaid by other beds, which, in the composition of their sediments, exhibit decided proof of a change of physical conditions. These beds have, throughout, been referred by Hayden and his assistants to the Laramie, and may correspond to what Dr. White had in mind when speaking of the Tertiary portion of this group. Beds which appear to belong here, are exposed on the Yampa River near Hayden, and extend down the valley to and below Craig. They consist of soft sandy strata with some shales and clays, occasionally cross-bedded soft sandstone, and beds of lignite which are a distinguishing feature since the coals of the underlying productive measures (Laramie) are, without exception, semi-coking and of very superior quality. I may state here that this series of beds corresponds to nearly all that is laid down as Laramie on our present geological maps, the productive measures below—traceable without difficulty from the Elk Mountains northward—being referred to the Pierre-Fox Hills, and the beds above to the Wasatch Eocene. With regard to the latter I have no doubt that the identification is correct. The former, however, must be considered Laramie, if the same series in the Elk Mountains, in which Dr. Newberry has identified a true Laramie flora, is to be referred to that group. The question then is, to what age shall we refer the intermediate series of beds which are lithologically distinct from either of the foregoing? Before making any suggestions in reply to this question it may be better to consider the characteristics of similar beds in the Grand River region, Elk Mountains, Denver Basin and elsewhere.

South of the Great Hogback at Coalridge, there is an abrupt change in the composition of the sediments previously regarded as Laramie. The firm gray sandstones of the coal measures are there succeeded by about 200 feet of soft white sandstones and yellow clays, followed by about 300 feet of tufaceous strata, more or less conglomeritic and usually loosely aggregated, but resting on a hard, coarse basal conglomerate about 40 feet thick made up wholly of eruptive debris. The tufaceous beds are in turn succeeded by 600 feet or more of shales and soft brownish sandstones which may be in part of Wasatch age. Southeastward along the slope of the Great Hogback to the northern extremity of the Ragged Mountains, there is a gradual increase in the thickness of the tufa-beds and between the Ragged Mountains and the Muddy Fork of the Gunnison, although the thickness has not been measured, I should hardly feel warranted in assuming it to be less than 600 feet and it may be much more. The same beds also appear, of great thickness, on upper Anthracite Creek and around Ruby Peak where they are known as the Ruby beds—a term which may be applied to all the beds of this character in that region.

The sandstones and conglomerates of the Ruby beds are, apparently, the consolidated ejectamenta of explosive eruptions, assorted and stratified by the action of water; the material being entirely eruptive (andesitic) and of such a nature that it could not have been derived from any eruptive masses known to have existed in that region at the time it was deposited, nor from any known to exist there at the present day. The occurrence, as a secondary product, of an abundance of red heulandite is highly characteristic throughout. It is a fact of some significance, that the same substance has been observed by Dr. Cross associated with the eruptive debris of the Denver beds, and by myself in the eruptive conglomerate which forms irregular sheet-like intrusions in the Laramie of the South Park basin. In both these cases it can be shown that the eruptive material was deposited in its present position subsequent to a time of great disturbance following the epoch of the coal-bearing Laramie. The strata which appear between the Ruby beds and the coal measures on Grand River, may be represented in the Ruby Peak region by certain friable sandstones overlying the Laramie on Ohio Creek, which differ from the true Laramie sandstones in containing an abundance of chert-pebbles, sometimes fossiliferous, derived from the erosion of Lower Carboniferous beds. The Laramie proper consists, in the main, of material derived from Archæan areas, so that it was necessary not only that elevation of the neighboring land-mass should occur but that certain beds should be eroded away before the Carboniferous beds were exposed to erosion. Hence the pebble beds may not have been the earliest deposits following this elevation. The amount of upheaval could not have been less than the thickness of the entire Cretaceous series of the Elk Mountains, for, even to-day, the Dakota overlaps in places all other sediments ; whence, this group and those above it must have been removed, and very probably the Jura also. In Huerfano Basin there are certain deposits (Poison Cañon beds) referred by myself to the Lower Eocene, which consist of massive, soft sandstones, often conglomeritic, alternating with relatively thin beds of yellow clay and some clay-shale. Away from the old shore-border they are apparently conformable with the underlying Laramie with which they might be confounded. But along the western margin of the exposures they show great angular unconformity with all Cretaceous beds and were clearly separated from them by a period of intense dynamic movement evidently coincident with the one we are accustomed to term post-Cretaceous or post-Laramie. I refer to the Poison Cañon beds in order to show that sediments which are undoubtedly younger than the Laramie may, in their lithological make-up, exhibit a closer resemblance to it than do others near the same horizon whose stratigraphical relationship is not so conclusively expressed.

The careful study of the small area of the Denver Basin by Emmons, Cross and Eldridge, has for the first time developed the fact that certain beds previously assigned to the Laramie, and having a fauna and flora related to it, are evidently unconformable with that formation. These geologists have shown that the same beds belong to two stages, themselves unconformable and distinguishable by the character of their sediments from each other and from the Laramie below. The older of the two series of deposits has been called the Arapahoe beds, the other the Denver beds. These deposits indicate a succession of events much similar to that chronicled in the Elk Mountain region. According to these authors, the Arapahoe beds consist of clays, sandstones and conglomerates in which are pebbles of all older formations including the Carboniferous and beyond. The Denver beds which follow, and which occupy a basin eroded out of the Arapahoe, consist largely of andesitic debris—the lower half of the formation being wholly composed of this material. The presence of Carboniferous, and older, fossiliferous pebbles in the Arapahoe beds indicate previous elevation, and the erosion of a great thickness of Mesozoic strata, as do the similar pebbles in the Ohio Creek beds. The source of the pebbles may have been the tributary area along the mountain border to the southward. At the same time a portion, or perhaps the whole, of the debris of this character may have come from the region of the South Park and Mosquito Range—a possibility suggested by what I at present regard as the most probable source of the andesitic material of the overlying Denver beds. While recently engaged in the examination of the small Laramie area in the South Park basin, I there observed unquestionable evidence of a former grand eruption, of a character not previously noted in that part of Colorado. The evidence consists in the occurrence of thick sheets of eruptive conglomerate, intruded partly into the marine Cretaceous and partly into the Laramie—to some extent above the workable coal. These sheets are continuous from Mine No. 5 near Como to the southern limit of the Laramie beds, a distance of fully fifteen miles, beyond which I did not trace the exposures. About three miles south of Mine No. 5 and about one mile south of Mine No. 6, the intrusions above and below the coal beds coalesce and form a body of conglomerate several hundred feet thick completely cutting out the workable measures for nearly a mile. The material consists of rounded pebbles and boulders of andesite embedded in a matrix of finer material of similar composition. Red heulandite occurs sparingly, coating the pebbles, or penetrating them along capillary fracture planes, after the manner observed in the Ruby beds. Thin sections of some of the pebbles indicate the predominance of quartz-bearing hornblende-andesites containing varying proportions of hornblende, some biotite together with apatite and zircon noticeable in both pebbles and matrix. The conglomerate is therefore of about the same composition as the material of the Denver beds described by Cross.*

Previous to the post-Bridger movement, what is now the Front Range highlands formed a comparatively low-

* Amer. Jour. Sci., Vol. XXXVII, p. 270.

lying land area and the South Park region, then as now, drained into the Denver Basin. In fact, unless the present direction of drainage was already determined at that time it would be difficult to explain its establishment after the post-Bridger upheaval of the Front Range. The eruption of the conglomerate took place parallel with the axis of flexing on the west side of the basin, the intrusive bodies apparently occupying the channels through which the eruption occurred. The material itself may be regarded as the product of intense dynamic movement, probably brought to the surface as a hot conglomeritic mud, or in a condition to produce an explosive eruption whenever, owing to diminished pressure, the contained water flashed into steam. The superficial examination of the country that I was able to make did not reveal remnants of tufaceous beds, which would be positive proof that an explosive eruption did occur. Nevertheless, I am of the opinion that intrusions of this character and magnitude so near the surface could only be formed in connection with an eruption of this nature and one on a grand scale. The material then thrown out and scattered over the surface would be in a condition to be transported in large quantities to the nearest area of sedimentation—the Denver Basin—and presumably at the very time when the Denver beds were laid down. Whether or not future investigations shall show that the South Park conglomerate and the material of the Denver beds have a common origin, the fact remains that in the occurrences themselves there is undoubted proof of dynamic movement and eruptive activity following soon after the epoch of the coal-bearing Laramie. It will be seen from the foregoing, that there is a decided parallelism between the Denver and Ruby beds as regards their composition, the probable origin of their respective sediments, their relation to the underlying coal-measures, and, in connection with the Arapahoe and Ohio Creek beds, the evidence they afford of the previous elevation of adjacent areas by dynamic movement, general in its effects and associated with eruptive activity. In Middle Park there are certain beds represented as Laramie on Hayden's map, which, according to S. F. Emmons, are stratigraphically and lithologically distinct from the coal-bearing Laramie and their deposition appears to have followed similar disturbances. In the Yampa and Poison Cañon beds, eruptive pebbles are wanting, but the evidence of physical change is unmistakable.*

So far as I am aware there is nothing to show that any great disturbance supervened between this movement and the one which occurred near the close of the fresh-water Eocene. Hence, it was the post-Cretaceous movement that effected these changes. From all that is now known, I feel warranted in the belief, that the Denver, Arapahoe, Ruby, Ohio Creek and Middle Park beds, certain remnants in South Park and at Cañon City and probably the Yampa and lowest Poison Cañon beds, form a series, distinct from the recognized Eocene above and the coal-bearing Laramie below. That the deposition of this series took place after the more pronounced disturbances of what is known as the post-Cretaceous or post-Laramie movement, but was probably contemporaneous with the later phases of this movement—as suggested by the proof of eruptive activity, and the evidence of disturbance in the interval between the stages of the Denver and Arapahoe.

Reverting to the question "to what age shall we refer this intermediate series of beds?" there seems to be no choice, from a stratigraphical point of view, but to regard them as early Eocene sediments; and in the absence of palæontological testimony to the contrary this conclusion could hardly be questioned. We are confronted, however,

* The existence of eruptive pebbles in the Huerfano Eocene, as stated by me in a paper describing this series (see Part I. this Volume) is only true of the upper division to which the term "Huerfano beds" is now restricted. The statement that they occurred in the lower division or "Poison Cañon beds" being due to an error in the original notes.

with the fact that both the fauna and flora of the Denver beds, which alone are known to be fossiliferous, represent Cretaceous rather than Tertiary life. According to Dr. Newberry, who has studied separately the flora of the several sub-divisions referred to the Laramie group, the plants of the Denver beds belong to the Upper Laramie. Evidently there is to some extent a difference between the flora of the Upper Laramie and that of the coal-bearing Laramie below, which prompts the inquiry whether, in view of the relation of the upper beds to the post-Cretaceous movement, it might not be equally consistent to regard them as post-Laramie or to revive the term "post-Cretaceous" in this sense, for the beds west of the continental divide included in this category are strictly those referred by Hayden to the post-Cretaceous Epoch. With regard to the vertebrate life, the most striking and characteristic is the *Ceratops*—a huge, horned Dinosaur which appears to have reached the very limit of specialization in its class. The molluscan remains are not decisive, one way or the other. Indeed, it is here that one might expect to find a commingling of Laramie and Eocene types.

It seems unnecessary to inquire—could not the Dinosaurs, as represented by *Ceratops*, have survived the changes initiated by the post-Cretaceous movement? As demonstrated by the careful investigations of Cross and Eldridge, on the relation of the Denver beds to the Laramie, they evidently did survive until this movement was completed and before the life systems had been radically affected by the permanent changes which inaugurated the true Eocene Epoch. In current literature, there is abundant proof of the unreliability of palæontological tests where applied to the correlation of horizons in widely separated regions of the globe, and it does not follow that because, in Europe, the Dinosaurs perished with the Cretaceous, struggling genera may not have survived, under favorable circumstances, during a succeeding transitional stage in North America. In the Belly River beds, we have an example of the uncertainty of the palæontological test when unsupported by stratigraphical evidence. In speaking of the fauna of these beds, Dr. White states conclusively that if the stratigraphical relations had not been considered this group would have been referred without qualification to the Laramie.* Nor should we ignore, in connection with this question, the proof of a gradual transition from the Cretaceous to the Tertiary afforded by the faunal remains of the Chico-Tejon series of California.

The substance of the foregoing discussion of the relations of the Arapahoe, Denver and equivalent beds, and the conclusions thereon, may be thus expressed. From all the evidence available it appears that stratigraphically these beds are not Laramie, since to refer them to the Cretaceous would bring us face to face with the necessity of conceding an earlier date than post-Cretaceous to the Rocky Mountain revolution. Nor are they, palæontologically, a part of the recognized Eocene. Whence we must conclude that they are not assignable to either of these terranes, but should be regarded as transition beds deposited subsequent to the beginning of the post-Cretaceous movement, or probably during its progress, and hence of post-Laramie age.† Unless the disturbances which produced the effects usually referred to as post-Cretaceous were of shorter duration than the results would lead us to infer, the absence of beds of the above character would be a geological anomaly.

Post-Laramie Elevation.—Some of the effects of the post-Laramie movement have already been mentioned. This movement, as now understood, began with a general uplifting of the interior portions of the continent, followed

* Amer. Jour. Sci., Vol. XXXV., pp. 432-438.

† The term "Ceratops Beds" recently proposed by Marsh for the formation containing *Ceratops* remains, should, as a palæontological designation, be restricted to the group above defined as "Post-Laramie" since it has yet to be shown that *Ceratops* ranged down into the coal-bearing or true Laramie.

by folding and differential displacement along the old structural lines. The flexing was not characterized, except in a few instances, by the development of folds of the reversed or **S** type of structure near the previous shore-borders—a type common to the Rocky Mountains, but which must in the main be attributed to the post-Bridger movement. It was simply the uplifting, anticlinally, of the entire mountain area in connection with the formation of broad flexures, of comparatively gentle inclination, coincident with the existing ranges; of broad plateaus bounded by monoclines of medium slope, and of faults amounting to several thousand feet. The effects of this movement have, I think, been often overrated, and results ascribed to it which should have been credited to succeeding orogenic disturbances. It can now be shown, conclusively, that, in nearly all cases, the tilting and overturning of strata observed along the mountain border, both east and west of the continental divide, are due to a general movement affecting all the Eocene sediments except the Uinta group, and was, therefore, long subsequent to the post-Laramie epoch of disturbance. The Wasatch Range is not included in this statement, although even in this case, it seems evident that only the more salient features of its orography were created in post-Cretaceous time.

The reversed fold along the northeastern base of the Wind River Range, seen below Lander on the Poposia, may be cited as a second exception to this statement, although, owing to erosion, it is not certain that the Wasatch Eocene, which, however, exhibits great angular unconformity with the Cretaceous in that region, may not have been to a great extent involved in this fold.

