Bulletin No. 225 Series A, Economic Geology, 33

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

CONTRIBUTIONS

TO

ECONOMIC GEOLOGY

1903

S. F. EMMONS
C. W. HAYES
Geologists in Charge

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., February 3, 1904.

SIR: I have the honor to transmit, for publication as a bulletin of the Survey, a manuscript entitled "Contributions to Economic Geology, 1903."

The report contains 51 contributions from 37 members of the Survey who have been engaged more or less continuously throughout the year in economic work, together with brief statements by the geologists in charge of the section of metalliferous ores and the section of non-metalliferous economic minerals, of the extent and character of the economic work being carried on in the Survey.

Very respectfully,

C. W. HAYES,
Geologist in Charge of Geology.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1903.

S. F. EMMONS,
C. W. HAYES,
Geologists in Charge.

INTRODUCTION.

By C. W. HAYES, *Geologist in Charge of Geology.*

This bulletin is the second of a series, the first being Bulletin No. 213, Contributions to Economic Geology for 1902. These bulletins are prepared primarily with a view to securing prompt publication of the economic results of investigations by the United States Geological Survey. They are designed to meet the wants of the busy man, and are so condensed that he will be able to obtain results and conclusions with a minimum expenditure of time and energy. They also afford a better idea of the work which the Survey as an organization is carrying on for the direct advancement of mining interests throughout the country than can readily be obtained from the more voluminous reports. The bulletin for 1902 was so favorably received by those interested in the development of the mineral industries of the United States that it is proposed to publish early in each calendar year a similar bulletin containing the results of the last year's field work in economic geology.

In the preparation of the present volume promptness of publication has been made secondary only to the economic utility of the material presented. The papers included are such only as have a direct economic bearing, all questions of purely scientific interest being excluded.

The papers are of two classes: (1) Preliminary discussions of the results of extended economic investigations, which will later be published by the Survey in more detailed form; (2) comparatively detailed descriptions of occurrences of economic interest, noted by geologists of the Survey in the course of their field work, but not of sufficient importance to necessitate a later and more extended description. A third class of papers was included in the bulletin for 1902, namely, abstracts of certain economic papers which had appeared in Survey publications during the year, chiefly such as gave a general account of the distribution and mode of occurrence of particular mineral deposits throughout the United States. Most of the publications on economic geology which have appeared during the past year were abstracted in Bulletin 213, and it has therefore been unnecessary to abstract them in this volume.

The papers have been grouped according to the subjects treated. At the end of each section is given a list of previous publications on that subject by this Survey. These lists will be found serviceable by those who wish to ascertain what has been accomplished by the Survey in the investigation of any particular group of mineral products. They are generally confined to Survey publications, though a few titles of important papers published elsewhere by members of the Survey are included.

The preparation of this bulletin, as well as of the corresponding bulletin, published last year, has been chiefly the work of Mr. E. C. Eckel, to whom is due in large measure the credit for planning the work and carrying it to a successful issue.

The results of the Survey work in economic geology have been published in a number of different forms, which are here briefly described:

1. *Papers and reports accompanying the Annual Report of the Director, United States Geological Survey.*—Prior to 1902 many economic reports were published in the royal octavo cloth-bound volumes which accompanied the Annual Report of the Director. This form of publication for scientific papers has been discontinued and a new series, termed Professional Papers, substituted.

2. *Bulletins of the United States Geological Survey.*—The bulletins of the Survey comprise a series of paper-covered octavo volumes, each in general containing a single report or paper. These bulletins, formerly sold at nominal prices, are now distributed free of charge to those interested in the special subject discussed in any particular bulletin. This form of publication facilitates promptness of issue for economic results, and most economic reports are therefore published as bulletins. Their small size, however, precludes the use of large maps or plates, and reports containing large illustrations are therefore issued in the series of Professional Papers.

3. *Professional Papers of the United States Geological Survey.*—This series, paper covered, but quarto in size, is intended to include such papers as contain maps or other illustrations requiring the use of a large page. The publication of the series was commenced in 1902, and the papers are distributed in the same manner as bulletins.

4. *Monographs of the United States Geological Survey.*—This series consists of cloth-bound quarto volumes, and is designed to include

exhaustive treatises on economic or other geologic subjects. Volumes of this series are sold at cost of publication.

5. *Geologic folios of the United States Geological Survey.*—Under the plan adopted for the preparation of a geologic map of the United States the entire area is divided into small quadrangles, bounded by certain meridians and parallels, and these quadrangles, which number several thousand, are separately surveyed and mapped. The unit of survey is also the unit of publication, and the maps and descriptions of each quadrangle are issued in the form of a folio. When all the folios are completed they will constitute a Geologic Atlas of the United States.

A folio is designated by the name of the principal town or of a prominent natural feature within the quadrangle. It contains topographic, geologic, economic, and structural maps of the quadrangle, and occasionally other illustrations, together with a general description.

Under the law, copies of each folio are sent to certain public libraries and educational institutions. The remainder are sold at 25 cents each, except such as contain an unusual amount of matter, which are priced accordingly.

Circulars containing lists of these folios, showing the locations of the quadrangular areas they describe, their prices, etc., are issued from time to time, and may be obtained on application to the Director of the United States Geological Survey. The following list shows the folios issued to date, with the economic products discussed in the text of each, the products of greatest importance being printed in italics.