The amount of post-Laramie upheaval with reference to the ocean cannot, of course, be determined, and it is only in the case of the plateau uplifts, whose inception dates from the beginning of this upheaval, that the evidence afforded is sufficiently clear to warrant an estimate of the probable amount with reference to the fresh-water lake-depressions. Nor, is this evidence altogether satisfactory, since the succeeding post-Bridger disturbances took place along substantially the same lines, greatly emphasizing the uplifts and flexures produced by the earlier upheaval and rendering it impossible to clearly distinguish between the effects of the two. For this reason the principal facts bearing on this question will be taken up later on in connection with the post-Bridger movement. Meanwhile, other facts will be presented which tend to show in a less direct way the nature and magnitude of post-Laramie disturbances.

The present position of tilted Laramie and marine Cretaceous beds in the Elk Mountains, the San Juan region, in South Park and near the head of the Yampa, in which localities they outcrop at from 10,000 to 11,000 feet above sea-level, suggests that only a low-lying land surface existed towards the close of the Laramie Epoch. In fact, I doubt if it can be shown from the present position and inclination of Cretaceous strata that the mean altitude of late Laramie land exceeded 1,000 feet. Observations in central Wyoming lead to the same conclusion with regard to that region. The upheaval and flexing which terminated this condition of things did not entirely cease with the opening of the Eocene Epoch. In the Huerfano Basin the 3,500 feet of coarse sandstones assigned to the Lower Eocene indicates progressive deepening of the long, narrow synclinal trough containing them ; showing that gradual flexing was in progress from the very dawn of the Eocene to a period as late as the Bridger. King concludes from the character of the Wasatch sediments in the Green River Basin that, during their deposition, the western part of this depression was steadily subsiding. As regards the region under consideration the movement was most intense in the beginning; sufficient to elevate above the base level of erosion all the formations down to and including, the

Carboniferous. That which followed may have been associated with the gradual rise, already referred to, of the Archæan bodies, or areas of erosion, concurrently with the subsidence of areas receiving sediments—an operation emphasized at intervals by more pronounced movements (post-Wasatch and post-Green River) tending to produce additional flexing, unconformity, and radical changes in the boundaries of the Eocene lakes. It is not often that one finds exposures near the old lake-borders that afford an idea of the amount of flexing attributable to this movement alone. The Huerfano Basin probably presents the best example of the kind. Here it is shown very clearly that the Cretaceous beds underlying the lowest Eocene were tilted about 30° before the Eocene sediments were laid down; while the latter were subsequently upturned about 70° by the post-Bridger movement. It does not follow, however, that this is the true ratio, since the steeper portion of the first-formed fold may have been removed by erosion while the Eocene beds were being deposited. On the other hand it seems probable that the quaquaversal uplifts of southern Wyoming were formed somewhere about the time of the post-Bridger disturbances; for at Rock Springs for example the Wasatch and Green River beds are found to have been equally involved with the Laramie in the upturning.

In the Wasatch Mountains we have a type of structure peculiar to that range, which may be regarded as the structural dividing line between the Great Basin on the one hand and the park region of the Rocky Mountains on the other. The map of the Fortieth Parallel Survey shows that east of Salt Lake City there is a transgression of the Cretaceous upon the edges of Lower Mesozoic and Carboniferous beds, indicating that part of the tremendous flexing and warping there observed may have occurred contemporaneously with the post-Jurassic plication of the western continental body of which this range then formed the eastern border. The transgression of the Wasatch Eocene over everything below it is, nevertheless, sufficient proof that the flexures were completed before these sediments were deposited and must therefore have been completed by the post-Laramie movement. Yet it is clear from the rapid rise of the Eocene beds as we proceed east from Salt Lake City, and of the same beds as we proceed westward from Green River, that the north end of the Uinta Mountains and probably the Wasatch Range also has undergone an elevation of several thousand feet since the close of the Eocene.

The faults which we may attribute to post-Laramie movement are not very numerous, though some which belong to an earlier date, such as those observed by Emmons in the Mosquito Range, may have been largely increased by these disturbances. Assuming that the Poposia fold of the Wind River Range is mainly of post-Cretaceous origin, the east-and-west fold of the Sweetwater Hills, which is an extension of this range eastward, should have had its inception at about the same time. This fold is traversed by a system of great north-and-south faults with the upthrow to the southward. These faults are no doubt referable in part to post-Laramie movement and largely to the movement (post-Bridger) which is seen to have affected the Eocene beds near by to the south and west. The Scofield fault of the Elk Mountains, which I shall have occasion to mention further on, may have had its inception at the time of the earlier movement, although it is certain that a large part of the differential displacement which brought the Marine Cretaceous down to a level with the Lower Carboniferous can be traced to disturbances contemporaneous with the uplifting of Treasury Mountain and which are seen to have been instrumental in the formation of the post-Bridger fold of the Great Hogback. The Glenwood fault, situated at the southern extremity of the White River Plateau, is undoubtedly of post-Laramie age. This fault marks the northern boundary of the depression lying between the plateau and the Sawatch uplift and was evidently produced at the time of the upheaval of the former. This relation of the two uplifts to the depressed intervening area was not changed by the subsequent formation of the Hogback fold, which skirts the uplifts and depression between them without any deviation of the vertical position of its axis. The Dallas fault of the San Juan Mountains and the Cimarron fault of the Vernal Mesa involve Cretaceous beds, though it is not certain in either case that the total displacement is entirely attributable to the disturbances of the post-Laramie epoch. Certain faults of limited displacement along the base of the Front Range also intersect Cretaceous beds, but the absence of Eocene sediments renders their age equally a matter of uncertainty.

In Colorado and northern New Mexico the drainage divide of the early Eocene differed but little from the existing one except that North Park probably drained to the west through Middle Park. On the south, the Sawatch and Conejos ranges formed the dividing ridge which, prolonged southward, separated the waters flowing westward into the Eocene basin of the San Juan from the waters draining eastward into the Huerfano and Galisteo lakes.* In Wyoming, the continental divide then extended from the Medicine Bow Range through the Archæan area of the Laramie Hills to the Big Horn Mountains, and not from the Park Range to the Wind River Range as it does now. This is shown by the extensive Eocene deposits of the Wind River Basin, which extend southward into the upper part of the Sweetwater Valley and have a broad,

* The Eocene age of the Huerfano lake has been established on the strength of mammalian remains. A similar age for the Galisteo beds is inferred on stratigraphical grounds. That they succeed the Laramie is clear, while the abrupt upturning of the strata into a vertical position argues previous subjection to a movement more intense than any recorded since the close of the Eocene, and which was here connected with plutonic eruptions of vast bodies of quartz-porphyry not hitherto observed protruding through rocks of Miocene or Pliocene age.

continuous connection by way of the South Pass region with the beds of the Green River Basin. In the San Juan Basin, the effects of erosion render the original extent of Eocene sediments extremely uncertain ; though it does not appear that this part of the principal Eocene lake received sediments after the Wasatch beds were deposited.

At the beginning of the Eocene the extent of this lake from north to south could not have been less than 500 miles ; but at the opening of the Green River Stage there was a contraction northward, and an extension westward by subsidence of the Basin region, so that the southern boundary of the lake east of the Green River Valley probably corresponded very nearly with the northern border of the Uncompahgre Plateau. This is partly suggested by the rapid thinning out of Eocene sediments toward the south, for instance under the Grand Mesa overflow. From my own observations in that region I hold it extremely doubtful if Eocene beds, even the Wasatch, ever entirely covered this plateau, but were laid down around it. The eastern boundary of the lake was evidently the western border of the Sawatch and White River Plateau uplifts, and the sediments must have extended some distance east of the line of the Hogback fold by which the Wasatch and Green River beds were steeply upturned. My investigations into the structure of the White River Plateau, have led me to believe that this uplift formed an Eocene land-mass, somewhat like the Uinta Mountains, though connected with the Sawatch, and other portions of the main land, by a broad area of erosion ; and the Eocene beds deposited around its northern margin extended to the western border of the Park Range uplift, which then formed the eastern boundary of the lake into southern Wyoming.

The greatest accumulation of Eocene sediments took place in the Green River Basin north of the Uinta Mountains, where, according to King, the Wasatch and Green

River beds aggregate about 8,000 feet. In the eastern portion of this basin, and in the Wind River region, the thickness is considerably less, the decrease being caused by the thinning out of the Green River beds, which north of Rock Springs are only about 500 feet thick. In Colorado, beneath the protecting eruptive cap of the Mam Mountains, the same groups aggregate less than 5,000 feet. In the region first mentioned, the sediments were derived almost wholly from the tributary land west of the lake where the surface subjected to erosion was more extensive than the Rocky Mountain area furnishing sediments on the eastern side. The thinner deposits of the Colorado portion of the lake were derived from the comparatively narrow tributary strip, whose eastern boundary must have corresponded in a general way with the existing continental divide.

At this point in the discussion it seems pertinent to observe that the lowest land surface of the eastern confines of the lake-basin at the end of the Green River Stage, must have been not less than 5,000 feet higher than the original bed of the lake in order to retain its waters, or determine the discharge to the westward. It is not probable that the mean altitude of the neighboring land was less than at the end of the Laramie so that the entire 5,000 feet of sediments which accumulated represents but a part of the total elevation produced in the bordering highlands, which should be augmented by the mean depth of material eroded from these highlands to form the Eocene deposits. This amount is not determinable; though, judging from the ratio of the area of erosion to that of sedimentation, it must have corresponded to a mean thickness of several thousand feet. As I will explain beyond, the minimum elevation of the White River Plateau due to this movement was not less than 5,000 feet,—an amount which was no doubt greatly exceeded near the axes of the principal ranges.

There is no recognizable proof of subsidence in the

Rocky Mountain region during the Eocene Epoch, nor of an extension of Green River sediments eastward. The transgression of these sediments westward into the Basin Region, which King regards as due to subsidence, may have been due, in part at least, to further elevation of the Rocky Mountains. In the Eocene area of the San Juan Basin—an area doubtless once connected with that to the north—there are no known Eocene beds later than the Wasatch; indicating that the country south of the Uncompahgre Plateau was uplifted at the time of the post-Wasatch, western extension of the lake-bed. To what extent the plateau was affected by strictly post-Laramie disturbances is not clearly indicated, although the thinning out of Eocene sediments southward, in the Uinta Basin, is proof that a certain amount of elevation involving Laramie beds did occur.

The termination of the Green River Stage was marked by considerable upheaval along the line of the Uinta Mountains and White River Plateau; so that during the Bridger, or toward the end of that stage, the two uplifts were probably connected by an anticlinal flexure, subsequently further compressed into the existing Axial Basin fold. There was thus formed to the north of these uplifts a new lake-basin in which the greater part of the Bridger sediments accumulated. If a new lake-basin was formed simultaneously south of the line of uplifts, it merely retained a drainage connection with the lake to the north; nor does the limited exposure of Bridger beds reported by Dr. White as present in the Uinta Basin suggest a very extensive body of water. It seems quite probable, however, that there was then, and had been since the close of the Wasatch, an east-and-west depression in process of formation between the Uinta Mountains and the uplift of the Uncompahgre Plateau whose fold extends from the San Juan Mountains westward as an anticlinal flexure, more or less parallel with the Uinta Range, until it becomes merged in the southern extension of the Wasatch Mountains. The formation of this depression, and the concurrent elevation of the plateaus, had its final expression in the post-Bridger movement and at the beginning of the Uinta Eocene an extensive fresh-water lake occupied the Uinta Basin which corresponded to this depression. The presence of Uinta sediments north of the line of uplifts, indicates a similar depression of the southern border of the Green River Basin by the same movement; although in this case the depression may have been more purely relative and the lake-basin then formed have been due to further uplifting of the Uinta Range and its eastern extension, the White River Plateau. In the same manner the mere elevation of the Uncompahgre Plateau may have sufficed for the production of the depression to the north of it, so that actual subsidence may not have occurred. This plateau, as before observed, was the site of an Archæan land-mass which remained unsubmerged until late in the Palæozoic.* The existing flexure is therefore approximately coincident with an Archæan mountain body.

Early Eocene Eruptions.—Exclusive of the explosive eruptions of post-Cretaceous time, to which we may refer the Ruby beds, the South Park conglomerate and the beds of the Denver Basin, the eruptive occurrences which may be regarded as of Eocene age are mainly those of the San Juan Mountains; though other occurrences whose age is doubtful may also belong to this epoch. The San Juan series of eruptions was among the grandest of the many recorded in the Rocky Mountains and Cordillerian region of the west. It was remarkable not only for the extent of country covered, but for the great depth of material erupted. The earliest outflow consisted of breccia, which accumulated

* Recent observations have shown that the complete submergence of the Uncompahgre Island did not occur until after the deposition of the "Red Beds." On the lower Grand the Archæan is exposed in direct contact with the pink-colored Triassic sandstone overlying the former.

to a depth of about 1,500 feet, and covered an area represented at the present time by the counties of San Juan, Hinsdale, Ouray, San Miguel and part of Rio Grande, Conejos and Gunnison. The material consisted of a compact andesitic matrix enclosing fragments of all sizes representing in the main different varieties of andesites, using this term in its broadest sense. This outflow was followed by others, of yet greater extent and aggregate thickness, in the same region. The material was mainly andesite; although rhyolite and trachyte are among the more recent outpourings. Previous to the breccia overflow, there was deposited in Ouray and San Miguel counties a coarse, shore-conglomerate which rests unconformably on Cretaceous and Lower Mesozoic beds, already subjected to movement. This conglomerate belongs, presumably, to post-Laramie or early Eocene times. Hence an earlier age cannot be assigned for the eruption of the breccia, which overlaps the conglomerate in the Mount Sneffles district and elsewhere is found in contact with every formation exposed in the San Juan Mountains, from the upturned Algonkian series recognized by Emmons and Van Hise to the Laramie of Tongue Mesa. That the last stages of the eruption took place in Eocene time, and previous to the post-Bridger movement, may be inferred from the fact that along the eastern border of the overflow where the rocks belong to the later eruptions these are found to have been involved in the disturbances which produced the San Luis Park depression and the final upheaval of the Sangre de Cristo Range which, since the close of the Palæozoic, had formed the eastern border of the San Juan peninsula.

Eruptions of brecciated material, of uncertain age, cover large areas of country in northern Arizona on the Rio Azule, and between this stream and the San Francisco. In the Black Range of New Mexico the eruptive breccia closely resembles that of San Juan and is of an age posterior to the folding of the Mesozoic beds there exposed. According to Cross, the eruption of Table Mountain near Golden occurred during the deposition of the Denver beds (post-Laramie). A small portion of this overflow consisted of brecciated material, and it is worthy of remark that the eruptions which occurred in the interval between the post-Laramie and post-Bridger disturbances consisted largely of fragmental material.

With the exception of the San Juan overflow the effect of these several eruptions upon the existing orographic configuration of the country was comparatively unimportant. The result of the former was to determine the position of a group of mountains whose summits now reach an elevation of over 14,000 feet above sea-level; the upper 5,000 to 6,000 feet of rocky, precipitous heights having been carved by glacial erosion out of the great overflow—thus producing in a characteristic form, and on a grand scale, what Powell, in treating of the geology of the Plateau Province, has described as "Tushar structure."