List of geologic folios, showing mineral resources described.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
1	Livingston	Mont	3,354	Iddings, J. P.; Weed, W. H.	Gold, copper, clays, lime, stone, *coal*.
2	Ringgold	Ga.-Tenn	980	Hayes, C. W	*Coal*, *iron*, manganese, lime, clays, stone, road metal.
3	Placerville	Cal	932	Lindgren, W.; Turner, H. W.	*Gold*, copper, quicksilver, chromite, stone.
4	Kingston	Tenn	969	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
5	Sacramento	Cal	932	Lindgren, W	*Gold*, copper, chromite, iron, coal, stone, lime, clay.
6	Chattanooga	Tenn	975	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
7	Pikes Peak-Cripple Creek.	Colo	932	Cross, W	*Gold*.
8	Sewanee	Tenn	975	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
9	Anthracite-Crested Butte.	Colo	465	Eldridge, G. H	*Coal*, *silver*, stone, lime, clay.
10	Harpers Ferry	Va.-W. Va.-Md.	925	Keith, A	*Iron*, *ocher*, copper, stone, road metal, lime, cement.
11	Jackson	Cal	938	Turner, H. W	*Gold*, *copper*, chromite, iron, manganese, ocher, coal, stone, lime, clay.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
12	Estillville	Va.-Ky.-Tenn.	957	Campbell, M. R	*Coal*, iron, marble, lime, stone.
13	Fredericksburg	Md.-Va.	938	Darton, N. H	*Greensand marl*, stone, fuller's earth, clays, sand, gravel, *underground water*.
14	Staunton	Va.-W. Va	938	....do	Iron, marble, lime, clay, coal.
15	Lassen Peak	Cal	3,634	Diller, J. S	Gold, infusorial earth, lime, stone, coal.
16	Knoxville	Tenn.-N. C	969	Keith, A	*Marble*, slate, stone, gold, lime, cement, clay, water power.
17	Marysville	Cal	925	Lindgren, W.; Turner, H. W.	*Gold*, coal, gas, clay, lime, stone, water supply.
18	Smartsville	....do	925	....do	*Gold*, copper, quicksilver, iron, lime, clay, stone.
19	Stevenson	Ga.-Ala.-Tenn.	980	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
20	Cleveland	Tenn	975	....do	*Iron*, lead, lime, stone, clay.
21	Pikeville	....do	969	....do	*Coal*, iron, stone, clay.
22	McMinnville	....do	969	....do	*Coal*, iron, stone, clay.
23	Nomini	Md.-Va	938	Darton, N. H	*Greensand marl*, fuller's earth, clay, stone, sand, gravel, *underground water*.
24	Three Forks	Mont	3,354	Peale, A. C	*Gold*, silver, copper, iron, coal, lime, clay, pumice, *mineral springs*.
25	Loudon	Tenn	969	Keith, A	*Coal*, marble, lime, stone, clay, iron, slate, water power.
26	Pocahontas	Va.-W. Va	950	Campbell, M. R	*Coal*, lime, stone, clay, marble.
27	Morristown	Tenn	963	Keith, A	*Marble*, *stone*, lead, zinc, lime, cement, clay, water power.
28	Piedmont	Md.-W. Va	925	Darton, N. H.; Taff, J. A.	*Coal*, iron, lime, stone, road metal, clay.
29	Nevada City special.	Cal	35	Lindgren, W	*Gold*.
30	Yellowstone National Park.	Wyo	3,412	Hague, A.; Weed, W. H.; Iddings, J. P.	National Park; no mining permitted.
31	Pyramid Peak	Cal	932	Lindgren, W	*Gold*.
32	Franklin	Va.-W. Va	932	Darton, N. H	*Iron*, coal, manganese, lime, stone, road metal, clay,
33	Briceville	Tenn	963	Keith, A	*Coal*, *iron*, lead, marble, lime, stone, clay.
34	Buckhannon	W. Va	932	Taff, J. A.; Brooks, A. H.	*Coal*, lime, stone, clay.
35	Gadsden	Ala	986	Hayes, C. W	*Coal*, *iron*, lime, stone.
36	Pueblo	Colo	938	Gilbert, G. K	*Stone*, *gypsum*, clay, iron, *artesian water*.
37	Downieville	Cal	919	Turner, H. W	*Gold*, iron, chromite, lime, marble.
38	Butte special	Mont	23	Emmons, S. F.; Tower, G. W.	*Copper*, *silver*, gold.
39	Truckee	Cal	925	Lindgren, W	*Gold*, silver, coal, stone, mineral springs.
40	Wartburg	Tenn	963	Keith, A	*Coal*, *oil*, iron, lime, clay.
41	Sonora	Cal	944	Turner, H. W.; Ransome, F. L.	*Gold*, quicksilver, copper, chromite, lime, stone.
42	Nueces	Tex	1,035	Hill, R. T.; Vaughan, T. W.	Stone, gravel, *underground water*.
43	Bidwell Bar	Cal	919	Turner, H. W	*Gold*, manganese iron, chromite, stone.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
44	Tazewell	Va.-W. Va	950	Campbell, M. R	*Coal*, iron, barite.
45	Boise	Idaho	864	Lindgren, W	*Gold*, silver, coal, diatomaceous earth, stone, clay, springs, artesian water.
46	Richmond	Ky	944	Campbell, M. R	Coal, fluorite, phosphate, clay, stone, road metal.
47	London	do	950	do	*Coal*, stone.
48	Tenmile district special.	Colo	62	Emmons, S. F	*Silver*.
49	Roseburg	Oreg	871	Diller, J. S	Gold, copper, quicksilver, coal, clay, stone.
50	Holyoke	Mass.-Conn	885	Emerson, B. K	Granite, emery, chromite, quartz, trap, sandstone, clay.
51	Big Trees	Cal	938	Turner, H. W.; Ransome, F. L.	*Gold*, silver.
52	Absaroka	Wyo	1,706	Hague, A	Silver.
53	Standingstone	Tenn	963	Campbell, M. R	*Coal*, oil, lime, clay.
54	Tacoma	Wash	812	Willis, B.; Smith, G. O.	*Coal*, *stone*, clay.
55	Fort Benton	Mont	3,234	Weed, W. H	Gold, *silver*, lead, iron, gypsum, *coal*, stone, artesian water.
56	Little Belt Mountains.	Mont	3,295	Weed, W. H	*Coal*, *silver*, lead, copper, iron, *sapphires*, mineral water.
57	Telluride	Colo	236	Purington, C. W	*Gold*, *silver*.
58	Elmoro	do	950	Hills, R. C	*Coal*, stone, *artesian water*.
59	Bristol	Va.-Tenn	957	Campbell, M. R	*Coal*, iron, zinc, barite, marble, clay.
60	La Plata	Colo	237	Purington, C. W	*Gold*, *silver*, coal.
61	Monterey	Va.-W. Va	938	Darton, N. H	Iron, stone, clay, road metal.
62	Menominee special.	Mich	125	Van Hise, C. R.; Bayley, W. S.	*Iron*.
63	Mother Lode district.	Cal	428	Ransome, F. L	*Gold*, silver, manganese, quicksilver, stone.
64	Uvalde	Tex	1,040	Vaughan, T. W	*Asphalt*, gold, silver, iron, coal, water supply.
65	Tintic special	Utah	229	Tower, G. W.; Smith, G. O.; Emmons, S. F.	*Gold*, *silver*, *lead*, *copper*.
66	Colfax	Cal	925	Lindgren, W	*Gold*, stone, clay, water supply.
67	Danville	Ill.-Ind	228	Campbell, M. R	*Coal*, clay, gravel, underground water.
68	Walsenburg	Colo	944	Hills, R. C	*Coal*, stone, clay, *artesian water*.
69	Huntington	W. Va.-Ohio	938	Campbell, M. R	*Coal*.
70	Washington	D. C.-Va.-Md.	465	Darton, N. H.; Keith, A.	Gold, iron, clay, stone, road materials, greensand marls, *underground water*.
71	Spanish Peaks	Colo	950	Hills, R. C	*Coal*, stone, gold, silver, *artesian water*.
72	Charleston	W. Va	938	Campbell, M. R	*Coal*, *salt*, *oil*, *gas*, iron
73	Coos Bay	Oreg	871	Diller, J. S	*Coal*, gold, stone.
74	Coalgate	Ind. T	980	Taff, J. A	*Coal*, stone, clay.
75	Maynardville	Tenn	963	Keith, A	*Marble*, coal, stone, lead, zinc, lime, road materials, clay, water power.
76	Austin	Tex	1,030	Hill, R. T.; Vaughan, T. W.	Oil, stone, lime, clay, cement, artesian water.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
77	Raleigh	W. Va	944	Campbell, M. R	*Coal.*
78	Rome	Ga.-Ala	986	Hayes, C. W	*Bauxite, iron, slate,* lime.
79	Atoka	Ind. T	986	Taff, J. A	*Coal,* stone, clay.
80	Norfolk	Va.-N. C	1,913	Darton, N. H	Sand, clay, *underground water.*
81	Chicago	Ill.-Ind	892	Alden, W. C	*Stone,* clay, molding sand, water power, water supply.
82	Masontown-Uniontown.	Pa	458	Campbell, M. R	*Coal, oil, clay,* stone, glass, sand, iron.
83	New York City	N. Y.-N. J	906	Merrill, F. J. H.; Hollick, A.; Darton, N. H	*Trap, marble,* granite, *road material,* clay, iron, water power, water supply.
84	Ditney	Ind	938	Fuller, M. L.; Ashley, G. H.	*Coal,* gas, clay, stone, iron.
85	Oelrichs	S. Dak.-Nebr	871	Darton, N. H	Stone, gypsum, lime, volcanic ash, *underground water.*
86	Ellensburg	Wash	820	Smith, G. O	Building stone, road metal, *ground water, artesian water.*
87	Camp Clarke	Nebr	892	Darton, N. H	Volcanic ash.
88	Scotts Bluff	do	892	do	Volcanic ash.
89	Port Orford	Oreg	878	Diller, J. S	*Coal,* gold, platinum.
90	Cranberry	Tenn	963	Keith, Arthur	Mica, gold, brick clay, *iron ore.*
91	Hartville	Wyo	885	Smith, W. S. T	*Iron ore,* copper, limestone.
92	Gaines	Pa.-N. Y	223	Fuller, M. L.; Alden, W. C.	*Oil,* coal.
93	Elkland-Tioga	Pa	445	do	Flagstone, limestone, gravels.
94	Brownsville-Connellsville.	do	457	Campbell, M. R	*Coal, natural gas.*
95	Columbia	Tenn	969	Hayes, C. W.; Ulrich, E. O.	*Phosphate,* iron.
96	Olivet	S. Dak		Todd, J. E	Granite, limestone, quartzite.
97	Parker	do	871	do	Quartzite, chalkstone, cement.
98	Tishomingo	Ind. T	986	Taff, J. A	Granite, limestone.
99	Mitchell	S. Dak	863	Todd, J. E	Sandstone, chalkstone.
100	Alexandria	do	863	Todd, J. E., Hall, C. M	Quartzite, sandstone, chalkstone.
101	San Luis	Cal		Fairbanks, H. W	*Bituminous rock,* building stone, road metal, chrome iron, hematite, manganese, pumice, infusorial earth.
102	Indiana	Pa	237	Richardson, Geo. B	*Coal, gas, fire clay,* brick clay, building stone.
103	Nampa	Idaho		Lindgren, Waldemar; Drake, N. F	Gold, coal, *opals,* building stone.
104	Silver City	do	871	do	*Gold, silver,* coal, opals.
105	Patoka	Ind.-Ill	938	Fuller, M. L.; Clapp, F. G.	Coal, gas, oil, asphalt, fire clay, brick clay, building stone, gravel.
106	Mount Stuart	Wash		Smith, G. O	*Gold,* copper, silver, nickel, quicksilver, *coal,* stone, road metal.
107	Newcastle	Wyo.-S. Dak		Darton, N. H	*Coal,* petroleum, *gypsum,* bentonite, salt brines, stone, water supply.
108	Edgemont	Nebr.-S. Dak		Darton, N. H.; Smith, W. S. T.	Water supply, coal, gypsum, stone, grindstones.

6. *Mineral Resources of the United States.*—From 1883 to 1894, inclusive, an octavo cloth-bound volume bearing the above title was issued annually, with only two exceptions, the years 1883–84 and 1889–90 being included by pairs in single volumes. The first of this

series was Mineral Resources of the United States, 1882; the last, Mineral Resources of the United States, 1893. In 1894 this form of publication was discontinued, in accordance with an act of Congress, and the material was included in certain parts of the sixteenth, seventeenth, eighteenth, nineteenth, twentieth, and twenty-first annual reports. The separate publication of the series on mineral resources was resumed, however, in 1901, in accordance with an act of Congress, and three volumes of the new series, Mineral Resources of the United States for 1900, for 1901, and for 1902, have been issued.

This publication contains a systematic statement of the production and value of the mineral products of the United States, a summary of new mineral resources developed, and occasionally short papers on economic geology, when necessary in accounting for the new developments.

INVESTIGATION OF METALLIFEROUS ORES.

By S. F. Emmons, *Geologist in Charge.*

ECONOMIC PUBLICATIONS OF THE YEAR.

The number of Survey publications primarily devoted to the economic geology of metalliferous resources that appeared in the year 1903 was smaller than in the previous year. This has been due to a combination of causes, the most important of which is the fact that the accumulation of material for publication has increased more rapidly than the Survey facilities for preparing the necessary maps and illustrations, so that many reports already completed by the authors have not yet reached the stage of publication. The list includes the following bulletins:

Bulletin No. 202, Tests for Gold and Silver in Shales from Western Kansas, by Waldemar Lindgren.

Bulletin No. 219, The Ore Deposits of Tonopah, Nevada (Preliminary Report), by J. E. Spurr.

To this may be added the following professional papers, presenting the results of geological reconnaissances in different parts of Alaska, in which special attention was given to such indications of the existence of deposits of the useful metals as might be of value to the prospector:

Professional Paper No. 2, A Reconnaissance of the Northwestern Portion of Seward Peninsula, by Arthur J. Collier.