Post-Bridger Movement.—The disturbances referred to this period may include others which terminated the Green River Stage, and yet others of subsequent occurrence which, owing to the absence of Uinta and Miocene sediments, it is impossible to identify locally. There is nevertheless, observable throughout, the effects of a movement overshadowing all others, except the post-Laramie, which I prefer to call post-Bridger, for the reason that it terminated the period of Eocene sedimentation in the Huerfano Basin, where the uppermost beds are palæontologically referable to this age; and, furthermore, it was followed by a great expansion of the Eocene lake south of the Uinta uplift and the deposition of the Uinta group upon the edges of strata presumably upturned by this movement. The discussion of the relative importance and distinguishing features of the post-Bridger movement, may receive some light from the consideration of certain facts pertaining to the structure of a region hitherto but little explored—namely, the White River Plateau, and its relation to the fold of the Great Hogback.

What now remains of the sediments deposited in this region before the close of the Cretaceous, except in the territory south of Roaring Fork, are off-shore accumulations; though in some cases, for instance the "Red Beds" and the Laramie, shallow, brackish-water conditions prevailed during their deposition. Consequently, the strata affected by the post-Laramie and post-Bridger movements, exhibit the angular conformity usually observed in sediments of this character in the Rocky Mountains, where previous dynamic movement did not manifest itself with sufficient intensity to produce unconformity away from the shore-borders of the old land-masses. Hence, the amount of flexing that has occurred at any point may be approximated by a study of the remaining strata, notwithstanding that the greater part of more recent beds may have been removed by erosion, as in the case to be considered.

The White River Plateau is bounded on the west by a great reversed or **S** fold which can be traced without interruption from the Elk Mountains northerly, along the border of the Sawatch uplift and the southwestern margin of the plateau, to a junction with the Axial Basin fold bounding the plateau on the north; thence, curving to the westward, it skirts the southern border of the Uinta Range which it follows to the eastern flank of the Wasatch Mountains. All the late Mesozoic beds formerly involved in the upper part of the Hogback fold have been carried away, but are still present in the lower part where they are in contact with the Ruby beds, or with the Wasatch Eocene. By the erosion of the soft shales of the Colorado and Montana groups a long monoclinal valley has been excavated between the Dakota and Laramie sandstones, so that the upturned strata of the latter form a high, precipitous ridge known as the Great Hogback. The Lower

Mesozoic and Carboniferous beds extend high up on the flanks of the plateau which, over the southern portion, is capped with Lower Palæozoic strata—the Archæan being in places exposed by erosion. At the northern extremity, near Mount Orno, the Laramie coal-bearing series directly underlies the basalt overflow capping that portion of the uplift, thus indicating its submerged condition previous to the post-Laramie movement. The present elevation of the uppermost strata of the Mount Orno Laramie is about the same as that of the Silurian limestone exposures of the central part of the plateau, viz: 11,000 feet, or about 6,000 feet higher than the top of the Laramie beneath the Wasatch beds at the mouth of Parachute Creek on Grand River—the lowest point in the adjacent portion of the Eocene lake-bed. But, on the supposition that all the sediments involved in the upheaval formerly arched over the uplift and were substantially conformable, a thickness of 11,000 feet (partly measured and partly estimated) of strata between the Silurian and the top of the Laramie, must have been removed from the higher part of the plateau; so that the original elevation of the latter above the given point at the mouth of Parachute would approximate 17,000 feet. This amount represents the aggregate elevation produced by the several movements between the Laramie and the Miocene; though mostly attributable to the more prominent ones of the post-Laramie and post-Bridger. This elevation, it should be observed, was relative, not absolute, and if the lowest depression in the Uinta Basin—the Green River Valley for example —were taken as the datum plane the relative elevation of the plateau would be increased; though if the comparison were made between this depression and the Yampa Plateau, near by, the local orogenic effects would remain about the same. The great length and even development, throughout, of the Hogback fold points to the simultaneous and nearly equal elevation of the adjacent uplifts including the Uinta and Sawatch.

The form of this fold is a very common one in the Rocky Mountains. The strata rise abruptly from a nearly horizontal position until they approach the perpendicular when they curve sharply in the opposite direction, the inclination being reduced to 25° or less on the borders of the plateau. The S portion of the fold is wholly due to post-Bridger movement since it involves the Wasatch and Green River beds along the entire length of the adjacent uplifts. The inclination of the Laramie strata of the Hogback is greatest at the top of the ridge, so that if the fold be restored the reverse curve would lie altogether above the present culminating line. Yet not very far above, judging from the inclination of the older beds rising from the base of the Hogback and resting on the slope of the plateau. The altitude of the ridge above the datum plane already mentioned is, approximately, 2,500 feet. Assuming that the reverse curve begins at the top of the ridge, and that the fold is symmetrical, as indicated, the elevation incident to its production would amount to 5,000 feet. It would be inconsistent to suppose that a fold of this character would be formed without the central part of the plateau being uplifted proportionately more than the borders. Hence, 5,000 feet is, as we shall see, considerably less than the probable amount produced by the post-Bridger movement.

This uplift is separated from that of the Sawatch by an area of depression, defined on its northern border by a great east-and-west fault-fold which marks also the southern border of the plateau. The axis of this fault-fold is essentially normal to the trend of the Hogback fold and the two constitute entirely independent lines of flexure or displacement. The former, which I have already referred to as the Glenwood fault, corresponds in amount to the present elevation of the plateau above the valley of the Grand River—that is, the Cambrian rocks capping the plateau horizontally are 5,000 feet higher than the disturbed beds of the same age exposed in Grand River cañon. This displacement of 5,000 feet is practically all of the plateau elevation that can be assigned to the post-Laramie movement, for the subsequent elevation (post-Bridger) involved alike the Sawatch and White River uplifts and the connecting depression between them. It even seems probable that part of the 5,000 feet of elevation ascribed to the earlier movement may be due to squeezing up of the central mass of the plateau during the formation of the Hogback fold, and possibly to an increase in the amount of displacement by inter-Eocene disturbances prior to the inception of this fold, which dates from the uplifting I have already stated occurred after the Green River beds were deposited. The remaining 12,000 feet of the elevation recognized, cannot all be credited to the post-Bridger movement. There was no doubt considerable elevation of the plateau at the time of the post-Wasatch upheaval of the region to the south, and of the Uinta Range to the west where, as noted by King,* the Wasatch strata were upturned 25° along its northern slopes, in the Henry Fork country, prior to the deposition of the Green River beds.

Of the total elevation of 17,000 feet shown to have occurred at this point, not to exceed 5,000 feet should be referred to the post-Laramie movement, and 5,000 feet plus an undetermined amount to the post-Bridger movement; while another undetermined amount which, however, sufficed to maintain the uplift above the level of Eocene sedimentation, should be ascribed to gradual inter-Eocene uplifting and post-Wasatch elevation. The 5,000 feet or more attributed to the post-Bridger disturbances only refers to the elevation of the White River Plateau, and does not take into account the elevation that occurred between the plateau and the main Rocky Mountain axis, which we know to have been considerable, but which our present knowledge will not enable us to estimate.

* Systematic Geology, p. 379.

The Scofield fault furnishes another of the numerous instances of uplifting wherein the effects of the principal disturbances are so combined that it is impossible to distinguish between them. The vertical displacement caused by this fault may be roughly estimated at not less than 8,000 feet. The upthrow is on the side toward the Sawatch uplift; the downthrow involving the uplift of Treasury Mountain whose amount should therefore be added to the total elevation of this border of the Sawatch mass by Cenozoic movements. The marine Cretaceous beds on the Treasury Mountain side of the fault-plane are 5,000 feet higher than the beds of the same age in the Gunnison Valley to the south. Hence, the total relative elevation of the Elk Mountain portion of the Sawatch was not less than 13,000 feet. The correct interpretation of the structure of this region is by no means a simple matter owing to the complications introduced by plutonic eruptions subsequent to post-Bridger time. The protrusion, through the strata, of the vast diorite mass of the Ragged Mountains—which took place after the formation of the Hogback fold, the Scofield fault, the Snowmass eruption and the uplifting of Treasury Mountain—seems to have produced considerable horizontal displacement in the country to the north, in effect, a movement of the entire body in that direction. This is suggested by the abrupt northeasterly curve of the Hogback fold as it comes within the influence of the great Ragged Mountain intrusion; also, by the apparent overthrusting of the Cretaceous upon the Lower Palæozoic on the slope of Treasury Mountain facing this intrusion.

The Hogback fold graduates into the Slate Mountain monocline, the strata of which rest on the Snowmass Mountain uplift, and through the latter a connection is discernible with the Scofield fault. The immense plutonic body of Snowmass, which tilts up the Cretaceous and older beds, was evidently thrust up conjointly with the formation of the Hogback fold with which the tilted strata are continuous.

My own observations in that region have been too imperfect to warrant a positive statement with regard to the Treasury Mountain upheaval. But the fact that the Cretaceous beds are much higher on the northern or Scofield side of the uplift than on the southern, notwithstanding the probable elevation of the beds on that side by the Ragged Mountain intrusion, indicates that the upheaval of this body began during the post-Cretaceous epoch of disturbance, and that it was subsequently tilted to the south during the post-Bridger folding of the Hogback, the eruption of the Snowmass diorite and the upthrusting of the Sawatch body along the fault-plane immediately to the north. This view of the matter, although of course largely tentative, involves the assumption that the 8,000 feet of Sawatch elevation indicated by the Scofield fault is attributable to post-Badger movement. If the inception of this fault occurred at the time of the post-Laramie disturbance, which I am not prepared to deny, the amount of displacement which then took place may not have exceeded the subsequent elevation indicated by the southern tilting of the Treasury Mountain mass, and the 8,000 feet of post-Bridger elevation, suggested, may still approach the actual amount. If the inception of the fault occurred during the later disturbances then the elevation exceeded the amount suggested. Nor in either event would it include the probable squeezing up of the main Archæan body of the Sawatch.

The same dynamic force which produced the upheaval of the Uinta Mountains and the White River Plateau effected simultaneously the further upheaval of the Uncompahgre Plateau which involved the Eocene sediments of the southern border of the Uinta Basin. This fold is less pronounced than that of the Great Hogback with which it is substantially parallel, though the northern inclination of the Laramie and Eocene beds as far west as Price often amounts to as much as 10°, while north of

Grand Junction it reaches 17°, but soon flattens out under the Book Plateau. South of the Grand the dip of the Lower Mesozoic beds approaches 25° with an abrupt upturning near the river.

In the La Plata region, the east-and-west fold involving the Wasatch beds is scarcely more abrupt than that of the Uncompahgre Plateau, with which it is also parallel. Yet the relative elevation must have been greater than in the case of the White River Plateau, for the Palæozoic beds, having approximately the same inclination as the Eocene strata, rise to such a height on the La Plata Mountains that an elevation of not less than 14,000 feet is clearly indicated. Part of this elevation, however, must be credited to the intrusion of the eruptive mass of the La Plata Mountains in the manner suggested by Holmes in his diagrammatic explanation of the structure of Hesperus Peak. In the San Juan Mountains the elevation was probably no greater, and in the Mount Sneffles district the presence of the supposed Eocene conglomerate does not indicate more than 5,000 feet. North of the White River Plateau, along the base of the Park Range, the effects of the post-Bridger movement are seen in a monoclinal fold, and supplementary anticline, nearly parallel with it, extending southeasterly across the Yampa and through Twenty-Mile Park where it becomes merged into the eastern continuation of the Axial Basin fold. The relative elevation is not determinable and the dynamic effects were manifestly less intense toward the northwest, where the force seems to have expended itself.

East of the main range; the movement was most intense in the Sangre de Cristo region, resulting in the formation of a pronounced **S** fold extending along the eastern base of these mountains south into New Mexico, and in the production of the broad valley depression of San Luis Park lying to the west of them.

From Stonewall valley northward to the Cuchara the inclination of the Dakota sandstone approaches 90°. Still further north, on Oak Creek, it is overturned about 60° so that it appears to underlie the Lower Mesozoic beds and the Upper Carboniferous conglomerate. On Middle Creek the Laramie strata are vertical, if not occasionally slightly overturned ; while from Veta Mountain north to the Huerfano they are generally overturned about 10°. Just beyond, in Poison Cañon, the recognized Eocene beds, overlapping the Laramie, are involved in the fold and are tilted about 70°, thus indicating an angular unconformity of about 30°. These figures show the structural and orogenic importance of the post-Bridger movement as compared with the one preceding it, since 30° is all that can be attributed to the post-Laramie movement augmented by the minor disturbances at the beginning and end of the Green River Stage.

Further evidence of the magnitude of the post-Bridger movement is seen in the formation of the San Luis Park depression, or at least of its main features. This area, in common with the Sangre de Cristo, had previously been invaded by Carboniferous waters, but there is nothing to indicate that Mesozoic sediments were deposited there ; though a limited exposure of beds assigned by Hayden to the Green River group occurs a short distance west of Saguache. Whether or not this dispression had its inception in post-Laramie time is an open question. With the evidence before us of the upturning of Mesozoic beds east of the Sangre de Cristo, and hence of a certain amount of upheaval along this range, we may reasonably infer that it had. The fact that San Luis Park was the eastern shore border of the San Juan peninsula, even as late as the beginning of the Carboniferous, that it then subsided until the close of the Palæozoic, when it was again uplifted and formed part of the San Juan land-mass, shows that disturbances were in progress there which might have determined the position of the depression at a very early date. Yet the inclination of the quasi-stratified Eocene overflows, which dip beneath the Quaternary accumulations of the valley, indicate post-Bridger time as the age of the movement to which, in the main, the existing orographic features are due—including the uplifting of the San Juan Mountains and Conejos Range

In the Wet Mountains, the tilting of the beds by the two sets of disturbances was of the same character as that observed along the Sangre de Cristo, though less pronounced and their relative effects rendered somewhat obscure by subsequent erosion. Yet at the contact of the Laramie and the Huerfano Eocene (Bridger) near the mouth of Turkey Creek, the former, where least eroded, is inclined about 50°–55° while the angular unconformity with the Eocene amounts to only 20°—indicating that the fold is largely of post-Bridger age. The same movement made itself felt in the prairie country immediately east of the Wet Mountain border where, in places, the Cretaceous beds are folded and disturbed.

The post-Bridger fold of the Sangre de Cristo and Wet Mountain region continues north along the base of the Front Range where the post-Laramie, Laramie and other Mesozoic beds, are abruptly upturned and highly inclined. Owing to the distance of this portion of the Front Range from the Huerfano Eocene basin, it cannot be shown positively that the entire amount of this fold was produced in post-Bridger time. It is, nevertheless, obvious, from the high inclination of the Denver beds, that by far the greater part of it was produced by movement subsequent to their deposition and, in the main, during the post-Bridger epoch.

The Front Range fold is continuous northerly into Wyoming where it follows the Medicine Bow Range and the Laramie Hills flexure. The fold on the west side of this flexure, and that which borders the northwesterly continuation of the Medicine Bow, are clearly the result of the same movement to which we may also ascribe the

Aurora anticline and the westerly curving flexures which extend far beyond the termination of the Archæan exposures of the Medicine Bow uplift. On the North Park side of this range the strata to the top of the Laramie are inclined somewhat abruptly away from the axis, and dip toward the North Park depression. On the west side of the park the strata bordering the Park range are also inclined toward the depression, which is likewise the case in Middle Park. In South Park, the post-Laramie and Laramie beds are tilted toward the east by what is practically a continuation of the Park Range fold. Whence it appears that the salient orographic features of the park depressions have resulted mainly from the combined effects of these movements. The operation of the same force was also manifested east of the Front Range in the production of a series of minor faults and flexures parallel with it, thus giving rise to the peculiar north-and-south drainage of that region.

The results of the movement above described were highly important, and the structure developed was in some respects characteristic. The flexures were in all cases more remarkable for their abruptness than for their amplitude. At the same time the great folds of post-Laramie time were largely increased—in some cases more than doubled in amount—and the enormous uplifts previously established were further elevated to an extent that more than counterbalanced the depth of Eocene erosion. The distinguishing feature of post-Bridger flexing was the formation of the reverse fold of the S type on the borders of the uplifted areas, which were before bounded by simple monoclines of smaller inclination. The production of this type of flexure in connection with secondary parallel anticlines indicates the operation of compressive force acting in the same direction as during the post-Laramie movement. In the two cases the force expended in producing the respective effects did not differ widely in amount, though the results were somewhat dissimilar owing to the fact that the second movement began where first terminated. If the post-Laramie movement had been further continued the resulting structure might ultimately have been the same, for after a certain amount of upheaval had occurred the great uplifts would have developed a tendency to flatten out and thus produce a reverse fold on their borders.

Post-Eocene Movement.—The latest fresh-water Eocene sediments deposited, are found in the Uinta Basin, in Brown's Park and eastward in the Yampa Valley. The beds south of the Uinta uplift were designated by Marsh and Emmons the Uinta group, and were by the former referred to the uppermost Eocene on the strength of mammalian remains—a conclusion since confirmed by the investigations of Scott and Osborn.* Meanwhile Dr. C. A. White referred the Brown's Park beds to the same group on the grounds of unconformity with all previously recognized Eocene sediments, and lithological similarity with the beds south of the uplift.† It is the movement which uplifted, faulted and flexed these beds that is referred to as post-Eocene; although it must be admitted that these results may be largely due to disturbances of later date. In the only region where the relation of these beds to older sediments can be studied, the amount of flexing and displacement attributable to this movement is relatively small; while in the main range of the Rocky Mountains, Uinta beds are wanting, so that the effects cannot be traced. According to Powell‡ the Brown's Park fault shows a downthrow of several thousand feet, which began before, and continued after, the Uinta beds were deposited. He shows further that the latter are tilted 25° against the Uinta sandstone (Upper Cambrian?). In the Yampa Val-

* Amer. Jour. Sci., Vol. XXXIX, p. 20.
† Hayden's Report, 1876, p. 20.
‡ Geol. Uinta Mounts, pp. 208–209.

ley, near the White River divide, the Uinta beds were deposited upon the edges of strata upturned by the post-Bridger movement. The latter dip to the south, or away from the valley; while the Uinta dips from 3° to 7° to the north or toward the valley—a fact previously observed by Emmons during his explorations in that region.* The axis of the Uinta Range passes through Junction Mountain and Yampa Peak (Cedar Mountain) toward which the Uinta sediments are inclined, so that it is necessary to assume one of two things, either that the northern inclination of these beds is due to post-Eocene upthrusting along the southern border of the uplift, or else that the latter suffered post-Eocene depression along its axis east of Green River—an assumption which would be in line with Powell's observation of a downthrow in the Brown's Park basin.

Further evidence of post-Eocene movement is seen in the relative elevation of the two extremities of the Uinta Basin, involving the Uinta sediments in the Green River Valley and westward. These beds, where exposed near the mouth of White River, are at least 4,000 feet lower than the exposures of the same age in the northwestern extremity of the basin, indicating a gradual rise parallel with the Uinta uplift, if not along its axis, until an upheaval of 4,000 feet or more was reached near the junction of this uplift with the Wasatch Range. A corresponding upheaval seems to have occurred in the Rocky Mountains; although, since Uinta sediments are absent here, the connection cannot be shown. This much, however, is clear, that there is a geosynclinal depression between the Rocky Mountains and the Wasatch Range which, as regards the portion west of the Green River Valley, originated during post-Eocene or later disturbances. The formation in the Plains region of shallow Miocene lake-basins, extending up to the base of the Front Range, was of concurrent

* Survey Fortieth Parallel. Des. Geol., p. 280.

occurrence with Uinta Mountain elevation, and suggests the probability of responsive movement in the intervening area of the Rocky Mountains.

The numerous faults of the Plateau Province have been shown by Dutton to have caused in some cases a vertical displacement of as much as 14,000 feet.* While these faults affect the Eocene beds of that region, it does not appear that the Uinta group is represented there. Consequently, the relation of the plateau faults to post-Eocene movement cannot be inferred. Dutton, however, states elsewhere† that since the Eocene Epoch the High Plateaus have risen from 10,000 to 12,000 feet—an enormous amount of elevation, which presumably includes the sudden and wide-spread uplifting which he declares came upon the country at a comparatively recent epoch and "after an immense period of repose."‡

Eocene and Miocene Drainage.—Early in the Eocene the continental divide was defined by the uplifts of the Medicine Bow and Big Horn ranges and the intervening area of the Laramie Hills. Some time after the close of the Bridger the divide was transferred to the Park and Wind River ranges by way of the east-and-west elevation separating Middle and North parks. In the South Park region the drainage conditions established early in the Eocene were emphasized but not otherwise altered by the post-Bridger disturbances. In the San Juan Mountains the position of the divide was probably changed by the extensive accumulations of eruptive material poured out near the end of the Wasatch Stage, and the present topographical features are in the main attributable to post-Bridger movement modified by erosion.

There can be little doubt that the upper channels of the Grand, Gunnison, Dolores, South Platte and Arkansas

* Tert. Hist. Grand Cañon Dist., pp. 111-113.
† Geol. High Plat. of Utah, p. 24.
‡ Ibid., p. 38.

were established at the very beginning of the Eocene Epoch. The extension of these rivers, and the formation in other cases of entirely new drainage channels, was a further result of the Cenozoic movements above described. As regards the causes which determined the present courses of the Gunnison, Grand, White and Yampa, I may say that they are clearly indicated by the structure of the country through which these rivers flow. The Gunnison, from its junction with the Uncompahgre to its junction with the Grand, follows the strike of the monoclinal fold of the Uncompahgre Plateau; while below this junction the Grand itself, to its junction with Green River, follows the same fold. Hence, independent of the Grand the waters of the Gunnison would doubtless have followed the same route to the Green. Why the Gunnison should have taken this course in the beginning may be explained on the ground that the extension of its channel progressed with the gradual contraction of the Eocene lake and the slow upheaval of the Uncompahgre Plateau. With regard to the courses of the White and Grand the cause is equally evident. The axis of the Hogback fold is about 2,000 feet lower on Grand River than near the base of the Elk Mountains. On White River the axis is not very much higher than it is on the Grand, but between the two streams it rises about 2,000 feet. This rise in the axis of the fold seems to be the result of upheaval along an east-and-west line, elevating and flexing the northern part of the Book Plateau and exposing a limited area of Wasatch beds. As a consequence, both the Grand and White, west of the mountain border, follow the course of post-Bridger or post-Eocene synclinal depressions. The fact that the White cuts through the uplift of Ravens Park depends on the existence of the Yampa Plateau on the north and the flexure just mentioned on the south rendering it impossible for the river to take any other course. The Yampa, after it leaves the base of the Park Range, follows the strike of the inclined strata affected by the Axial Basin fold and the Yampa Plateau—in which respect it resembles the Gunnison, and the original determination of its course may be explained on similar grounds. During the earlier period of its existence this stream must have had its outlet into the northern of the two Uinta Eocene lakes, which will be further commented on in connection with post-Pliocene movement. Previous to this time neither the White nor the Yampa had any material development since their origin was due to the post-Bridger movement. The Grand, however, drained a considerable area of country throughout the Eocene, its upper course having been determined by the post-Laramie depression between the Sawatch and White River uplift and by the depression established at a still earlier period between the Park Range and Gore Mountains.

Reference to the drainage west of the main range would be incomplete without a few remarks on the primary establishment of the main artery, the Colorado River, and its great northern tributary, the Green. We cannot assign an earlier date than the beginning of the Eocene for the inception of the Colorado, when it was probably the channel through which the surplus waters of the great Tertiary lake found an outlet to the sea. This channel must have advanced northward with the contraction of the lake and early in the Miocene have extended well into the Uinta Basin. The most natural location for the principal drainage channel would be the lowest part of the depression between the Rocky Mountains and the Wasatch Range. As a matter of fact the channels of the upper Colorado and of the Green occupy the lowest part of this depression to-day—as can be seen from the gradual rise of the Eocene and Cretaceous strata east and west of the Green River valley. The profound depth of the channel of the Colorado in the plateau region is proof of the unchanging course of this river from the beginning. The conclusion expressed by Gilbert and Dutton that the course of the Colorado was determined by the configuration of the bed of the Eocene lake is clearly in harmony with the facts, which do not in the least suggest the theory advanced by Prestwich that the course was originally determined by fissuring. The great depth of the chasm through which the river runs is attributable as much to limited erosion in the surrounding region, which since the Miocene has been marked by extreme aridity, as to active erosion by the River itself. As intimated by Powell and Gilbert, had a humid climate prevailed throughout the Cenozoic, the High Plateaus would long ago have been scored down, and the topography so changed that the cañon of the Colorado would have expanded into a broad tillable valley, bordered by rolling hills and undulating rounded profiles. The course of Green River south of the Uinta uplift is simply a continuation of the valley of the Colorado northward, and was no doubt determined by the same cause; although the extension of this stream across the Uinta Mountains was a somewhat later occurrence as I will endeavor to explain after the remaining disturbances, which in a measure bear on this question, have been discussed.

Of the other rivers tributary to the Colorado—the San Juan and the Dolores—it appears that extension followed the upheaval, at the beginning of the Green River Stage, of the region south of the Uncompahgre Plateau; so that their courses were already established prior to the post-Bridger movement. As regards that portion of the San Juan drainage affected by the uplift of the La Plata Mountains, it was no doubt largely modified and in part created at the beginning of the Uinta Eocene. The effect of this movement on the course of the Dolores and its tributaries is involved in doubt. The upper part of this stream has cut its way through a fold or uplift formed simultaneously with the intrusion of a laccolitic mass of porphyrite, which appears to be more nearly related in composition to the post-Eocene, or possibly post-Bridger, eruption of the La Plata Mountains than to the breccias, trachytes, rhyolites and andesites poured out in the San Juan Mountains, presumably at an earlier date. The structure of the country leads to the inference that the channel of the river was securely established at the time the uplift was formed, otherwise its waters would have taken an entirely different course. It seems probable that the inception of the Dolores followed the eruptions of the San Juan group and that the laccolite referred to was formed at or near the time of the La Plata Mountain eruption and evidently after the establishment of the river channel.

Turning to the drainage east of the continental divide, we find that two of the principal rivers—the North Platte, flowing northerly through North Park, and the Rio Grande, flowing south through San Luis Park—had their upper courses determined by late Eocene or post-Eocene movements. In these cases the structural results were similar. The Medicine Bow Range bears the same relation to the North Park depression and the opposite Park Range that the Sangre de Cristo does to the San Luis Park and Conejos Range. The existence of a shallow depression in San Luis Park previous to the post-Bridger movement is quite probable. Yet it is not necessary in that case to suppose that the drainage should have been southward, as at present, any more than to the north into the region of Arkansas drainage, or even eastward into the Huerfano Basin since the post-Laramie Sangre de Cristo upheaval may have been insufficient to entirely prevent the transportation of sediments from the west through gaps in the low hills then representing this range. There can be no question, however, that after the disturbances of the post-Bridger epoch the Sangre de Cristo Range formed an impassable barrier to eastward drainage. Hence, we may regard late Eocene time as the period when the upper course of the Rio Grande was securely established; though there were subsequent changes, causing the uplifting, transverse to this course, of an Archæan body at the south end of the park, which produced the late Pliocene or early Quaternary San Luis Lake, necessitating the cutting of the present channel through the sediments then deposited.

Regarding the North Platte, it appears that up to the close of the Laramie the North Park depression formed a single hydrographic basin in common with the Middle Park depression, with an outlet to the westward near the junction of the Park Range and Gore Mountains. Whether or not these conditions existed during the Eocene I am not prepared to say. The character of the results produced by the two grand movements rather indicates post-Bridger time as the date of production of the east-and-west uplift between the two depressions and the establishment of the independent drainage basin of North Park with a northern outlet corresponding to the course of the North Platte River. This basin was occupied subsequently by a bay of the fresh-water Pliocene sea and the present channel of the river is, therefore, the result of Quaternary erosion in the Pliocene beds.

I have explained in connection with the post-Laramie deposits, that the South Platte River was probably established in its course through the Front Range, early in the post-Laramie epoch, and discharged its waters into the Denver Basin previous to the opening of the Eocene. The post-Bridger movement did not materially change the original course, which was maintained through the Front Range notwithstanding the enormous upheaval to which the latter was in the meantime subjected. If the rate of upheaval had very much exceeded the cutting power of the stream the South Park drainage would have been diverted into the Arkansas. It seems that we have in this instance undoubted proof of the slow rate of mountain growth, and the absence of cataclysmical action during the uplifting of the most lofty of Rocky Mountain granite ranges and the flexing of the strata along its eastern border. Unlike the other rivers of the period an extension of the South Platte channel eastward did not take place at the close of the Eocene. On the contrary, we may suppose that whatever extension occurred after the deposition of the Denver beds, was obliterated by the deposition of the Monument Creek beds during the early Miocene.

The influence of the post-Bridger movement on the course of the Arkansas and its extension eastward seems to have been unimportant, and of the post-Eocene presumably still less. The rather high northern inclination of the Laramie near Colorado Springs, coupled with the absence of Miocene beds south of this point, indicates that the Monument Creek Miocene Lake did not extend as far south as the Arkansas, and that the waters of the latter after leaving the mountain border may have flowed some distance eastward through an area of erosion substantially as in Eocene time. The most noteworthy feature in connection with this river is the erosion of its channel through the northern continuation of the Wet Mountain and Sangre de Cristo uplifts which are evidently in part of of post-Bridger age since the folds on their flanks are continuous with those involving the Eocene beds of the Huerfano Basin. In this respect the Arkansas resembles the South Platte, Grand, Green, Dolores and main branch of the Gunnison.