Professional Paper No. 10, Reconnaissance from Fort Hamlin to Kotzebue Sound, by W. C. Mendenhall.

Professional Paper No. 15, The Mineral Resources of the Mount Wrangell District, by W. C. Mendenhall and F. C. Schrader.

Second editions of Bulletin No. 182, by F. L. Ransome, on "The Economic Geology of the Silverton Quadrangle, Colorado," and Bulletin No. 193, on the "Geological Relations and Distribution of Platinum and Associated Metals," by J. F. Kemp, both mentioned in Bulletin No. 213, have also been published during the year.

Bulletin No. 202 represents the results of work carried on in the spring of 1902, at the instance of the Assistant Secretary of the Interior. Reports had been current for some time that the Fort Benton shales, which cover a large portion of western Kansas, contain gold in paying quantities. Those who claimed to have obtained the best results by assay admitted that a large proportion of their tests gave no values, but accounted for these negative results by assumed imperfections in modern methods of assay. Of others who assayed the material, few were able to find any gold whatever. The representations of the believers in the occurrence of gold, to the effect that the shales might be treated by smelting or some other process at a profit, naturally appealed to the imagination of those who owned land in that region, since the quantity of these shales on their land is practically unlimited. With a minimum estimate of profit of only a dollar a ton one might calculate a half million dollars to the acre, and it would take comparatively few square miles to pay the national debt, as there was no reason for assuming that one part of the shales was richer than another. It seemed highly improbable, however, that gold could be extracted from the shales at a profit by any known process, even if they contained as much gold as the most enthusiastic advocates claimed for them.

Mr. Lindgren's samples (19 in number) were taken, and the assays (77) were conducted, it is hardly necessary to say, with great intelligence, care, and accuracy. Their results showed that the vast majority of the samples contained no trace of gold whatever, values of a few cents being found in a small number of the specimens, which, however, could not always be found on a repetition of the assay.

These results, though convincing to the scientific mind, do not necessarily affect opinions that are based on the supposed unreliability of assay methods, though Mr. Lindgren gives good scientific reasons why these methods are the most reliable for determining the presence or absence in rock material of very minute amounts of the precious metals. The final test will necessarily be the success or failure of practical attempts to treat the material on a large working scale.

Bulletin 219 is a preliminary report on the results of Mr. Spurr's final examination of the Tonopah district of Nevada, which he completed during the past summer. It is a brief summary, not yet checked by final microscopic and other office work, intended for the immediate use of those engaged in mining in the district.

Under the system of free distribution recently ordered by Congress, the first edition of this bulletin was exhausted on the day of its publication. The report is, however, reprinted in this bulletin.

ECONOMIC PUBLICATIONS IN PREPARATION.

Other investigations of metalliferous ores which have been brought to completion during the past year, reports of which will soon appear as professional papers, are as follows:

Professional Paper No. 12, Ore Deposits of the Globe District, Arizona, by F. L. Ransome.

Professional Paper No. 21, Geology and Ore Deposits of the Bisbee Quadrangle, Arizona, by F. L. Ransome.

Professional Paper No. 24, Zinc and Lead Deposits of Northern Arkansas, by George I. Adams.

Professional Paper No. 25, Copper Deposits of the Encampment Quadrangle, Wyoming, by A. C. Spencer.

Professional Paper No. 26, Economic Resources of the Northern Black Hills, by J. D. Irving.

Professional Paper No. 27, Geological Reconnaissance Across the Bitterroot Range and the Clearwater Mountains in Montana and Idaho, by Waldemar Lindgren.

Professional Paper No. —, Ore Deposits of the Bingham Mining District of Utah, by Arthur Keith and J. M. Boutwell.

Professional Paper No. —, Copper Deposits of the Clifton-Morenci District, Arizona, by Waldemar Lindgren.

An abstract of Professional Paper No. 26 appears in subsequent pages of this volume. Abstracts of all the others have already been published in Bulletin No. 213.

The following geologic folios, which contain matter of economic importance, are also in more or less advanced stages of preparation:

Franklin Furnace, New Jersey, by J. E. Wolff.
Globe District, Arizona, by F. L. Ransome.
Nampa, Idaho, by Waldemar Lindgren.
Silver City, Idaho, by Waldemar Lindgren.
Bisbee District, Arizona, by F. L. Ransome.
Silverton, Colorado, by Whitman Cross.
Bradshaw, Arizona, by T. A. Jaggar, jr., and Charles Palache.
Redding, California, by J. S. Diller.
Sturgis-Spearfish, South Dakota, by T. A. Jaggar, jr.

ECONOMIC WORK ON METALLIFEROUS DEPOSITS IN PROGRESS.

The economic work done during the past field season is briefly noticed below, by geographic sections, States, and Territories, alphabetically.

ALASKA.

Field work in Alaska was actively carried on during the last season by geologists under the general charge of Mr. A. H. Brooks. Concise statements of the results accomplished are given in the following pages under these titles:

(1) Placer Mining in Alaska in 1903, by Alfred H. Brooks.

This paper gives a broad general review of the present conditions of placer mining in various parts of the Territory, with recommendations as to their possible amelioration.

(2) The Juneau Gold Belt, by Arthur C. Spencer.

This is an account of the geological relations and developments of the gold-bearing deposits in the neighborhood of Juneau, in southeastern Alaska, which also includes the famous Alaska Treadwell and adjoining mines.

(3) The Porcupine Placer Mining District, by Charles W. Wright.

This describes a comparatively new placer district, also in southeastern Alaska, to the northwest of the Lynn Canal.

(4) The Gold Placers of the Fairbanks District, by L. M. Prindle.

This describes the geology and placers of a new district about which there was some excitement during the past season in the upper portion of the Tanana Valley.

(5) The Kotzebue Placer Gold Field of the Seward Peninsula, by F. H. Moffit.

This describes the placer developments on the northeast slope of the Seward Peninsula along the shores of Kotzebue Sound.

(6) Tin Deposits of the York Region, Alaska, by Arthur J. Collier.

This gives an interesting description of the newly discovered tin deposits at the western extremity of the Seward Peninsula, which are among the few occurrences of ore in place yet opened in this extreme northern region. Although the developments are as yet too limited to afford an entirely satisfactory idea of the manner of occurrence of the ore, they afford valuable data with regard to their mineral association. They occur generally in or near bodies of granite, but it is not yet certain whether they are all strictly contact phenomena.

APPALACHIAN REGION.

During the field season of 1903 various reconnaissance examinations of metalliferous deposits have been made in the Appalachian region. The following are noticed in the succeeding pages:

Gold Quartz Veins in Maine and Vermont, by George Otis Smith.

This is the result of an examination of various quartz veins which were said to carry gold in paying quantities.

Notes on Cupriferous Deposits of Vermont, by W. H. Weed.
Some Georgia Copper Deposits, by W. H. Weed and T. L. Watson.
Notes on Copper Deposits in New Jersey, by W. H. Weed.

The first two deposits noted belong to the general zone of large pyritiferous deposits in the crystalline rocks which stretch along the front face of the Appalachians from Georgia to Nova Scotia.

The New Jersey deposits are associated with the sandstones and traps of the Newark system.

These are reports of preliminary observations made in a general investigation of the cupriferous deposits of the entire Appalachian system.

Recent Zinc Mining in East Tennessee, by Arthur Keith.

This gives the result of an examination of zinc deposits in the upper part of the Knox dolomite, in the center of the eastern Tennessee Valley between Knoxville and Morristown. The ores, which are zinc blende altered to carbonate and silicate near the surface, occur in brecciated zones in the limestone of which they form a part of the cementing material.

CALIFORNIA.

Economic Geology of the Redding Quadrangle, by J. S. Diller.

In the course of his areal mapping of the Redding quadrangle in northern California, which he completed last summer, Mr. Diller gathered data on its general economic resources, which will appear as part of the text of the folio. An abstract of this report is given elsewhere in this volume. The data on copper ore was given in less complete form in Bulletin No. 213.

COLORADO.

The only economic work in Colorado during the past season has been the resurvey of the Cripple Creek district, which has been undertaken in cooperation with the State authorities, half the expense being paid by Colorado.

The original field work in this district was completed ten years ago, and in the time that has elapsed mining developments have been carried on most actively to a depth, in many places, of over 1,000 feet. The district is the largest gold producer in the United States, and the mine owners are naturally desirous of knowing whether the geological conditions of the district shown by the present developments indicate any probable falling off of the ores with depth. The extent of ground to be studied was so great, and the problems to be solved so delicate, that it was deemed wise to employ two of our best geologists to do this piece of work. Messrs. Lindgren and Ransome were thus assigned to it, it being arranged that, while they divided the field between them, each should be cognizant of and verify all important conclusions arrived at by the other. They were assisted in the field by Messrs. Graton and Rock. Mr. Ransome carried on his field work continuously during the summer. Mr. Lindgren was called out of the country by private business at the end of July, but returned in January, and will complete his part of the field work in April, 1904. The present condition of the work is as follows:

The revision of the areal or surface geology is completed and over half of the underground work is done. Under these conditions it is not practicable to present any preliminary report. It can only be said that evidence of secondary enrichment has not been found in the ore bodies thus far studied, and this, as far as it goes, is in favor of the permanence of the rich ores in depth. The work will be pushed to completion as rapidly as its delicate nature and the Survey facilities for carrying it on will permit.

IDAHO.

A special examination of the Coeur d'Alene mining district of Idaho is in progress. The area to be surveyed covers two 15-minute sheets, or one-eighth of a square degree. Mr. Calkins has been occupied during the summer on the areal geology of the region—that is, the geological mapping. This work was not completed before the field season was closed by snow. Completion of the areal geology and investigation of the ore deposits will be carried on during the coming season. No preliminary report is made.