Late Eocene and Miocene Eruptions: Among the most important events associated with Cenozoic disturbances was the series of grand eruptions within the disturbed area; which served in some cases to amplify the effects of simple orogenic movement, and in others to produce an entirely different type of structure. The eruptions referred to had their beginning in late Eocene time, but continued at intervals into the Miocene. According to my own observations, there are but few exceptions to the general rule that, in the Rocky Mountains of New Mexico, Colorado and Wyoming, all the important eruptive bodies belong to a time not earlier than the close of the Cretaceous, and the majority to a time subsequent to the close of the Eocene. The rocks observed by Emmons in the Mosquito Range, as being faulted and folded by the Jurassic movement may be cited as an exception to this rule. Nor do I include under this head numerous relatively unimportant occurrences of doubtful age met with in the older sedimentaries and crystalline schists. But the general absence of eruptive pebbles in the conglomerates of Mesozoic and older formations, while not absolutely conclusive, supports the conclusion that no important outbursts of eruptive material took place previous to the Tertiary. Moreover, the great overflows are so situated as to demonstrate, clearly enough, that they belong to a period subsequent to the beginning of the Eocene; while the enormous plutonic bodies of the Elk and La Plata mountains, and the Spanish Peaks region, are found to have uplifted and tilted post-Laramie and Eocene strata. Indeed, wherever these strata occur sufficiently near to intrusive eruptive bodies the latter have invariably upturned or displaced them.

It is not certain how far into the Miocene these eruptions continued; neither is it possible in all cases to determine the order of succession. There are instances where it can be shown that the eruption occurred simultaneously with the formation of a post-Bridger fold, and in other instances at a somewhat later date. Thus, the huge diorite body of the Snowmass group, which rises conformable with the continuation of the Hogback fold is evidently related to the latter in time. The vast bodies of the Ragged Mountains, the Anthracite Range, Mount Marcellina, Mount Beckwith, Mount Carbon, Mount Wheatstone, Gothic Mountain and Crested Butte, constitute an independent group, essentially of the same lithological character and belong to the same epoch of eruption—a time somewhat subsequent to the formation of the Hogback fold. The reasons for entertaining this view depend on the relation of the Chair Mountain extremity of the Ragged Mountain mass to the Hogback fold and the intrusion of Snowmass Mountain. The fold—and apparently with it the Snowmass body—has been thrown out of the general line a distance to the northward equal to about one-half the width of Chair Mountain, which, at its base, is nearly three miles across. The Ragged Mountains widen to the eastward, and on account of the nearness to one another of the bodies above specified the probability is suggested that they are simply the protruding portions of much larger bodies underlying the country. It would be impossible for the Ragged Mountain mass to have been forced up through the earth's crust without an accompanying horizontal displacement of the country adjacent to it. The abrupt northerly curve of the Hogback fold as it comes within the influence of this mass seems to warrant the conclusion that the folded sediments, together with the Snowmass intrusion and the country around Treasury Mountain, were thrust bodily to the northward at the time of the Ragged Mountain eruption.

The eruptions of the Spanish Peaks region were, probably, in some instances, contemporaneous with the post-Bridger disturbances; while in others they evidently belong to a later period. None, however, can be assigned to an earlier date than the termination of Eocene sedimentation in the Huerfano Basin. This is demonstrated by the fact that the pleutonic eruptions tilted up and fissured the latest Eocene strata, which are intersected by the systems of radial dykes resulting from this fissuring. It is further demonstrated by the absence of eruptive debris in the Lower Eocene beds; only the uppermost beds of this epoch containing occasionally eruptive pebbles, and these of a character not represented by any known occurrence in the Spanish Peaks region, though they may have been derived from the Rosita occurrences to the north. The results of these eruptions is seen in the typical and modified lacolitic bodies of the Spanish Peaks, Silver Mountain, Veta Mountains, Sheep Mountains, Black Buttes and Badito Cone (Sugar Loaf). These bodies consist of porphyries, augite-diorites, and hornblende—and augite—porphyrites. The same rocks also appear in the numerous dykes which radiate from the laccolites, and are represented by intrusive sheets occurring conformable with both horizontal and upturned Cretaceous strata. Associated with the latter are similar sheets, and also dykes, of granular basalt or dolorite—though this material was evidently erupted in a highly fluid condition and did not form laccolitic masses. Casual observation in the region might lead one to infer that the intrusive sheets, occurring conformable with the folded sedimentaries, were erupted previous to the date of the disturbances by which the fold was produced. But the facts above cited render it obviously improbable that the eruptions took place earlier than the post-Bridger movement, notwithstanding that the eruptive sheets were apparently folded by this movement. The operation appears to have been governed by this principle, that the bedding planes being the direction of least resistance, no matter whether the strata were horizontal, inclined or vertical, the tendency was for each injection of lava to follow these planes.

In the La Plata Mountains we have another example of the eruption of a great plutonic body simultaneously with the development of orogenic movement affecting Eocene strata. The intrusion of an enormous mass of quartz-porphyry adjacent to the Galisteo beds of central New Mexico is also a case in point.

The intrusions of basaltic material in the Elk Head Mountains of northwestern Colorado are of the same nature as those of the Spanish Peaks country. The larger intrusive bodies protrude through Cretaceous and Eocene strata, and send off conformable sheets traceable along the outcrop of inclined Laramie beds as far south as the Yampa. Connected with these sheets are many prominent dykes which cut up through the Wasatch Eocene. Here again is an instance of the injection of sheets of lava into strata previously flexed by post-Laramie and post-Bridger disturbances.

The structure developed by these intrusions is illustrated by numerous examples in central and southern Colorado, in northern New Mexico, and in southeastern Utah. In its typical form, that of the laccolite, it is seen in the Henry Mountains, where it was first studied by Gilbert. It results from the uplifting of the strata in the form of a dome, by the intrusion of a lense-shaped or ellipsoidal eruptive mass, sometimes accompanied by a rupture of the dome near the summit, or by more or less radial fissuring—the openings in both cases being filled by exudation of the plastic material. Only a few laccolites possess this characteristic development. Yet the operation of the principle on which they were formed, has given rise to a great many modified examples. In its mode of origin, and the fissuring which has often resulted from it, the sheet-like intrusion may be considered as an extreme form of this type. The opposite extreme is seen in such occurrences as Mount Marcellina, Gothic Mountain and Crested Butte—enormous bodies, bounded by steep, sometimes nearly vertical sides; the original form being, in a measure, comparable to a beehive. From the sheet-like laccolite there are, therefore, intermediate gradations to the mass of the beehive form 3,000 feet high. It is evident, in many cases, that the formation of the typical laccolite belongs to an early stage in the evolution of the form most commonly observed—that is, after the typical form had been developed the process was continued until a mass of mountain dimensions protruded through the dome. Anthracite Range may be cited as an example of this kind. Generally, however, long continued erosion has sufficed to render the original form somewhat uncertain, and it is not always possible to determine to what extent the sedimentaries formerly enveloped the eruptive core. This is especially true in the Elk Mountains where, with the single exception of the Coal Basin laccolite, which is typical, erosion has so far advanced that there only remains the upturned strata at the base to indicate the nature of the intrusion. In the case of Crested Butte, erosion has penetrated still deeper, and at Gothic Mountain it has reached the base of the core itself. The different modifications of Henry Mountain and Silver Mountain structure developed in the Elk Mountains, the Spanish Peaks region, and elsewhere in Colorado and New Mexico, are eminently characteristic of this part of the Rocky Mountains and have exercised an important influence on the existing configuration of the country.

In addition to the eruptions just described, there were others, of great magnitude, consisting of basaltic lavas poured out in successive over-lapping flows. The eruptions of the Raton Mountains, the White River Plateau and Grand Mesa furnish the most striking examples. These overflows are all clearly referable to Miocene time, certainly not to a later period, for these reasons: (1) The rocks either overlie Eocene strata (Grand Mesa) or are unconformable with beds flexed by late Eocene movement (White River Plateau and Raton Mountains). (2) No considerable amount of erosion had taken place between this movement and the time of eruption, so that the overflows usually show a nearly even plane of contact. They are thus distinguishable from later extravasations which, in general, occupy valleys of erosion. The succession of flows which characterized these eruptions impart to the exposures a quasi-stratified appearance, that can be seen to great advantage in the Trappers Lake amphitheater.

The tendency of these overflows has been to retard erosion and produce elevated plateaus bordered by escarpments of basalt occasionally several hundred feet high, such as appear, for instance, around the head of the Yampa. This form of elevation is not uncommon in New Mexico, and is noticeable in the region around Camp Apache in Arizona. In a modified form it is extensively developed in the Uinkaret Plateau, whence it has been designated by Powell "Uinkaret structure," though for general application this term might properly be restricted to the form developed by the older Uinkaret eruptions since the more recent cone eruptions of the plateau give rise to the structure common to volcanic districts and in the Rocky Mountains both forms occur independently.

Post-Miocene Movement.—So far as our present knowledge justifies a conclusion, the close of the Miocene was not marked by disturbances producing in the mountain area important orographic results; though, no doubt, had there been a more general distribution of Miocene sediments we might be able to correlate the recognizable effects of movement in the mountain region with subsidence in the region of the plains and the expansion of the Miocene lake-basins into the extensive area of fresh-water sedimentation in the Pliocene. Yet proof of post-Miocene movement of a mountain-making character is not wanting. The most noteworthy was the elevation of the Park Range and Gore Mountains whereby a shallow Pliocene lake was formed along the western border of Middle Park. This elevation probably coincided with a certain undeterminable amount of absolute subsidence, for we may note that at about this time the North Park area was depressed and formed a fresh-water bay having a connection northward with the main body of the Pliocene lake. There is also evidence of a slight upheaval of the White River Plateau, causing the formation of two small, presumably Pliocene lakelets, one on Eagle River near Gypsum, the other on

Roaring Fork near the mouth of Cattle Creek. In like manner the Santa Fé and Huerfano marls afford evidence of movement both in the Toas-Glorieta Mountains and in the northern continuation of the same range—the Sangre de Cristo.

During the Pliocene Epoch, the eastern base of the mountains was probably but little elevated above sea-level and the country, from the far north to the Gulf coast, was low-lying and largely covered with water; though, as the Pliocene sediments were the first to suffer erosion in the Quaternary, the form and extent of the great lake occupying the Plains Region is now a matter of conjecture.

In the Basin Region, west of the Wasatch Range, Pliocene sediments—the Humboldt group—accumulated over broad areas; but the relation of these deposits, and of others in the Snake River Valley, to the beds of the same epoch east of the Rocky Mountains has not been definitely established. Neither has the relation of the latter to the North Park beds and the more limited accumulations of the mountain area been satisfactorily determined.

Post-Pliocene Movement.—The disturbances terminating the Pliocene were more remarkable for their continental than for their mountain-making effects. By this movement the entire Rocky Mountain region was uplifted 4,000 feet or more above the previous Pliocene level, as shown by the persistent southeastward slope of the Pliocene beds in the region of the plains. This movement was clearly recognized by King and still earlier by Warren, as quoted by King.* The latter also recognized evidence of pronounced post-Pliocene disturbance along two lines of orographical displacement, viz: the eastern base of the Sierra Nevada, and western base of the Wasatch Range, "both in regions of previously defined faults."† He fur-

* Systematic Geology, p. 427.

† Ibid., p. 442.

ther observed a tilting of Pliocene beds, amounting to from 10° to 20°, in Cache Valley and on the divide separating the drainage of Snake River from the Salt Lake Basin; but remarks on the exceptional character of these occurrences and the general absence of faulting and folding traceable to this movement. In the Rocky Mountains there is little evidence to show that anything more than distinctly recognizable inclinations were added to the sum of previous dynamic effects. In the Green River Basin and Uinta Mountains there are certain facts which might suggest post-Pliocene movement; though the evidence, even in this case, is not at all conclusive, depending, as it does, on the age and origin of the structureless, non-fossiliferous Wyoming Conglomerate. With regard to the age of this formation, it is generally conceded to be very late Pliocene or early Quaternary; but, as to its origin, those who have examined it are inclined to different views, on the one side that it is of sub-aqueous deposition and on the other that it is simply a sub-aerial accumulation. If this conglomerate is a sub-aqueous deposit of late Pliocene age, it is certain, from the present distribution of its preserved remnants, that the lake of that epoch must have existed on both sides of the Uinta uplift, have extended high up on its flanks and across it near the disturbed junction of this uplift with the Yampa Plateau. The existence of a lake thus situated, of the extent and depth which the conditions presuppose, would involve either previous great depression of the entire Uinta region or else great elevation of the Plateau region to the south—practically amounting to a reproduction of the essential features of Middle Eocene configuration. This would entail post-Miocene movement, considerable in amount and differing in its effects from preceding Cenozoic disturbances. The subsequent reversion to orographic conditions, similar to those existing before the lake was formed, would involve a post-Pliocene movement more intense than that recorded in the Basin

Region. The same movement must also be invoked in order to explain the difference in elevation of nearly 2,000 feet, shown by the atlas of the Fortieth Parallel Survey to exist between the remnant of the conglomerate at Vermillion Bluffs and that of Bishop's Mountain, or between the latter and the large remnant west of the mouth of the Yampa, or the difference of 1,000 feet between the patches of Quien Hornet Mountain and Tabor Plateau. If, on the other hand, the conglomerate is a sub-aerial deposit, accumulated during a time of great floods such as we may reasonably suppose characterized the gradual inauguration of the Glacial Epoch, the assumption of intense post-Pliocene movement is unnecessary since such accumulations would not follow the ordinary law of sedimentary deposition. Evidently, the existence of a late Pliocene lake, situated as above described, would oblige us to refer the establishment of the course of Green River across the Uinta uplift to early Quaternary time; which seems too late a date when we compare the amount of erosion performed by this stream with that performed by others whose inception can be shown to have occurred in Eocene time. The structureless character of the Wyoming Conglomerate does not favor the idea of sub-aqueous origin. Moreover, the sudden creation of a great Pliocene lake—covering both flanks of the Uinta Range and extending over one portion of it, together with its equally abrupt obliteration, in a region which had not previously received Miocene or Pliocene sediments, demands a succession of disturbances not elsewhere recognized and also an amount of post-Pliocene (possibly Quaternary) local displacement and uplifting which the structural facts, as shown on the maps of the Fortieth Parallel and Hayden surveys, in nowise support. Independent of the possibilities which a belief in the sub-aqueous origin of the Wyoming Conglomerate would suggest, there are no reasons for assuming an orographic post-Pliocene movement in the Uinta region comparable with that noted by King in the Salt Lake Basin, or for supposing that true sedimentary beds of Pliocene age were deposited there—a conclusion which, as Dr. Peale affirms, holds good in the northern part of the Green River basin in Wyoming.*

Origin of Green River.—Accepting the correctness of the above conclusion, the events connected with the establishment of the channel of the Green may be thus inferred. After the post-Bridger movement, whereby there was a great upheaval of the Uinta, Yampa and Uncompahgre plateaus and the region of the continental divide, lakes were formed on both sides of the Uinta and Yampa uplifts, and to a certain extent parallel with them. The northern of the two lakes drained into the southern by way of the depression at Lodore Cañon, which was, no doubt, the lowest point in the line of uplifts at that time. This we may regard as the inception of the course of Green River across the eastern extremity of the Uinta Mountains. The configuration of the surface north of the lakes determined the course of the upper Green at about the same time; while the outlet of the southern lake may have extended south a short distance before joining the Grand and thus forming the Colorado.

The early representatives of the Yampa and White drained into the lakes respectively north and south of the uplifts. By the post-Eocene movement a synclinal depression, between the Yampa Plateau and the eastern extension of the Uinta fold, was formed in the Uinta Eocene beds, and in the latter the course of the lower Yampa was first established in such a way as to determine the erosion of its channel through the northern border of the plateau uplift which was partly covered with Uinta sediments. The course of White River was established, in a similar manner, by a slight depression of the Uinta Basin parallel with the east-and west axis of the uplifts. From that time to

* Hayden's Report, 1877, p. 641.

the present, the Green River and Uinta basins have been areas of denudation, with established water-courses subject to variable rates of erosion. This was probably greater throughout the Rocky Mountains at the beginning of the Miocene than at the close of that epoch, and decreased as the high ranges and plateaus were gradually planed down, the precipitation of moisture lessened correspondingly, and the transporting and cutting power of the rivers reduced as their fall and volume diminished. By the post-Pliocene elevation the fall of the rivers and their cutting power were again enormously increased, to be augmented later by the long-continued floods of the Glacial Epoch, when the Rocky Mountain ranges and plateaus were capped by local ice-sheets, and furrowed by valley glaciers which since that time have retreated so slowly that their final extinction was a quite recent event.*

The assumption of post-Bridger time for the establishment of the course of Green River across the Uinta Mountains is in keeping with the amount of erosion performed by this stream, as compared with other rivers whose inception must have occurred at a still earlier period. In this respect a fair comparison may be instituted between the Green and Grand. The former is usually termed the main branch of the Colorado, though as regards volume the measurements made by A. H. Thompson (quoted by Dutton) show that, at the junction, the Grand is the larger of the two. Nevertheless, this relation does not hold good if the comparison be made between the volume of the former above the confluence of the White and Uinta rivers, with that of the latter above the confluence of the Dolores and Gunnison; and the volume of the Green at Lodore Cañon

* It may be interesting to remark that on the broad summit of the White River Plateau, glacial flutings and striæ are everywhere noticeable, and there can be no doubt that it was formerly capped by an ice-sheet, covering all the country above the contour of 9,500 feet and flowing down the valleys heading in the plateau. Similar conditions must have prevailed over the Yampa Plateau, in the Uinta Mountains and over the elevated areas of the principal ranges, as numerous observations have shown.

will no doubt exceed that of the Grand at the mouth of Parachute, though not very much. The inception of the channel of the Grand across the Eocene beds of the Uinta Basin must, as I have already explained, have coincided with the contraction of the Eocene lake and the production of a post-Bridger or post-Eocene fold between this stream and the White. Since that time the river has excavated a channel to the depth of 4,000 feet with reference to the original surface of the Eocene beds. During the same period the Green has excavated a channel to about the same depth through the eastern extremity of the Uinta Mountains. In the former case, a broad cañon was eroded out of soft Tertiary strata; in the latter, a narrow cañon (Lodore) was eroded out of relatively hard, mostly Palæozoic strata.

Whether or not the present relative volume of these streams has been approximately maintained from the beginning there is no direct evidence to show, one way or the other. Yet it appears that at least as far back as the Middle Quaternary the topographical conditions along the principal water-sheds were substantially the same as now; while no small portion of the drainage of the two rivers has, throughout, been adjacently situated, so that I can imagine no serious objection to the present relative volume of water being made the basis of a rough comparison of the work performed by the two streams. In this connection there are two facts of importance to note, viz: the stated depth of erosion by the Grand is very nearly the total amount; for, as before explained, the overflow of Grand Mesa and the Mam Mountains has protected the Eocene beds previously but little eroded, and it is safe to conclude that nearly the original thickness is exhibited. With the Green, on the other hand, the total amount can hardly be estimated owing to the impossibility of determining what the general erosion of the uplift has been since the course of the river was first established. That since the close of the Eocene it has been considerably greater than that of the relatively low-lying Uinta Basin there can be no doubt. Hence, it is difficult to avoid the conclusion that, notwithstanding the firmness of the beds operated upon, the depth of erosion effected by the Green since the date of the post-Bridger movement, has exceeded that effected by the Grand during the same period—yet probably not any more than is due to superior volume of water. Confronted as we are with the fact that on the North Platte, the upper Grand and elsewhere, the Pliocene beds are, at the most, but a few hundred feet above the turbulent channels of these streams, the view that Lodore Cañon has been formed wholly in Quaternary time cannot well be entertained.

Pliocene and Later Eruptions.—Of eruptions that occurred in Pliocene time we have but little definite knowledge. Certain basalts of the Rio Grande Valley and Northern New Mexico, judging from the amount of erosion, are probably of late Pliocene or early Quaternary age, or were erupted near the time of the post-Pliocene elevation. The later eruptions of central and northern New Mexico and the one at Dotsero in Colorado evidently took place in late Quaternary or recent time, since the flows occupy deep valleys of erosion. In the Huerfano Basin, near the southern border of the Wet Mountain Range, there are ash-beds containing vertebrate remains of late Pliocene age; and similar material has been observed at a number of localities on the plains. There are, nevertheless, but few occurrences to which either an earlier or later date cannot be assigned. Nearly all the eruptions of New Mexico included under this head, and also the later ones of the Uinkaret Plateau, gave rise to what may be termed volcanic structure. The flows occurring in the deep valleys are often traceable to vents situated in the neighboring highlands. The larger flows of ropy, scoriaceous material occupying the low country are sometimes surmounted by cinder cones of which Mount Capuline, situated at the eastern end of the Raton Mountains, is a striking example.

Quaternary Movement.—The disturbances of the Basin Region referable to this epoch, suggest the probability of simultaneous disturbances having occurred in the Rocky Mountains; though, whether or not they exerted an appreciable influence on the configuration of the country, the physical conditions of the Quaternary were such that no definite record could be handed down. The contemporaneous outpouring of lava in New Mexico, Arizona, Utah and west to the Pacific coast, also suggest wide-spread Quaternary disturbance. The effects of the movement, so far as they have been identified, were developed entirely outside of the region under discussion. The Lake Bonneville post-Glacial beach-lines of the Salt Lake Basin, as shown by Gilbert, have been displaced by faulting of a comparatively recent date. He also shows as a result of careful instrumental observations, that the central portion of the lake-basin has been elevated into a broad, flat dome to the extent of nearly 200 feet. On the west side of the Great Basin the Owens Valley earthquake of 1872, accompanied as it was by recognizable displacement, indicates that mountain-making in that region has not entirely ceased; in fact, that the operation may still be imperceptibly, though steadily, progressing, subject to periods of acceleration and sudden movement, resulting from an over accumulation of stress.

Summary of Cenozoic Events.—The sequence of Cenozoic events in the south central Rocky Mountains, as indicated in the foregoing, are briefly these. At the close of the Laramie Epoch a widespread orographical movement was inaugurated in connection with the general elevation of the entire area of Mesozoic sedimentation. This elevation was acccompanied by the formation of flexures, of comparatively gentle inclination, along the previous shore borders, of faults in part parallel with them, of the early uplifts of the Uinta, Yampa and Uncompahgre plateaus, the Wasatch flexures and of the more pronounced folds of the Sweetwater and Wind River regions. Before the expiration of this movement, and during an epoch of explosive eruptions, the post-Laramie beds—to which may be referred the Arapahoe, Denver, Ohio Creek and Ruby terranes, probably part of the Poison Cañon. Yampa, South Park and Middle Park deposits and the remnants near Cañon City—were laid down as the earliest sediments in the fresh-water lagoons which at the close of this movement expanded into the Eocene fresh-water lakes.

At the termination of the Wasatch Stage, which throughout appears to have been associated with gradual subsidence, there was an uplifting of the Rocky Mountains, the Uinta and Wasatch ranges and the eastern half of the Plateau Province, accompanied by either an actual or relative depression of the eastern portion of the Basin Region. The result was a contraction of the Eocene lake northward and an extension of it to the westward at the beginning of the Green River Stage. It appears probable that the earlier eruptions of the San Juan Mountains were associated with this disturbance. The end of the Green River Eocene witnessed further movement in the same regions, which resulted in great contraction of the area of sedimentation, especially south of the Uinta Mountains. Whatever may have been the effects of these inter-Eocene disturbances east of the Rocky Mountains, we have now no definite record. In the Huerfano Basin, the character of the sediments indicates progressive depression of the synclinal trough during the early Eocene; and that it was probably further depressed to the extent of 3,000 feet previous to the laying down of the Huerfano (Bridger) beds, though part of the depression may have been contemporaneous with their deposition.

At or about the close of the Bridger Eocene, another grand movement occurred nearly as widespread, and equally as intense, as that which closed the Cretaceous. This disturbance terminated the long period of Eocene sedimentation in the Huerfano Basin, tilting at a high angle the beds deposited immediately before it, uplifting the Sangre de Cristo and Wet Mountain ranges, and probably the Conejos Range and the San Juan Mountains between which and the Sangre de Cristo there was now formed the broad valley depression of San Luis Park. The southern continuations of these ranges were involved in the same movement; while to the north, the Front, Medicine Bow, Park and Sawatch ranges were uplifted several thousand feet and the flanking sedimentaries abruptly and steeply upturned. To the west, the post-Laramie uplifts of the White River, Yampa and Uinta plateaus, were enormously increased and the strata on their flanks to the top of the Green River beds upturned from 40° to 70°—in one instance forming a continuous line of flexure from the Elk Mountains to the Wasatch. By this movement the White River Plateau was elevated 5,000 feet or more, an amount which was probably exceeded in the Uinta Mountains; while in the Elk Mountains not less than 8,000 feet of elevation took place. At about the same time the Wind River and Sweetwater ranges, the La Plata Mountains and the Uncompahgre Plateau, underwent further upheaval accompanied by tilting of the Eocene sediments on their flanks. Immense bodies of diorite and quartz-porphyry were now intruded, laccolitically, into the marine Cretaceous and older formations; followed at a somewhat later period by similar enormous intrusions of porphyrite.

The Uinta Eocene lakes, whose origin is clearly attributable to this movement, covered a much greater area, south of the Uinta Mountains, than had previously received Bridger sediments. The lakes situated respectively north and south of these mountains had a connecting channel between them, and this channel became the permanent course of Green River through the uplift. South of the Uinta lake the channel of the Colorado had now advanced so as to form an outlet for the surplus Uinta water; while the Grand, White, Yampa, Dolores, the branches of the Platte, Arkansas and a number of smaller streams were plowing deep furrows through the rising folds. The effect upon the San Juan and its tributaries was merely to increase the declivity of the channels and thus augment the cutting power. As elevation at this time probably exceeded in rapidity the rate of erosion there was an increase in the precipitation of moisture and the scoring and cutting was correspondingly more active than at any time since the beginning of the Eocene.

With the termination of this epoch further movement took place, but its effects were not at all comparable with the uplifting and flexing at the close of the Bridger. There was, nevertheless, a certain amount of uplifting of the principal ranges, accompanied by recognizable flexing and differential movement, and the formation of the shallow Miocene lakes east of the mountain border.

About this time there were other intrusive eruptions of porphyry, porphyrite, granular basalts or dolerites, and possibly, to a limited extent, of intrusive nepheline-bearing rocks of the last named type. These were followed, during the Miocene, by vast extravasations of basalts poured out in successive overlapping flows.

The movement which brought the Miocene to a close and greatly extended the area of sedimentation in the Plains Region, produced a recognizable uplifting of the principal ranges, the relative or actual depression of the troughs between them, and a decided deepening of the basins of the North, Middle and Huerfano parks. There may have been limited outflows of basalt about this time, though none have been identified as clearly related to this movement.

The termination of the Pliocene Epoch witnessed an uplifting of the Plains Region and Rocky Mountains amounting to fully 4,000 feet in the mountain area. This movement was of a continental character and, except in the Basin Region where pronounced displacements are shown to have occurred, was mainly one of general elevation. As the latter progressed the precipitation of moisture was enormously increased so that great floods marked the last stages of upheaval and the inauguration of the Glacial Epoch. It is to this period of floods that we may refer the Wyoming Conglomerate of the Uinta Mountains, together with similar deposits in Wyoming, the Huerfano Basin and elsewhere. Later on, differential movement is indicated by the post-Bonneville faults of the Basin Region, with which I am led to associate the numerous scoriæ, eruptions of northern New Mexico, the Plateau Province and westward. Such manifestations of dynamic force have been of intermittent recurrence up to the present time and may be expected to occur in the future.

Orographic and Structural Effects.—From the evidence presented in the foregoing discussion of Rocky Mountain orography, the following conclusions suggest themselves. I will remark in the first place that, while the disturbances of post-Carboniferous and late Jurassic times exercised an important influence on the internal structure of the country, the great orogenic events were those which, beginning with the post-Laramie revolution, were distributed through the Tertiary epochs and were vastly augmented by the grand eruptions of the period. I am, therefore, in line with those geologists who regard the Cenozoic Era as the chief mountain-building time in the south central Rocky Mountains. The simplicity and uniformity of the structure developed by the Cenozoic disturbances is remarkable; characterizing as it does a region extending through nearly 600 miles of latitude. The influence of Tertiary eruptions in augmenting and modifying this structure is most marked; while of yet greater importance are the numerous isolated laccolites, or their plutonic modifications, whose development has contributed in no small degree to the sum of orographic results. The final outgrowth of the mountain-making movements referred to, is expressed in a system of lofty, meridional granite ranges flanked by abruptly upturned sedimentary beds, curving successively westward as they graduate into the east-and-west uplifts and flexures produced by the same series of disturbances.

It is noteworthy, that the east-and-west folds terminate along a north-and-south line of great differential movement, defined by the profound faults of the Plateau Province and the Wasatch zone of displacement toward which, as Dutton has shown, these faults converge.* The western base of the Wasatch is the eastern boundary of a broad region characterized by approximately north-and-south lines of post-Jurassic flexing—the "Basin Ranges"—and by Tertiary and later irregular fault-displacements, trending more or less in the same direction. This region has for its western boundary the eastern base of the Sierra Nevada, also a zone of multiple faulting and displacement. The western base of the Wasatch is, therefore, the true structural dividing line between the Basin Province and the Rocky Mountains. West of this line Cenozoic disturbances were expressed by differential movement; east of it by east-and-west flexures sweeping in great curves to the southward. I regard it as definitely established that this structural line has been one of considerable orographical disturbance even up to the time of the post-Bonneville faults; though probably not to the extent claimed by King. Nor do I regard as improbable the view

* It should be understood that the fault-line indicated on the accompanying sketch-map, as bounding the western base of the Wasatch Range, is intended to represent an irregular zone of multiple faulting and displacement rather than a single, well-defined plane of differential movement.

entertained by Gilbert that further disturbance may occur along this line at any time in the future and that the Wasatch Range is still in process of formation.