INDIAN TERRITORY.

Reported Gold Deposits of the Wichita Mountains, by H. Foster Bain.

This presents the results of an examination of the mines and prospects of the district, made for the purpose of determining whether the land is mineral land under the Government definition. The most promising and important prospects were visited and their ores carefully sampled. These were then assayed in the laboratory of the Survey, with the result that no trace of gold was found in any of the samples, and in only one or two cases was a small percentage of copper or lead found.

ILLINOIS.

Lead and Zinc Deposits of Illinois, by H. Foster Bain.

This is a review of the present condition of the mining industry of these two metals in the State of Illinois, the main production at present being from zinc ores, mostly sulphides, in the northwestern part of the State.

NEVADA.

Economic Geology of the Silver Peak Quadrangle, by J. E. Spurr.

During the past summer Mr. Spurr made an examination of the ore deposits of the Silver Peak quadrangle, an area lying southwest of Tonopah, along the Nevada-California boundary. In this area mining has been carried on very intermittently since 1864. It contains a large amount of low-grade ores, carrying values in gold and silver. Litigation has been one of the causes which have retarded its development. Another probable cause may be found in the rather unusual character of the deposits from a geological standpoint. They are not true veins in the ordinary sense of the word. The most important quartz bodies, according to Mr. Spurr, are offshoots from a very siliceous granite; others are contact deposits in limestone around the periphery of the granite bodies. In either case it is difficult to foretell their probable extent in depth. The extremely arid character of the region is, moreover, a serious obstacle to cheap exploitation. The intelligence and energy of the American miner will probably find means to overcome these difficulties, and from the future development of the mines it is hoped that valuable information may be obtained with regard to the characteristics of this rather unusual class of ore deposits.

Notes on the Geology of the Goldfields District, Nevada, by J. E. Spurr.

The Goldfields district lies about 23 miles southeast of Tonopah. It was briefly examined by Mr. Spurr during the past summer, and the above-named paper, which is printed in a subsequent part of this volume, contains his notes on the geology of the region. The ore deposits themselves were as yet too little developed to permit any judgment to be formed as to their probable value.

SOUTH DAKOTA.

Ore Deposits of the Northern Black Hills, by J. D. Irving.

This paper, which appears in a subsequent part of this volume, is an abstract of the report on the mineral resources (mainly gold) of the northern Black Hills, now in process of publication.

UTAH.

Park City Mining District, by J. M. Boutwell.

The study of the geology and ore deposits of the Park City mining district has been continued during the past summer by Mr. Boutwell and his assistants. This district is situated in the most complicated part of the great Wasatch Range, which itself is remarkable for its complex geological history, and it has been of the utmost importance to decipher the geological structure of the region, for this affords the only sure guide for the miner in following his ore bodies.

The working out of this structure has been rendered especially difficult by the peculiar local conditions, and it was not until autumn that Mr. Boutwell was able to consider this portion of his labors completed and undertake the detailed examination of the mine workings in the light of the knowledge thus acquired. As a consequence of this delay the underground work is not yet completed. In the latter part of this volume Mr. Boutwell gives a sketch of the general results achieved since the publication of his preliminary notes in Bulletin 213. He also gives the result of an examination of iron deposits in the Uinta Mountains, farther eastward, which are especially interesting because of the general absence of the deposits of the useful metals in that range.

INVESTIGATION OF NONMETALLIFEROUS ECONOMIC MINERALS.

By C. W. Hayes, *Geologist in Charge.*

The investigation of the nonmetalliferous minerals has been carried on during the year 1903, as heretofore, largely in connection with work on areal geology. In addition to such incidental investigations, however, certain classes of deposits have been independently studied.

Iron ore.[a]—A systematic study of the Lake Superior iron-ore districts was completed during the year by the publication of monographs on the Vermilion district, by J. Morgan Clements, the Mesabi district, by C. K. Leith, and the Menominee district, by W. S. Bayley. Field work has been continued in the Lake Superior region during the year, chiefly by Messrs. Leith and Smith, for the purpose of preparing a final summary report on the entire region. Under the general supervision of C. R. Van Hise an investigation of the Baraboo district has been made by Samuel Weidman, of the Wisconsin survey. A brief summary of his conclusions appears in this bulletin, in Mr. Leith's paper.

During the year there has been a renewal of interest in the iron-ore deposits of the West, and two groups of deposits in Utah have been examined—one in the Uinta Mountains, by J. M. Boutwell, and one in southern Utah, by C. K. Leith. A brief statement of their conclusions appears in this volume.

Fuels.—The fuel resources of the country have received a large share of attention during the past year. In the Appalachian field M. R. Campbell and his assistants have been actively engaged in detailed areal work in the bituminous field of Pennsylvania, and summary reports on this work have been prepared by Messrs. Burrows, Stone, and Butts. Mr. Campbell has made a special study of the Meadow Branch coal field in West Virginia, a brief report on which appears in this volume. This field is at present attracting considerable interest on account of the character of the coal and its proximity to the eastern markets. The coal is essentially an anthracite, occupying an isolated basin a long distance east of the main Appalachian coal field. It may be regarded as the southernmost representative of the anthracite coal basins of Pennsylvania.

Mr. George H. Ashley has continued the work begun in 1902 on the Cumberland Gap coal field, in cooperation with the State of Kentucky,

[a] Investigations of the ores of iron and aluminum are made by the section of the Survey having charge of the economic geology of nonmetalliferous minerals.

and has prepared a brief summary report on the structure of the field and the character and distribution of the coal.

Mr. W. T. Griswold has continued his detailed investigation of the geologic structure in the southeastern Ohio oil fields, the methods and results of which were described in the last economic bulletin (Bulletin 213). The work has been extended eastward from the Cadiz quadrangle over the adjacent Steubenville quadrangle. Important conclusions have been reached regarding certain necessary modifications of the anticlinal theory of oil and gas accumulation, a statement of which will be made in a forthcoming bulletin of the Survey.

During the past season George I. Adams and assistants made a detailed investigation of the Iola oil and gas district. Special attention was given to the measurement of gas pressures and volumes in order to determine the probable life of the field.

Mr. N. M. Fenneman has completed the investigation of the Boulder oil field, and is preparing a full report on the geology and mineral resources of this district. A summary of this report, giving important conclusions regarding the structure of the field and its relation to the oil pool, appears in this volume.

One of the most important investigations on the fuel resources of the country undertaken during the past season was that by G. C. Martin on the petroleum fields of Alaska and the Bering River coal fields. While the amount of development in the oil fields has not yet been sufficient to enable conclusions of great importance to be reached, Mr. Martin's work has brought to light extremely valuable coal deposits, which must be of the highest importance to the entire Pacific coast of America.

Cement, stone, and other building materials.—The policy of summarizing each year all available information regarding some important mineral product has been carried out during the past season by the investigation of the cement resources of the United States. The work has been in charge of E. C. Eckel, who visited all producing cement districts and personally examined a large proportion of the cement plants. The results of his work on this industry will therefore contain much more than a summary of existing knowledge, since he has been able to make extensive observations on the geological occurrences of the cement materials and the technical and commercial conditions surrounding its manufacture. Special attention was given to the investigation of the industry in Alabama and Mississippi in view of the great activity of the industry in those States in preparation for the probable demand in the construction of an Isthmian canal. The geological relations of the Alabama cement materials were investigated by State geologist E. A. Smith, and he has prepared for this volume a brief summary of his report. The Lehigh district received special attention by Mr. Eckel, on account of the great volume of its production, and a short paper on the district appears in this bulletin. Mr. Eckel is now preparing a voluminous report, which will be published during the year 1904.

In connection with his investigation of the cement resources Mr. Eckel visited numerous slate quarries throughout the country with the expectation of making a systematic examination of the slates of the United States during the coming year. He has prepared a brief account of certain slate deposits in California and Utah for this volume, which also includes notes on Arkansas roofing slates by T. Nelson Dale.

Clays have been examined in many localities in connection with the preparation of geologic folios. Important deposits have been examined, particularly in Pennsylvania, and a report on the clays of the Ohio Valley in Pennsylvania has been prepared for this volume by L. F. Woolsey. Investigation of clay resources has been made by H. E. Gregory in connection with folio work in the Connecticut Valley, and by Mr. Fenneman in the Boulder district, Colorado. A systematic examination of the clays of Mississippi has been undertaken in cooperation with State officials, the work being done by A. F. Crider under Mr. Eckel's supervision.

Gypsum, salt, sulphur, etc.—A systematic summary of information relating to the gypsum deposits of the United States has been made during the past year under the direction of George I. Adams. Chapters on the deposits of the various States have been contributed to this report by specialists particularly familiar with the subject. This report is now in press. In addition to summarizing existing information it contains a large amount of new information, the results of personal examinations of the various deposits by the experts employed to contribute the several chapters.

The salt industry of Utah and California has been investigated by Mr. Eckel in connection with his work on the cement deposits, and a brief report has been prepared for this volume. Mr. Adams visited the Rabbit Hole Sulphur mines, near Humboldt House, Nevada, and has prepared a report upon the geological relations and development of these deposits. In connection with his work on the Silver Peak quadrangle, Mr. Spurr examined the natural alum deposits in Esmeralda County, Nev., and has prepared a brief report upon them.

Miscellaneous nonmetalliferous minerals.—The fluorspar deposits of southern Illinois were investigated by Mr. Bain in connection with his studies of the lead and zinc deposits of the Mississippi Valley. He has reached important conclusions regarding the relations of the fluorspar and the associated lead and zinc, and has made a special study of the development of these deposits in their commercial aspects. The deposits of graphite in the eastern Adirondacks have been examined by J. F. Kemp in connection with his folio work, and a brief report has been prepared for this volume. Deposits of barite in southern Pennsylvania have been examined by G. W. Stose, also in connection with folio work, and a brief report has been prepared for this volume.