The idea of post-Cretaceous overthrusting of Wasatch strata upon the Archæan basement, advocated by Prof. Dana,* whether by an advance of this basement toward the east or by a thrust of the overlying strata toward the west, seems entirely reasonable and warranted by the evidence of movement in the strata themselves. I am nevertheless of the opinion that, so far as our imperfect knowledge of that complicated area will enable us to judge, we cannot attribute the observed effects altogether to this cause. If the overthrusting was sufficient in amount it was obviously capable of producing the flexing and warping ascribed to it. But, as I have already remarked, the facts suggest that the flexing began previous to the deposition of the Dakota sandstone, presumably during the epoch of post-Jurassic disturbance, and that it was developed and completed by the post-Laramie movement—although I recognize the probability that the flexures may have been emphasized by later disturbances. As near as we can judge the folding and uplifting of the Uinta Range was coincident in time with the movement that effected the development and completion of the Wasatch flexures, and the question is presented, did this folding and uplifting, which involved a linear reduction of area amounting to from 7 to 10 per cent. terminate at the topographical junction of the two ranges or did it extend to the line of faulting and displacement on the west side of the Wasatch? The continuity, in line of strike, of the flexed Wasatch strata with the upturned beds of the Uinta Mountains rather favors the view that the north-and-south tangential force which produced the Uinta uplift was expressed by compressive flexing as far west as the zone of displacement. If this zone was of

* Amer. Jour. Sci., Vol. XL, p. 181.

prior establishment, as there seems no reason to doubt, it was already a line of weakness along which horizontal, as well as vertical, displacement might occur; and flexures normal to this line might be developed in connection with horizontal displacement and contraction on one side of it, yet not be developed to a corresponding degree on the other—in fact might not be developed at all. The aspect of the folds and warps along the structural line, indeed, suggests horizontal movement east of this line toward a common point—the great flexure at the junction of the Uinta and Wasatch axes. Admitting the reasonableness of the argument in favor of overthrusting, and the probability that part of the flexing and warping may be due to this cause, I am yet of the belief that future studies will demonstrate a connection between the origin of these flexures and the north-and-south compressive folding which has developed the characteristic structure of the broad region east of the Wasatch Range.

The probable existence of overthrust faults and flexures in the Rocky Mountain Region to the east, ought not to be overlooked, though I question if they have been developed to an important extent. I have already suggested the possibility of an overthrusting of the Cretaceous upon the Lower Palæozoic in the Elk Mountains. In this instance, if an overthrust took place, it did not result from regular orogenic movement, but from the intrusion of an enormous eruptive body near by. Indeed, it may be nothing more than an example of unconformable transgression, at the time indicated, of which there is unquestionable evidence in the same region.

The abrupt plication of strata at the before mentioned Oak Creek locality east of the Sangre de Cristo Range, where the Dakota is overturned about 60° and dips westward beneath Upper Carboniferous beds, may be cited as a possible case of overthrust faulting to a limited extent for a short distance. At least it is an advanced stage in the production of a fault of this character in which the final result would have been an upward and eastward thrust. In South Park the Laramie and older beds are steeply upturned on their western border, but along the eastern border, a few miles distant, upturning in the opposite direction is not always apparent nor are there any beds exposed below the post-Laramie which rests directly on the Archæan of the low hills occupying the eastern portion of the park. Here again, an overthrusting due to the upturning of the strata on the western border, or partly to the intrusion of eruptive bodies on that side, may at least be suspected. But in this case also if an overthrust occurred it was evidently to the eastward. In the Wind River region on the other hand the facts rather favor movement in the opposite direction or, correctly speaking, to the south-west. The east-and-west range of the Seminoe, Ferris and Sweetwater mountains clearly resulted from a southern heave of the Archæan body lying to the north; producing in this body east-and-west Archæan ridges, and squeezing up the granites and schists into a low range of mountains flanked on the south by steeply upturned Palæozoic and Mesozoic strata. This range is severed in several places by north-and-south faults with the upthrow to the south. The most prominent of these separates the Seminoe and Ferris mountains by a displacement of from 15,000 to 20,000 feet—the former being thrown that much to the southward. The direction of the movement is indicated by the presence of abrupt secondary flexures south of the Seminoe Mountains, while none were observed south of the Ferris Mountains. This interesting line of uplifts graduates into the more prominent Wind River Range. Here the shove to the south was translated into a corresponding shove to the south-west, or normal to the axis of the range, producing the parallel Poposia fold. This is essentially a fold of the **S** type, but, as compared with the Front Range—Sangre de Cristo fold, the form, with relation to the range axis, is reversed. In this case the strata, at first, inclined away from the axis, are sharply upturned into a vertical position and then as sharply flexed in the opposite direction into a gradual monocline, also dipping away from the range line.

In the Wind River Mountains the pre-Cambrian schists and slates have an enormous development but they were folded up previous to the deposition of the Cambrian sandstone. Hence, no great thickness of sediments was available to insure rigidity during an overthrust movement, and the result of the range-ward shove was to buckle over the strata in the manner described. No doubt, had the movement been from the opposite direction the form of the fold would have been reversed. The Front Range and Sangre de Cristo, like the Wind River Mountains, were low-lying areas at the time the folding occurred so that the conditions were pretty much the same. But in the cases first named the buckling over was decidedly to the eastward, thus suggesting that the fold was due to a shove from the westward. The secondary anticline on the Yampa presents the steep part of the fold toward the Park Range, but the direction of movement as compared with the Poposia fold was reversed—that is, it was to the northeast. The course of the flexures in the western San Juan region is quite irregular, yet the general tendency of Cenozoic disturbances was to produce monoclines of gentle slope or, in exceptional instances, to develop folds which, if the operation had continued, would ultimately have buckled over the sediments toward the body of the mountain or in an easterly direction. So far as the facts can be credited they indicate that at the most easterly bend of the Rocky Mountain Chain, whatever the amount of thrusting may have been, it was from the west against the Plains Region; while at the point where the prominent bend to the southwest occurs the resultant of the thrust forces was south-southwest or in a direction favorable to the augmentation of the east-and-west flexures of the region east of the Wasatch Range.

An interesting feature of Rocky Mountain development which I deem worthy of remark is the great uplifting and displacement that has occurred along pre-existing shore-borders. The Wasatch and Sangre de Cristo are prominent examples of uplifts so situated when formed. The Ferris and Seminoe mountains originally occupied a similar position with reference to the old land-mass of the Sweetwater region, and even the Mosquito Range may be said to have held the same relation to the Sawatch mass and the South Park pre-Tertiary bay. The Front Range,* in a measure belongs to the same category. If the upturned strata along its eastern border were restored to their original position previous to the post-Laramie movement the Archæan body of the range would, with reference to the Plains Region, be reduced in topographical importance to the condition of the Laramie Hills, which it probably resembled when first furrowed by the waters of the South Platte. Yet the fact that, except at a few points, the Mesozoic sediments still overlap those of the Palæozoic, shows that the present base of the range corresponds approximately to the old shore-border. This range was enormously uplifted by the Cenozoic disturbances and is probably to-day the most elevated of the Archæan areas. The movement appears to have resulted in an upward, and to some extent an eastward, shove which encountered great resistance along the Plains border, where the effects are seen in the abrupt Front Range fold and the gentle parallel flexures to the east of it, which cannot be explained by simple uplifting alone.

The structural dividing line between the Rocky Mountains and Basin Region is evidently the zone of displace-

* The term "Colorado Range" is also applied to this most easterly of the great mountain ridges, and should, ordinarily, be given the preference. The former has been used here for the reason that it suggests the geographical position of this range with relation to the others of the Rocky Mountain group.

ment at the western base of the Wasatch. The corresponding line between the Rocky Mountains and the Plains Region is the eastern base of the Front Range, and of its extensions north and south. The three regions thus distinguished are entirely dissimilar in their orographic and structural features, and it is important to note the difference between the two geographical extremes. While it cannot be regarded as definitely established that the Basin Region has been cut up by faults to the extent suggested by Le Conte,* there is, nevertheless, indisputable evidence that the entire area was one of plication, faulting and displacement from Carboniferous time even up to the present, as shown by the formation of the Basin Ranges, the post-Wasatch subsidence, the faults of Tertiary and post-Bonneville times and the historic Owen's Valley earthquake. On the other hand the region of the Great Plains, from Texas north to Dakota, has been one of relatively great stability and unaltered structure throughout the geological ages. Except in a narrow zone adjacent to the mountain border, faults, flexures and displacements are practically unknown, and the only recorded disturbances are those of simple subsidence and elevation. If this broad, and structurally undisturbed, region was ever subjected to horizontal movement producing a shifting of its position to the east or west, the disturbance was deep-seated and of continental extent. It was an advance of the continental basement, and involved equally the adjacent regions. Unless the movement was of a continental character the Plains Region must have remained stationary. I have just explained that in late Cretaceous and early Eocene times the Front Range was a comparatively low-lying area. By the post-Bridger movement, which multiplied the effects of post-Laramie elevation, it was uplifted into the most lofty of the granite ranges, as though by

* Amer. Jour. Sci., Vol. XXXVIII., p. 257.

reaction against the vast stable body of the Plains Region during an eastward shove from the Cordilleras.

The advanced position of the Front Range axis with reference to the general line of Rocky Mountain upheaval, which from this point has a northwesterly trend through Wyoming, and a south-southwesterly trend through New Mexico and beyond, rather favors the idea of a small amount of eastward movement in the mountain area; though the great eastward bend of the Rocky Mountain Chain may be largely, or even wholly, due to another cause—or rather to two causes combined. In neither case is a connection capable of direct proof, but may be inferred from the apparent mutual orographic relation of the eastern and western provinces of the continent during early development and later mountain-making movement. The first of these causes, is the probable influence of the form of the northeastern Archæan nucleal V in determining the general trend of Rocky Mountain post-Archæan folds—substantially as suggested by Prof. Dana.* The second, is the probable eastward advance of the central continental basement at the time of the Appalachian revolution, responsive to the enormous linear contraction which then took place in that region apparently contemporaneous with disturbances thoughout the western Cordilleras—thus suggesting a sympathetic movement of continental extent.

In the statements referring to the various orogenic manifestations I have made use of the terms uplifting, upheaval and elevation interchangeably and, during the prevalence of marine conditions, in an absolute sense. After the close of the Mesozoic, the terms were necessarily applied with reference to neighboring depressions, and hence were often used in a relative sense; though in each case absolute elevation may have occurred. The term subsidence, when

* Amer. Jour. Sci., Vol. XL., p. 182.

not otherwise specified, refers to the shore-borders and adjacent areas of sedimentation, and not as a rule to the Archæan bodies of the highlands from which the sediments were derived. As previously intimated it seems necessary to assume that these bodies have, from their earliest establishment, been subjected to the action of a force which produced a more or less constant, though probably gradual, upflow of the crystalline material composing them. By this I do not mean a mere underflowing of plastic substance on the hydrostatic principle—a theory which finds current acceptation—but an upflow also, or, to be more explicit, a long-continued mild form of plutonic eruption expressed by an imperceptible upwelling of the crystalline mass during past geological ages. This gradual squeezing up of the granite cores of the ranges, whether continuous or not, was marked by periods of acceleration corresponding to epochs of pronounced orogenic disturbances. The mere operation of the hydrostatic principle, whereby areas subside under an accumulating weight of sediments and areas that are unloading develop a tendency to rise, may have been competent to produce a certain amount of the gradual upflow referred to. Yet it evidently was not the cause, except remotely, of the acceleration and mountain-making, since the great post-Bridger upheaval of the Front Range for instance did not follow a period of sedimentation in the adjacent Plains Region; though the disturbances of that time may have been influenced by the tendency of the great lake-basins to subside when the Uinta Eocene lakes were formed.

The diversity of opinion existing on nearly all questions relating to geological physics may well suggest caution in dealing with this subject; nor do I wish to add to the confusion by expanding the already long list of unverified hypotheses. I shall therefore merely state the facts which appear to warrant the assumption of a constant upflow of granitic material along the range axes.

In my first reference to this matter, I declared that the thickness of sediments (pre-Cenozoic) derived directly or indirectly from the erosion of the Archæan areas of Colorado, corresponded to an Archæan mass, equal to these areas in superficial extent, having a mean altitude of about 20 miles. From the exposures of Palæozoic rocks along the old shore-borders we can say with confidence that, since the beginning of the Cambrian, the Archæan areas have at no time been greater on the whole than they are to-day; while the relatively small unconformities observed along these borders and in the inter-range depressions or parks, are proof that the post-Carboniferous and Jurassic disturbances did not produce flexing and upheaval comparable in amount with the subsequent orographic developments of Cenozoic time. The uplifting of the Uinta Range, estimated by Powell at 30,000 feet, was, as Dutton clearly recognized,* the result of the combined Cenozoic disturbances and not of one movement alone. There is not the least evidence to show that the Cenozoic relative uplifting of the Rocky Mountains exceeded this amount, even along the axial lines. Yet this was preëminently the time of upheaval, folding and mountain-making; while the enormous squeezing up which we are now considering was that which furnished the material of the Palæozoic and Mesozoic sediments. It cannot be shown, or even inferred, that more than a small fractional part of this material was forced up, cataclysmically, during the post-Carboniferous and Jurassic movements. If the total upsqueezing were reduced one half, and this referred to post-Archæan disturbances, the mean altitude of the land at the beginning of the Cambrian would be about 10 miles which, roughly speaking, would indicate an altitude little short of 20 miles along the range axes. We cannot believe that in Cambrian time these narrow ranges, separated by the broad park depressions of Palæozoic and Mesozoic sedimenta-

* Geol. High. Plat. Utah, p. 14.

tion, towered 100,000 feet above the surface of the surrounding ocean. Hence, as I once before remarked, the conclusion is forced upon us that over the Archæan areas of the Rocky Mountains a slow, but more or less constant, squeezing up or upflow has been going on, which furnished the material of the existing sediments. A process of this character, whereby incipient plasticity is developed by the steady application of a constant force, seems a more plausible operation than the development of relatively great plasticity where the squeezing up is due to the more energetic action of pronounced dynamic movement; as shown, for example, in the formation of the Sangre de Cristo Range. Up to the close of the Palæozoic this range lay within the area of marine deposition, which then extended west to the present line of the Conejos Range. During the Mesozoic it was the eastern shore-border of the San Juan peninsula. By the post-Laramie movement it was elevated into a low ridge—the uplift occurring along the line of post-Carboniferous superabundant sedimentation. The final crumpling was produced by the post-Bridger movement, when the granite core was squeezed up, and moulded, between two zones of steeply upturned sedimentaries, which if removed would expose the core as a long, lofty but very narrow Archæan body. The abrupt face of the Front Range, as seen at Cheyenne Mountain, and the narrow granite ranges of the Sweetwater region where the crystalline material welled up against the resisting strata, are also cases which serve to show that granitic rocks may develop a high degree of plasticity if the requisite amount of force be persistently applied.