GOLD AND SILVER.

In addition to the papers here included, which represent the results of recent work by the Survey in important precious metal mining districts, other reports bearing incidentally on the subject of gold and silver will be found under the head of "Copper," on pages 169 to 201.

THE JUNEAU GOLD BELT, ALASKA.

By Arthur C. Spencer.

INTRODUCTION.

In the summer of 1903 the writer and Mr. Charles W. Wright made a detailed study of the geology and mineral resources of a limited area, including the Alaska-Treadwell and associated mines near Juneau, Alaska. In addition to this work, visits were made to nearly all the mining camps of the mainland portion of southeastern Alaska, between Windham Bay, about 75 miles southeast of Juneau, and the Porcupine placer district, in the Klehini and Salmon river basins of the Chilkat River drainage, about 120 miles to the northwest.

The Juneau gold belt resembles the gold belt of California in several ways. Not only are the various rocks which occur in this part of southeastern Alaska similar in character and partly equivalent in age to those forming the country rock of the Mother Lode district, but there is as well a definite linear distribution of some of the gold-bearing veins parallel with the general strike of the bed-rock formations, though, as in the neighborhood of the noted systems of veins in the California gold belt, there are many independent deposits lying outside the main complex of lodes.

Prospecting has been in progress in different parts of this belt since 1876, but the main incentive to vigorous exploration came with the discovery of the Gold Creek placers and the founding of Juneau in 1880. Several early attempts to work gold veins occurring adjacent to the productive placers in the Silver Bow Basin, at the head of Gold Creek, were unsuccessful, the first mine to be put upon a productive basis being the Alaska-Treadwell, on Douglas Island, about 2 miles southwest of Juneau. This property was opened in 1881, and it continued to grow in importance for several years, so that by 1889 it had reached its present rating as one of the great mines of the world.

The success of this enterprise was an incentive to prospectors, the region had become favorably and somewhat widely known, and capital appeared to be ready to prove the value of several properties when, in 1896, the discovery of the Klondike gave a great impetus to prospecting in the interior of British Columbia and Alaska and caused the mineral region tributary to Juneau to be temporarily abandoned as a field for investment. The gold fields of the interior turned out to be of more than passing value and the exploitation of their rich placers has naturally held the main interest of both investors and promoters, to the great disadvantage of the longer known, though less rich, coastal region, the development of which would have involved greater outlay and slower returns. It may be said that only now, after seven years, has the district regained the position which it appears to have held in 1896.

At present a growing interest in the gold belt here under consideration is apparent from the number of properties which have recently changed hands, from the number of experienced engineers making examinations in the field with a view to acquiring property for their clients, as well as from the demand for experienced miners, which is continually bringing new men into the Territory.

The number of miners and laborers at present engaged in the region is estimated as follows:

Number of miners estimated to be engaged in Juneau region, Alaska.

Independent prospectors	140
Douglas Island mines	900
Mainland mines south of Juneau	80
Mainland mines near Juneau	80
Mainland mines north of Juneau	90
On other islands, mining and prospecting	50
Placers	100
Total	1,440

About 30 per cent of the miners in the region were engaged in prospecting and preliminary development during the year, and indications are that the exploration of properties recently purchased by outside parties will materially increase the proportion of men engaged in work not immediately productive.

In 1903 there were seven productive mines in the district in addition to the placers of Porcupine and adjacent creeks. These were the Alaska-Treadwell, Alaska-Mexican, and Ready Bullion, on Douglas Island; the Silver Queen, on the mainland opposite; the Sumdum Chief, 60 miles to the south, now worked out and abandoned; and the Alaska-Juneau and Ebner mines, in Gold Creek, both of which will soon be opened on a large scale. The product of these mines for the year is estimated at $2,400,000, while the total output of the belt to the end of 1903 has been more than $20,000,000.

Several properties which were formerly worked are not now producing bullion, either because they have been worked out or because the conditions of further development would involve too great an increase in mining costs.

The examinations which have been made indicate that the known prospects in the belt tributary to Juneau are of sufficient promise to warrant all the work now in progress and the expenditure of still more capital in development work. There is still room in this field for development companies with adequate capital for acquiring control of promising properties to be explored and sold to operators when their value has been proved. The participation of new interests, which seems about to begin, will undoubtedly bring about a rapid quickening of the mining industry, but the development of the field has reached a critical stage, and owners of unproved or partially explored claims should remember that, though experienced operators are willing to pay good prices for properties of determined value, it can not be expected that they will make the heavy cash payments often demanded for the privilege of risking larger sums in developing mere prospects. It is commonly reported that overreaching in this direction has already done much to retard the progress of mining operations in the Juneau belt.

GEOLOGY.

The observations of the summer were confined almost entirely to the mainland opposite Stephens Passage and Lynn Canal, where a belt nearly 200 miles in length was examined with sufficient care for the determination of its main geologic features. The results of this work will be published in a report dealing with the geology and mineral deposits of the district, which will contain a topographic and geologic map of the mainland from Windham Bay to the head of Lynn Canal and the Porcupine district.

Structure.—In the mainland belt northward from Windham Bay the bedded or sedimentary formations all strike northwest and southeast, and dip, almost without exception, toward the northeast into the mountains. The igneous rocks closely follow the structure of the sediments, as a rule, so that viewed either in detail or in their general relations the rocks are found to occur in bands parallel with the general trend of the coast.

Division of the rocks.—The rocks may be grouped into three series, which are named in the order of their occurrence from southwest to northeast: (1) Black slates and black limestones alternating with greenstones, and more or less metamorphosed; (2) highly metamorphic schists; (3) intrusive dioritic rocks, forming the main mass or core of the Coast Range.

The average width of the sedimentary belt on the mainland is about 6 miles, while the diorite zone is from 50 to 80 miles across, and therefore extends into Canadian territory.

Black-slate-greenstone series.—The series composed mainly of black slates and greenstones, with some beds of limestone, occurs all along the shores of Stephens Passage and Lynn Canal up to the crossing of the great mass of dioritic rocks about 30 miles below Skagway. It occurs also on many of the adjacent islands of the Alexander Archipelago, but its westward extent has not been determined. The slates have been derived from fine-grained carbonaceous shales, their slaty cleavage being a secondary structure produced by pressure metamorphism which accompanied folding and upturning of the rocks of the region. Carbonaceous matter, which occurred in the original shales, has been converted almost entirely into graphite, which is disseminated throughout the slates and is encountered in large amounts in some of the mines. The limestones sometimes contain graphite, but as a rule their carbonaceous matter has not been crystallized by metamorphic action, and freshly broken fragments usually give a strong odor resembling that of petroleum, which indicates the presence of hydrocarbons. Fossils of Paleozoic age have been found in the limestones belonging to the series at Taku Harbor, 20 miles south of Juneau, and lower Carboniferous forms occur in the Porcupine district, 120 miles to the northwest, but near Juneau organic remains have not been found.

The greenstones interbedded with the slates are mostly volcanic rocks, which flowed out over the surface at different periods during the deposition of the sedimentary strata in which they occur.

Schist series.—East of the slate-greenstone series, and sharply defined from it, there is a series of highly metamorphic schists, characterized by hornblende, mica, and garnet. A few bands of quartzite and limestone are intercalated in the schists, which, in connection with existing strata-like alternations in the composition of the schists, prove the sedimentary origin of the series. The schists occupy a belt about 3 miles wide opposite Juneau, but their area of outcrop narrows in both directions along the strike, and they are not found beyond 30 miles northwest of Juneau, being gradually cut out by Coast Range diorites.

Coast Range intrusives.—Beyond the schists, when these are present, but elsewhere occurring next to the slate-greenstone series, coarse granular rocks having the appearance of granite occur. These form the great mass of the Coast Range, not only opposite Stephens Passage and Lynn Canal, but throughout the corresponding mountains which border Pacific Ocean southward nearly to the boundary between

British Columbia and the State of Washington. The intrusive rocks of this zone have been grouped by Dawson under the name of Coast Range granite, and they have been described in general terms as hornblende-granites. With our present knowledge this designation can not be followed consistently, because in the portion of the belt which has been examined with more or less care by the geologists of the Survey, dioritic rocks are the rule and granites the exception.

In the Juneau district the diorites show a considerable variation not only in the main mass which bounds the sedimentary rocks, but also in the outlying arms and stocks which are intrusive in the schists and black slates. Some of the masses are normal hornblende-diorites or quartz-diorites, others are granodiorites, while an extreme variety is the albite-syenite, occurring in the Treadwell mines. In general, the rocks are closely related and similar in appearance to the granular intrusives of the Sierra Nevada.

The diorite masses generally follow the stratification of the older rocks. Locally there is a certain amount of crosscutting, and in the case of the main contact the amount of transection is measured by the varying width of the schist band, which is noted above.

The main mineralization of the Juneau belt occurred subsequent to the intrusion of the diorite, in which respect the deposits correspond in general with those of the gold belt of California.

THE GOLD VEINS.

The principal geologic features of the Juneau region have been described in the foregoing paragraphs. It seems appropriate to speak of the mainland strip which is accessible from the waters of the inland passage as the Juneau gold belt, for the reason that gold is found very generally distributed throughout the area in which the crystalline schists and the slate-greenstone series outcrop. In the former band, however, and in the main diorite of the mountains back of the coast, but little promise has been found of valuable mineralization, such veins as exist being mostly mere stringers, showing little tendency toward segregation into workable lode systems.