There can be no doubt that the material which went to form the sediments of the regions adjacent to the Rocky Mountains and probably of regions more remote, except to the small extent that they may be chemical precipitates, was derived from the limited areas of the granite ranges; and whether this vast quantity of material was squeezed up cataclysmically, or by slow and imperceptible degrees, the development of plastic yielding and upflow was a necessary part of the operation. The facts point to the slow, long-continued process as the one most likely to have occurred. The experiments of Main and McConnel on the plasticity of glacier ice* are noteworthy as suggesting, in this connection, the indefinite extension and deformation which a holocrystalline body may undergo when the necessary force is continuously applied. I am not aware to what extent the question of the gradual upflow of granite masses under similar conditions has been considered by others in relation to occurrences elsewhere. In no portion of the continent is the operation of this process so strongly suggested as in the Rocky Mountains, where the land conditions first established remained practically the same through Palæozoic and Mesozoic times.

I have several times alluded to evidence of compression and linear reduction of area in discussing the effects of Cenozoic movements. Nevertheless, I do not maintain that all of the disturbances were associated with tangential compression and contraction. Yet the operation of a force thus expressed is clearly discernible in the crumpling produced by the post-Laramie and post-Bridger movements, and especialy by the latter. The folds of the Uinta and White River plateaus must have involved a contraction in those areas of from 6 to 10 per cent. The system of parallel flexures extending northwesterly from the termination of the Archæan body of the Medicine Bow Range, is evidently the result of compressive folding in that region. The continuity of the Hogback fold from the Uinta uplift to the Elk Mountains indicates the probability of more or less contraction over the mountain area of the Sawatch; while the Sangre de Cristo is indisputably the result of compressive movement. In their studies of Rocky Mountain disturbances, Emmons and Eldridge have both recog-

* Proceedings. 1889.

nized the effects of a force thus manifested. There is no reason to doubt that the superficial crust of the earth is now, and always has been, in a condition of compressive stress, yet not to an extent competent to account for the enormous contraction that has occurred in some parts of this continent; nor has science yet offered an adequate explanation. In the present case the compression producing the flexures east of the Wasatch structural line, even as far north as the Sweetwater River, was apparently the result of north and south movement toward the Uinta Range, or region of greatest orogenic effects. In the Rocky Mountains proper, such facts as bear on the subject favor the view that Cenozoic crumpling was effected by movements from the west against the stable body of the Plains Region; though at intermediate points in the great warp the two directions of compression were evidently combined. The normal faults so numerous and profound, of Tertiary age, observed in the Plateau region and in the Great Basin, indicate east-and-west expansion at the time these movements occurred; and the question suggests itself, how far the settling of a region previously uplifted and faulted may produce the effects of shoving in adjacent areas.

The principal movements of Cenozoic time were identical in direction, and the general trend of the great flexures was clearly determined by the axial lines established in post-Laurentian time, as urged by King, and earlier by Prof. Dana as a general proposition. It further appears that the course of these early Archæan folds may have been since greatly altered by an eastward advance of the central continental basement, in sympathy with the crumpling up of the Appalachian Chain.

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PROCEEDINGS

OF THE

COLORADO

SCIENTIFIC SOCIETY.

VOL. III, PART III,

1890

SUPPLEMENT.

The Publication Committee deems it necessary to explain that the manuscript of Mr. Guiterman's paper on "Gold Deposits in the Quartzite Formation of Battle Mountain, Colorado," received by the Committee, was not the full draft as it should appear in the Proceedings, but merely that which had been prepared for the condensed monthly abstract. The attention of the Committee was not called to this fact until too late to remedy the mistake, and the paper as published is simply an abstract of the original.

In justice to the author, and on behalf of the many members who will be interested in this important contribution to the literature of ore deposits, the revised paper, entire, is herewith appended as a supplement to the present volume.

ON THE GOLD DEPOSITS IN THE QUARTZITE FORMATION OF BATTLE MOUNTAIN.

BY FRANKLIN GUITERMAN.

At the suggestion of Mr. Richard Pearce, whose recent researches on gold, its alloys, and mineral associates, have been productive of such remarkably interesting and unexpected discoveries, I have undertaken to gather for the Society a few facts relative to the nature of the very rich auriferous ore deposits that are found and mined in the Ground Hog mining claim, located on Battle Mountain, Red Cliff Mining District, Eagle County, Colorado.

The ores found in this mine would naturally have drawn attention from their extreme richness in gold, this being found not infrequently in the nugget form, but the mineralogical character of the ore, which thus forms the matrix of the gold, adds a heightened interest to the investigation.

Before entering upon a description of the ore deposits in the Ground Hog mine, a brief review of the geological features characterizing Battle Mountain may be appropriate.

The formations revealed by the gulches traversing the country, consist of Cambrian quartzites—resting upon the Archæan—followed by Lower Silurian limestone, and this in turn by an intrusion of porphyry succeeded by shaly beds (Carboniferous?) Triassic and Jurassic strata, with magnesian limestones topping the section.

The quartzite formation is composed of two distinct layers, the physical features of which are quite dissimilar. The lower band, of a thickness of 125 to 150 feet, which is found to be very white, vitreous and brittle, having a massive appearance, without cleavage; the upper band, of an avarage thickness of about 175 feet, is gray in color, with a tendency to turn dark on exposure to the atmosphere, is much softer than the lower quartzite, and has a lamellated structure. The cleavage in this rock is perfect along the lines of the bedding-planes, which have not been entirely effaced by metamorphism as is the case in the lower band. Locally the upper quartzite is termed trachyte.

In immediate contact with the quartzite formation is the Lower Silurian limestone, (dolomitic,) which is also composed of two layers, the lower one of which is drab in color with a block structure, while the upper layer is massive and of bluish appearance. The total thickness of the limestone deposit may be averaged at 200-225 feet; the blue limestone being about 60 feet in thickness. The limestone is separated from the overlying shales by the intrusive mass of porphyry previously mentioned.

To the miner, the limestone and quartzite formations are alone of interest, for to them the ore deposits, as shown by discoveries to date, have solely been confined, and it is according to the location of these ore deposits, either in the limestone or quartzite zones, that the claims are locally known as limestone or quartzite mines. The ore bodies in the limestone mines are either confined to the lime-porphyry contact, occur in channels, or are found in pockets within the "blue lime," the boundary of such deposits appearing to be marked by the "drab lime." An exception to this characteristic may be noted in the Bleak House mine, where a vertical ore-bearing fissure has been found which cuts through the drab limestone and underlying quartzite to the granite.

In the quartzite mines, the valuable ore deposits occur in caves and channels, but the locus of such deposits appears to be confined to the contact-plane between the two quartzites, at least I am told that there never has been found outside of this contact, in the quartzite zone, any commercially valuable mineral.

What connection, if any, there may be between the respective limestone and quartzite ore deposits, is foreign to our present subject. Mineralogically, the difference between them may be summed up as follows:

The limestone ore deposits consist of predominating argentiferous lead carbonates with some unaltered galena, and below the natural water level, large bodies of unaltered pyrites associated with some galena. The quartzite ore deposits on the contrary are comparatively free from lead and are in the main composed of iron-pyrites at and below the water level, while above this level gradual alteration has been effected by oxidation.

The pyritiferous deposits of the two zones differ not only in physical appearance, but also in the silver and gold contents, the limestone pyrite being of dull lustre, coarse-grained and associated with a greater or less percentage of zinc blende; while the quartzite pyrite is of fine grain, lively and bright appearance, and is comparatively free from zinc, the maximum contents of this element being about 3 per cent.

Regarding the silver and gold contents of the two ores, it may be said, that the limestone pyrite will average probably 30 to 40 ounces of silver to the ton, with 0.40 to 0.60 of an ounce of gold, while with the same silver contents, the quartzite pyrite will carry 1.50 to 1.75 ounces of gold to the ton.

Both the unaltered sulphide deposits are remarkably free from quartz, the average silica contents not being over 2½ per cent.

From a mineralogical point of view, the quartzite sulphide deposits are of greater interest, for not only does their richness in gold form a marked exception to that ordinarily looked for in massive iron-pyrites deposits, but the alteration and secondary products resulting from oxidation, while they are so unique and beautiful, give at the same time, by means of continuous links, an almost positive proof as to the manner in which these changes were brought about.

The quartzite rocks between which the lower deposits are found, have an average dip of about 10° to the northeast. The contact between the two layers is sharply defined, the contact-filling being a quartzite breccia, more or less iron-stained and at times impregnated with unaltered pyrite. This breccia-filling has an average thickness of perhaps 4½ feet, occasionally expanding to 6 feet and contracting to a minimum of 4 feet.

The ore chimneys occurring in this filling are found at intervals, their presence being invariably marked at the outcrop by what is locally termed the "joint clay," an aluminous deposit, heavily iron-stained, occurring on top of the ore body and following it along the roof for a distance of perhaps 200 feet, when it gradually thins out; disappearing entirely when the unaltered sulphide is reached. The ore chimneys have a maximum width of about 4 feet, their distance being limited to the distance between floor and roof. While the quartzite roof is invariably smooth, the lower quartzite which forms the floor is quite rough, in fact, almost corrugated in appearance, and gives strong evidence of the chemical action exerted upon it, during the deposition of the ore. The floor is at times impregnated with ore, which does not however extend for any great distance into it.

As stated, the ore chimneys, which are continuous, have a maximum thickness of 6 feet, the pay ore itself being confined at times to a thickness of a few inches, and again swelling from floor to roof. The pay ore in the oxidized portion of the deposit carries on the average about 7 ounces gold and 50 ounces of silver to the ton.

In mining the ore it is customary to follow the floor as a guide. The individual ore chimneys are connected laterally by cross chutes, giving the appearance in section of a net work. It is a common occurrence for an ore chimney to divide, the separate branches either reuniting further on or again splitting up, the ramifications coming together again at intervals into one main chimney. The rock which fills the space where the divergence has taken place is of the same nature as the breccia-filling, only more compact, and is impregnated to some extent with pyrite.

These fillings are termed "islands" or "rib rock" and are left standing as pillars after mining the ore.

The characteristics of the quartzite ore deposits may be summed up as follows:

The outcrop of the ore chimney is characterized by the "joint clay," which is succeeded by a zone of complete oxidation for about 200 to 250 feet, gradually merging, as the natural water level is approached, through a zone of mixed oxides and sulphides into the zone of unaffected sulphides.

It has been mentioned that the "joint clay" gradually disappears as the sulphides are approached, and it is interesting to note that while the silica contents of the ore in the zone of complete oxidation are from 30 to 60 per cent., these also lessen as the zone of the unaltered sulphide is approached, diminishing from a maximum of 60 per cent. to an average in the sulphides of 2½ per cent.

With regard to the zone of complete oxidation, it must not be understood that it is a zone in which the ore is entirely free from oxygen compounds of sulphur. On the contrary, sulphates are present in appreciable quantities, noticeably ferric-sulphate which occurs as the crystalline minerals coquimbite and copiapite. The following analysis of a sample representing several car-loads of ore from the Ground Hog mine, made by Mr. F. C. Knight, of the Boston and Colorado Smelting works, will show to what extent this sulphate is present.

Hydrated sesqui-sulphate of iron	12.00
Hydrated sesqui-oxide of iron	54.30
Silica and alumina	32.20
Barium sulphate	2.70

On the Ground Hog mining claim there have been two chimneys of ore developed, 600 feet apart, the deposits having the essential characteristics of the quartzite deposits previously described. These deposits have been followed from the outcrop for about 250 feet in length. While lateral branches, which will undoubtedly connect these chimneys, have to some extent been exploited, the connections have not been entirely established, but from what is known of adjacent quartzite mines, it is not at all likely that the ore chimneys in the Ground Hog will prove an exception in this respect to the other deposits.

The two ore chimneys in the Ground Hog—one of which is worked by Messrs. Brock & Co., and the other by Mr. John Baumeister—have been prolific in nugget production; though the nuggets of the respective ore chutes differ widely in appearance. Those occurring in the Brock chimney are isolated and have a peculiar, spirally twisted form, often resembling a ram's horn. Those found in the Baumeister chimney are inclined to be lumpy, and on close inspection are seen to be made up of individual crystalline grains, of variable size, cemented together by ferric-sulphate and horn silver. In each case the nuggets are found in troughs in the quartzite floor, imbedded in clay and intimately associated with very rich silver-ore, which proved on examination to be horn silver—a most remarkable association in itself. With the nuggets, and in their vicinity, are also found lumps of clay, which show high gold results on assay, but from which it is almost impossible to obtain a color by panning.

The latest find by Mr. Baumeister yielded about 14 pounds of gold nuggets, the largest one of which weighed 9 ounces. This deposit was imbedded in a mass of clay and ore which was carefully taken out and which weighed 630 pounds. From this ore was obtained, by screening, 182 ounces of coarse gold, the screenings yielding about 426 ounces of gold and somewhat over 1,000 ounces of silver to the ton. The fineness of the nugget gold was about 900.

No tellurium or bismuth has been detected in such samples of Ground Hog ore, as have been brought to my notice, the examination for these elements being made in conjunction with Mr. Pearce. Tellurium has, however, been found in the district, and it is of course among the possibilities that these elements will be discovered later on in this particular deposit.

While it has been assumed by both Wurtz and Le Conte that the secondary deposition of gold, in the form of crystals and nuggets, was accomplished through the medium of a solution of persulphate of iron, derived by the slow oxidation of iron-pyrites, I think I am safe in saying that it has remained for the discoveries in the Ground Hog mine, to demonstrate, almost beyond question, the correctness of that theory.

The progressive development of the oxidized ore from the original sulphide, as seen in this mine, to the culmination of the process in the production of a rich auriferous ferric-sulphate, in which, the presence of the gold, owing to its extreme fineness, cannot be easily detected by the miner's test of panning, and, finally, the cementation of the nuggets to a large degree by the ferric-sulphate, are to my mind as conclusive a verification of that supposition as is ever likely to be reached.

In conclusion, I beg to say that I am greatly indebted to Mr. W. M. McMechen, superintendent of the Ground

Hog Mining Company, and to Mr. John Baumeister, lessee on the company's property, for the many facts they have given me in connection with their careful observations on the characteristics of the quartzite mines. To their kindness I also owe the exhibit of ores and specimens, which I have been able to make to-night.

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VOL. III. PART I.

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