All of the promising prospects, working lode mines, and placers of the Juneau belt occur in the outer part of the mainland strip or on Douglas Island adjacent, either in the slate-greenstone band or in intrusive masses of diorite which lie outside of the main core of the Coast Range. In the aggregate gold-bearing quartz veins or other forms of mineralization are distributed throughout the whole exposed width of this band between its inner boundary next to the crystalline schists and the channels which separate the mainland from the adjacent islands. Although only their large geologic features are known, many of these islands contain mineral veins, and Admiralty Island, which parallels the coast for 70 miles opposite the Juneau belt, affords indications which have warranted considerable prospecting each year. The rocks are in part lithologically similar to the slates of the Juneau belt, and the island is separated from Douglas Island by a channel in places less than 2 miles wide. The distance between known areas of mineralization on the two islands is much less than the width of the Juneau belt, and it seems that, though practically separate, the island and mainland belts are two parts of a wide zone of mineralization, divided longitudinally by Stephens Passage.

The Admiralty belt has not been studied with care, but many of its features conform with those of the Juneau belt. In both belts many of the veins and composite lode systems follow the strike of the country rocks, frequently holding to the vicinity of contacts between beds of different character, such as slate and greenstone. Composite lode systems, such as Becker has called stringer leads, are perhaps a characteristic type for the region at large, but in the Juneau belt there are many crosscutting veins which are sometimes well defined for long distances when contained in massive rocks, such as diorite, or greenstone which has not received schistose structure. In the slates crosscutting veins are seldom found, because these rocks are too flexible to break with extensive continuous fractures.

Toward the northwest both the Admiralty and the Juneau belts should appear on the west shore of Lynn Canal, the course of which is slightly diagonal to the strike of the formations. Reports of the comparatively small amount of prospecting which has been done in this region suggest that the veins occurring in the vicinity of James Bay and Endicott River correspond in a general way with the Admiralty belt, while mineralization existing on Sullivan Island lies directly in line with an extension of the Juneau belt beyond the Berners Bay district. Measured across the strike of the rocks the distance between the known deposits of the two belts is practically the same as that already noted between deposits on Douglas and Admiralty islands, and it is believed that future work in the region west of Lynn Canal along the shores of Chilkat Inlet will demonstrate intervening mineralization.

The data collected during the season have been sufficient to bear out the previously suggested existence of a main-lode system, which is now known to follow a definite geologic horizon for a long distance on the mainland. The observed facts do not warrant the further suggestion that there are other narrow bands conforming to divisions in the bedrock formations, in which profitable mineralization is to be expected throughout great distances along the strike. It seems, on the other hand, that outside of the main-lode system mineralization has been widely and irregularly distributed. Gold veins or vein complexes may follow or recur along certain beds for several miles, but no zones of limited width can be designated as specially suited for their occurrence and, therefore, as eminently favorable for prospecting. At the same time, in the neighborhood of known mineralization further search along the strike is the most logical procedure.

The main-lode system.—The most prominent feature of the Juneau gold belt is a system of stringer leads, which resembles the mother lode of California. It occupies a band of variable width in black slates lying northeast of, that is, stratigraphically above, a thick group of greenstone beds, which includes the highest of the basaltic flows of the slate-greenstone series. This group of slates and the underlying greenstones have been traced throughout the entire length of the Juneau belt from Windham Bay almost to Berners Bay, where they are cut out by the transverse contact of the main diorite of the Coast Range, and at many points throughout this distance a great deal of veining and mineralization is found.

The greenstones are locally schistose, and where they have this structure they are sometimes impregnated along surfaces of particularly intense sheeting with sulphides locally accompanied by gold. In such cases quartz is seldom present. Elsewhere when the rocks are unaffected by secondary structure they contain stringers, or even fairly well-defined veins of quartz, which sometimes carry the same values as the veins in the main lode system.

The slates in which the quartz veins of the main lode are found bear a general similarity to those occuring throughout the stratigraphic band of which they form a part. They are highly metamorphosed, and having been originally carbonaceous now contain large amounts of graphite, which, with other secondary platy minerals, is arranged in conformity with the slaty structure of the rock. As a whole the slates are but little plicated, and their secondary cleavage follows the original bedding, which in turn is parallel with the greenstone contact. Locally, as in the Gold Creek mines, where dikes are intruded into them, there is some intricate folding, and when this feature is present the secondary structures do not conform to the original bedding, but keep their normal attitude parallel to the average position of the stratigraphic planes.

The quartz veins which compose the lode are not continuous for long distances, but occur as independent lenses, or in series of interrupted overlapping veins closely following the structure of the slates within a zone which may often attain a width of 100 feet, or again in the form of stringers filling gashes slightly oblique to the main structure, but ranged in sets along some particular horizon. Often the large lenses or stringers are joined by networks of minor veinlets which follow secondary joints arranged with more or less regularity.

MINES OF THE DISTRICT.

Gold Creek mines.—The lode system, which has been described in general terms, is most strongly developed in the vicinity of Juneau, where the Gold Creek placers, which first called attention to the region, were derived from it, and where several lode mines are now being developed. Here mineralization is rather irregularly distributed through the black slates in a zone averaging somewhat more than 800 feet in width, running parallel with the easily recognized outcrop of the greenstone, which forms the effective foot wall of the vein system. This vein complex is well defined from the middle slope of Juneau Mountain, where recent prospecting has been in progress, through the Ebner, Humboldt, Alaska-Juneau, and Alaska-Perseverance properties to Sheep Creek divide and thence southeastward across the basin of Sheep Creek, a total distance of about 5 miles.

In the northwest half of the portion of this zone which lies in Gold Creek an important feature is the occurrence of several dikes of highly altered and sometimes mineralized rock, commonly known as diorite or brown rock. The original character seems to have been gabbro, but the rock has suffered so complete metasomatic alteration that its original nature is seldom observable.

When these dikes are present the quartz occurs mostly in the form of oblique gash stringers, which often recur along the contacts between the dikes and the slates. Locally auriferous sulphides, mostly pyrrhotite, impregnate the body of the igneous rock between the veinlets of quartz, but the values are principally in the veins. The free-milling ores, which are confined to the northwestern mines of the lode system in Gold Creek, are said to contain only small amounts of silver, the bullion sometimes running as low as 4 dollars of silver in 1,000.

In the southeastern part of Gold Creek the brown diorite dikes are smaller and more irregular, and while many cross-cutting stringers are present in the slate, a large part of the veining takes the form of interleaved stringers and irregular bunches following the slaty cleavage. Here only a small amount of pyrrhotite is found, the sulphides being principally galena and sphalerite, with a small amount of chalcopyrite. The proportion of silver varies from three to six times the gold by weight.

Formerly in working the deposits of Gold Creek the quartz was picked out and milled by itself, but this was not found profitable, and it is now realized that the only possibility of economic operation lies in the direction of mining and milling a large tonnage of unsorted material.

The average values of the ores mined in a large way and unsorted is very low, but the strength and persistence of the lode system leads to the belief that both mineralization and values will continue to any depth likely to be reached in mining.

The estimated output of Gold Creek lode mines and placers to date is $1,500,000.

Sheep Creek mines.—The lode system of Gold Creek extends without interruption southward across the Sheep Creek divide, though its physical character and its metallic contents are somewhat different. Strong and fairly continuous veins of quartz occur in the black slates for a distance of from 400 to 500 feet from the greenstone contact, and these veins, almost without exception, follow the slaty structure. Veining is prominent at four horizons, though but two of these have been systematically explored and worked. The main operations have been in the Glacier and Silver Queen mines, which have produced in the neighborhood of $500,000. The sulphides are the same as those in the adjacent part of Gold Creek, but the silver values are very much higher, and the ores are really silver ores.

Farther to the southeast, though still undeveloped, the four veins are well marked and locally mineralized, as far as the Regan group of claims, beyond which they are covered by rocky débris and vegetation in the bottom of the gulch. Where they reappear in the ridge between Sheep Creek and Grindstone Creek they are much less prominent, and probably too small and too much interrupted to be of value. This lode system does not seem to attain any importance on the opposite side of the ridge in the basin of Grindstone Creek nor upon the shore of Taku Inlet beyond.

Mines south of Juneau.—Most of the veins which have been discovered and worked south of Juneau lie on or near the line joining the mines of Gold Creek with those near the head of Windham Bay. This line trends about N. 40° E., nearly parallel with Stephens Passage, and follows approximately the extension of the contact between the upper greenstone and the overlying shales.

Southeastward from Sheep Creek no important veining is known near the contact until the vicinity of Port Snettisham is reached. On the south side of this long inlet, near Snettisham post-office, about 3 miles from Stephens Passage, there has been considerable prospecting, and one mine has already produced a few thousand dollars. Again, at Sumdum, on Endicott Arm, 20 miles farther down the coast, the black shales carry veins from which approximately $450,000 have been extracted. From these properties mineralization is fairly continuous across the intervening mountains to the head of Windham Bay.

Placers located on the streams tributary to Windham Bay were worked in a small way with more or less profit at various times between their discovery, in 1869, and 1888. In 1888 a hydraulic plant was installed to work deposits of gravel near the mouth of Spruce Creek, about one-fourth mile from the head of the bay. About the same time an attempt was also made to work a higher basin on the same creek, but these large-scale operations failed, presumably because of inexperienced management, since the possibility of making wages with a shovel and pan along the edges of the deposits has been demonstrated.

Shuck River, the main affluent of Windham Bay, also contains good-sized gravel deposits, some of which have yielded more or less profitable returns to sluice-box mining. It is reported that a proposition is now afoot to install a dredge on this river.

The lode mines of the district have received a great deal of attention, but with discouraging results. Two sorts of deposits have been prospected—quartz veins and mineralized bands in the slates. The former are usually crosscutting, containing various sulphides and free gold, but they are extremely irregular and unreliable and are often mere stringers or bunches, as has been demonstrated in several places. There are several bands of mineralized slate that contain a large amount of disseminated pyrite which carries some gold, but these bodies have not been found sufficiently valuable to constitute even low-grade ores.

No points beyond Windham Bay were visited, but prospecting is known to be in progress in the vicinity of Hobart Bay, and it is regarded as probable that a connection will yet be established between the Juneau gold belt and some portion of the Ketchikan district, throughout which mineralization is so widely distributed.

Mines north of Juneau.—At present more attention is being directed to the northern portion of the mainland belt than to the region south of Juneau. During the summer of 1903 considerable development work was done and some promising leads were discovered. and still greater activity is promised for 1904.

Northward from Juneau the upper greenstone contact can be traced nearly as far as Berners Bay, though from Mendenhall River, 10 miles beyond Juneau, its outcrop trends less to the west than in the lower part of the belt. Between Juneau and Mendenhall River no important discoveries have been made along the line, but farther north there are important placers in McGinnis, Montana, and Windfall creeks, and the black slates next to the upper greenstones contain many quartz stringers, both in the creeks named and northward in the tributaries of Cowee Creek. In the drainage of this last stream, a few miles from Berners Bay, the greenstone and slate beds are cut off by the transverse contact of the Coast Range diorite.

Hydraulic plants were installed in McGinnis Creek and Windfall Creek early in the season of 1903, but the exceptionally dry season made it impossible to operate them and doubtless mining will begin early in the coming summer.

On the landward side of the well-defined lode system there is in the aggregate a large amount of mineralization, though present development has revealed no workable deposits. Stringers of quartz, often carrying sulphide and gold, are to be found throughout the area of schist between the black slates and the main intrusive mass of the Coast Range, and these intrusives are also known to be mineralized locally, so that it is not improbable that workable deposits may yet be discovered.

On the seaward side of the slate-greenstone contact the number and importance of the gold veins in the northern belt is quite as great as in the principal lode system. In this region the bands of greenstone are relatively narrower than farther south, but they are more numerous, and the slate-greenstone series is therefore less homogeneous. The many contacts between the greenstone beds and the slates are frequently marked by veins which resemble the stringer leads of the main system, though they are not traceable through the same distance. Many of them are, however, well marked and practically continuous for several miles. Besides these, there are also many veins following well-defined fissures transverse to the structure of the rocks. Such cross veins are ordinarily confined to massive portions of the greenstone beds and seldom, if ever, cross the contacts with the slates, which are not massive, and therefore ill adapted for supporting continuous fissures.

Only a portion of the slate-greenstone band occurs north of Berners Bay, the upper or inland portion being cut out by masses of diorite. A broad band of this intrusive rock, separated from the main mass which forms the Coast Range by a narrow band of slate and greenstone, is present south of the bay, and, reappearing on the north side, cuts diagonally across the peninsula between Berners Bay and Lynn Canal. In this region no mineralization has been discovered in the black slates, which form the prevailing rock of the end of the peninsula. Most of the veins which have been opened within the drainage of Johnson Creek and Sherman Creek occur in the outlying band of intrusive diorites. The Jualin, Comet, Eureka, Kensington, and other properties, are all situated in this formation, most of them on veins which fill strong fissures belonging to two systems. The Greek Boy property, however, is a strong stringer lead, which occurs in the slate belt near its contact with the main diorite at the head of Berners Bay.

The combined output of the Berners Bay mines to date is estimated at about $1,100,000.

The Juneau belt can not be definitely recognized beyond the Berners Bay Peninsula, which it crosses diagonally and beyond which it strikes into Lynn Canal. Copper deposits which are reported at Sullivan Island, near the west side of the canal, nearly opposite Davidson Glacier, may represent a continuation of the belt, but the nature of the rocks and their stratigraphic position relative to the strata of the mainland toward the southeast is not known. The next known gold deposits toward the northwest are in the Porcupine district of the Chilkat drainage, 50 miles distant. The gravels which are being profitably worked on several creeks in this district are regarded as of local origin, from the facts of their occurrence, though the actual source of their gold has not been discovered. The country rocks are mainly black slate, containing some limestone, in which Carboniferous fossils occur, but there are no massive flows of greenstone like those of the Juneau belt, and no sufficiently detailed studies have been made to warrant correlating these rocks with the slates in the southern districts. The region lies several miles from the main contact of the dioritic rocks which form a continuation of the Coast Range intrusives, and as these invading rocks are crosscutting toward the west in the vicinity of Berners Bay, it is probable that the rocks of the Porcupine field belong to the formations which carry mineral veins on Admiralty Island and on the west side of Lynn Canal, at James Bay, and on Endicott River.

Treadwell mines.—The main feature of interest on Douglas Island is the Treadwell group of mines, consisting of the Alaska-Treadwell, 700-foot, Alaska-Mexican, and Ready Bullion properties. The mines are advantageously located on the inner or mainland side of the island, close to tide water. The ore, which is of low grade, averaging about $2 in value, occurs in a series of ore bodies lying between a mass of greenstone on the hanging wall and black slate on the foot wall. The strike of the deposits and of the country rock is about N. 45° W., slightly diagonal to the shore of Gastineau Channel, which trends about N. 40° W., and the average dip toward the northeast is about 50°.

The ore bodies are brecciated masses of intrusive syenite, filled with a network of quartz and calcite veinlets, and impregnated with pyrite, which occurs both in the veinlets and in the rock itself. The gold occurs both in association with the pyrite and native, and a large, though variable, proportion of the values are saved by amalgamation. Visible specks of the metal are sometimes, though rarely, found.

The following associated minerals have been observed: Pyrrhotite and magnetite are always present, and molybdenite is of common occurrence; native arsenic, realgar, and orpiment have been noted, and arsenic is commonly found by the assayer, probably indicating the presence of arsenopyrite; stibnite occurs in small amounts with the quartz. Bullion assays indicate only small amounts of silver.

The syenite bodies which have been worked occur as somewhat irregular dikes. In the Alaska-Treadwell property two of these dikes are mined, each having a width of about 200 feet. Between them there is a band of barren slate perhaps 50 feet across, and there are some minor masses of the country rock included in the ore bodies. The south or foot-wall dike has a known length along the strike of 800 feet, and from the lenticular outline of its horizontal cross section the entire extent can not be much in excess of this figure. The hanging-wall dike has been mined continuously for a distance of nearly 2,000 feet through the Treadwell and 700-foot workings, but beyond this toward the southeast there are several separate ore bodies of lenticular cross section, which occupy the same position under the greenstone, as is shown in the Alaska-Mexican and Ready Bullion mines. Toward the northwest only narrow dikes are present where the base of the greenstone has been prospected.

The distribution of values is irregular, as in nearly all gold deposits, but there is no suggestion of impoverishment in the deepest workings, which are nearly 1,000 feet below the sea.

While only the hanging-wall bodies of the syenite have thus far been found productive, many other dikes of the rock occur for a distance of about 3,000 feet across the strike of the black slates, toward the southwest. They are almost entirely confined to this side of the greenstone, though a few are found between it and the channel, and a large mass forms an island about one-fourth mile offshore. Along the strike the dikes extend for a distance of 3 miles, mainly northwestward from the vicinity of the mines, and the greenstone may be traced for a much longer distance in this direction.

OTHER DEPOSITS ON DOUGLAS ISLAND.

Aside from the deposits of altered syenite, the black slates are locally found to contain systems of quartz stringers or sometimes veins of fair size. One of these systems of stringers forms an extension of the Treadwell deposits, and is traceable for several miles along the mainland side of Douglas Island, and though it has been prospected to a certain extent no mines have been discovered.

Several other areas of strong mineralization are found on Douglas Island, two of which occur in the massive basaltic greenstone which forms the outer two-thirds of the island and may prove of future value. One of these is situated on Nevada Creek, about 3½ miles southwest of the Alaska-Treadwell mine, where an area of bleached rock impregnated with small cubes of iron pyrites extends about 1 mile along the creek below the main divide of the island and for a distance of about 1½ miles along the strike of the rocks. Parts of the altered and mineralized greenstone give fairly good assay, but no well-defined ore bodies have been discovered. Locally there are narrow, irregular veinlets which carry galena and sphalerite, and these are richer both in gold and silver than the main mass of the rock. A few irregular quartz veins occur, but as a rule the sulphides are not accompanied by this mineral.

The second case of mineralization mentioned above is a zone in the greenstone occurring about 1 mile west of the Treadwell deposit. The mineralized band follows the structure of the rocks and varies in width from perhaps 100 to 300 feet. It is traceable for more than a mile by the altered and bleached condition of the greenstone, through which pyrite is distributed in the form of small cubes similar to those occurring in the Nevada Creek deposit. It is reported that gold occurs throughout large parts of the mineralized mass in amounts somewhat less than $1. Here also, as in Nevada Creek, there are occasional narrow stringers of high-grade sulphides. Several hundred feet of prospecting by means of a shaft on the Yakima group of claims has, however, developed no deposit of workable ore.

POWER PROBLEM.

Throughout the Juneau belt, and in southeast Alaska in general, the water powers now utilized are available for not over seven months in the year. Winter precipitation is almost entirely as snow, and melting is at a minimum between December 1 and May 1, so that during this period the effective run-off in most of the streams is very small or nil. Consequently auxiliary steam plants have been employed where continuous power has been needed throughout the year, and double installations must always be planned where mining and milling operations are to be carried on without interruption. However, sufficient water power for even extensive development work is seldom wanting.

The streams now used have been naturally selected because they were easily accessible, and it has thus come about that only creeks of steep grade and small drainage area are furnishing power. Many large and constant rivers exist, but the length of the ditches required and the difficulty of keeping them open in winter have thus far prevented, and probably always will prevent, the utilization of streams of low grades.

It seems at present that plants large enough to furnish power throughout the year can be installed only where favorably situated natural lakes can be turned to account for winter storage, and to tide over seasons of exceptional dryness, such as was experienced in the summer of 1903. One project of this sort now under advisement by the engineers connected with the Alaska-Treadwell and associated interests will, if successfully inaugurated, greatly reduce the already low cost of working the large bodies of low-grade ores controlled by these companies. The problem of transmission for long distances and across the deep fjords which abound throughout the region will be an important factor in deciding the practicability of any large water-power plant.

The necessity of reducing power costs, if possible, is evident from the price of coal, which is reported by the Treadwell management to be not less than $6 per ton under favorable return cargo conditions.

The existence of coal beds at several points on Admiralty and Kuiu islands has been known for many years, and early, though unsuccessful attempts were made by the Navy Department to locate workable deposits. The proximity of these localities to Juneau and the possibility of establishing a coaling station, if good coal could be found and worked to advantage, has led to a great deal of private prospecting in recent years, but no minable deposits have been found. At Killisnoo it is reported that the seams are too thin to be mined economically, while at Murder Cove the coal and the rocks in which it occurs are said to be too much broken to be of value. At present, therefore, these occurrences do not promise any reduction in the cost of fuel, though a comprehensive examination of the areas in which the coal-bearing rocks occur may yet lead to valuable discoveries. The reason for this belief is that the amount of folding, faulting, and crushing in these rocks seems to vary from place to place, and if regions only slightly disturbed exist, they may contain workable coals.

Peat deposits which exist in many parts of Alaska may locally become a factor in the power problem. The fuel value of peat is of course comparatively low, but under favorable conditions it can be cut at small cost and used for making steam or, possibly with greater economy, to produce fuel gas for gas engines.

On the inner side of Douglas Island a broad bench at an elevation of about 400 feet is covered by large areas of peat, and though the material has never been prospected or tested, it apparently exists in unlimited amount and could undoubtedly be used for fuel in either of the ways suggested.

PLACER MINING IN ALASKA IN 1903.

By Alfred H. Brooks.

INTRODUCTION.

Though the development of lode mining of gold, silver, and copper is progressing rapidly, yet over six-sevenths of the value of Alaska's mineral output comes from the gold placers. No great increase of production can be expected until the mining plants now being installed are ready to begin operations. The activities of the past year have been devoted to the introduction of better equipment and to more energetic development in the larger mining camps. While no new districts have been discovered within the calendar year, the prospecting of some which had been previously only very superficially examined has placed them among those of commercial importance. In this category belong the Fairbanks district, on the Tanana; the Good Hope district of Seward Peninsula; and possibly also the Kowak placers, as they may eventually prove to be of commercial importance.

Of vital interest to placer mining, as well as to other Alaskan industries, are the improvements made in the means of communication. The completion of the military telegraph line, which now extends from Valdes to Eagle, on the Yukon, and down that river to the mouth of the Tanana, from which point one line connects with the new Fairbanks district and another with St. Michael, on the Bering Sea, is of the greatest possible importance. It is hoped that the installation of the wireless system will connect St. Michael with Nome. This, by using the Canadian line from Dawson to Skagway, and the United States military cable to Seattle, will give a complete system from Nome to the outside world. A short cable connects Juneau with Skagway. It is possible, therefore, to telegraph to many of the important mining camps in Alaska. It is to be hoped that the War Department may be able to extend this system, as it plans to do, by a cable to Valdez and another to Ketchikan.

The transportation facilities also have shown some improvement, but are still far behind the requirements of the miners. The ocean steamers now sometimes give a six-and-a-half-day service between Seattle and

Nome, but even this could be improved. It costs probably $5 per ton to land freight from the steamer at Nome—one-third of the entire expense of sending it from Seattle to the Nome beach. Last season about 60,000 tons were landed at an expense of $300,000, which can be regarded as a direct tax on the mining industry. Moreover, this is not all, for the delays incidental to stormy weather, or a late season, much increases this tax. Plans are under consideration for the construction of a pier at Nome which shall extend out to deep water. If such a pier could be built, it would be a great boon to the region. The ordinary difficulties of engineering such a structure are very much enhanced in this northern region, because it would have to be built strong enough to withstand the tremendous ice floes which pile up on the Nome beach, sometimes to a height of 100 feet.

The handling of freight at Nome is done fairly expeditiously during the good weather of early spring and summer, but is very uncertain after the stormy weather of fall begins. Freight for other points on the coast of Seward Peninsula is frequently transferred to small steamers at Nome, a very costly and time-consuming system.

The uncertainties of Yukon River traffic were well illustrated by the conditions in the summer of 1903, when low water delayed many steamers until midsummer, and, as a result, many of the supplies and equipments did not reach their destination. While there is not likely to be actual suffering because of these interruptions to traffic, yet, as a result, provisions will be overexpensive in several camps and many mining operations will be blocked. Until the Yukon placer fields are reached by a railway from the coast a repetition of such a state of affairs may be expected every year. Two railway projects have been under consideration: (1) From Resurrection Bay to the Tanana, crossing the Alaskan Range at Caribou Pass (elevation, about 2,000 feet); (2) from Valdes across the Chugach Mountains at Thompson Pass (elevation, 2,200 feet), and across the Mentasta Mountains through Mentasta Pass (elevation, 2,400 feet). Neither route presents any serious engineering difficulties, and both are known through the reconnaissance maps made by the United States Geological Survey. There are also several projects for reaching the Yukon placer fields by railways through Canadian territory.

In southeastern Alaska the transportation question is a simple one. The principal mining camps can be reached by comfortable steamer from Seattle in two to five days.

KOWAK[a] REGION.

The Kowak[b] placers, which received some attention in the summer of 1903, have produced a few thousand dollars, and the reports have

[a] The river from which this name is derived is known locally as the Kobuk.

[b] A general account of this region will be found in "A Reconnaissance from Fort Hamlin to Kotzebue Sound," by Walter C. Mendenhall, Prof. Paper U. S. Geol. Survey No. 10, 1902.

been sufficiently encouraging to cause a considerable movement of prospectors from Nome and from points on the Yukon to this far-away region. The placer gold has been found in the basin of Shingnek Creek, a small northerly tributary of the Kowak, which can be reached by a steamboat journey of 225 miles from the sea. So far as known the gold has its source in a complex of metamorphic schists, limestone, quartzites, and greenstones, which find an extensive development in the Kowak Valley. As early as 1899 gold was found on some of the creeks of this district, but it was only during the last season that actual values have been developed. It is of interest to note that placer gold was discovered some years ago on one of the tributaries of the upper Noatak, and this locality seems to lie in the strike of the formation of Shingnek Creek. The facts at least suggest that gold may have a wider distribution in this region than has been generally supposed, and lead to the hope that valuable placers may yet be discovered.

The district is not easy of access, and the workable placers must give a very large yield during the three months of open season. The summer journey from Nome to Hotham Inlet is made by ocean steamer, which must be of shallow draft, and thence by river steamer to Shingnek Creek, from which point the creeks are reached overland. As the Arctic Ocean is seldom clear of ice before the middle of July, it will hardly be possible to reach the diggings before the 1st of August. Many prospectors will reach the new camp by winter journeys with dog teams.

The valley floors and slopes are clothed with spruce, poplars, and birches up to an altitude of 2,000 feet above the sea. The miner will have to transport all his supplies with him, for game is very scarce, though there is considerable fish.

These isolated camps offer a field to the individual miner, especially if he be of that restless class which seldom remains in a district after its development has begun on a commercial scale, yet they have little effect on the gold output of the Territory. Some of these districts, like the Koyukuk, have produced gold for nearly a decade, and will continue to yield grub stakes, with an occasional small fortune. It is, however, to the larger and more accessible camps that we must look for Alaska's wealth of placer gold. These attract the engineer and the capitalist, without whose services large mining plants capable of materially increasing the output can not be installed. It is the influx of capital and experienced mining men which makes the future outlook of Alaska's development so bright.

SOUTHEASTERN ALASKA.

Southeastern Alaska is essentially a field of lode mining. The pre-Glacial gravels, which were undoubtedly more or less auriferous, were in a large measure removed during the invasion of the ice. The gravel terranes laid down during, in, and after the glaciation, were often deposited in the deep fiords, into which the drainage channels discharge. There are, however, some post-Glacial auriferous gravels which have been, and are being, mined at a profit.

The Juneau placers had yielded large returns long before a stamp had fallen on any of its lode ores. In the Silver Bow basin is the oldest placer mine of the region, which has not been abandoned, but it was not in operation during the calendar year. A comprehensive scheme has been in course of development during the past three years to hydraulic the gravels of the Last Chance placer mine. This property includes a gravel-filled basin on Gold Creek, 1 mile from Juneau. A tunnel has been driven for half a mile, through which it is proposed to hydraulic the placers. As yet but little sluicing has been done, difficulty having been experienced in getting rid of a large mass of bowlders at the upper end of the tunnel.

Extensive hydraulic plants have been installed at McGinnis and Windfall creeks, northwest of Juneau. Some hydraulic operations are also being carried on at Lemon Creek, 10 miles northwest, and at Windham Bay, 75 miles southeast of Juneau.

The Porcupine is the largest of the placer districts of southeastern Alaska. As it lies close to the International Boundary its development has been retarded by the uncertainties of control of a part of its area. It is expected that with the settlement of this difficulty it will now take a new lease of life. A description of this district by Mr. Wright will be found elsewhere in this report.

YAKUTAT BAY REGION.

This region would not here be worthy of mention were it not for the current reports of the discovery of new placer fields. The latest report accredited Yaktag River with gold-bearing gravels, and the rumors have been sufficiently definite to attract some prospectors. It has not been learned, however, that these prospects are of any commercial importance. The fact that gold has been found in the beach placers at Yakutat and Lituya bays, where it apparantly has been concentrated from glacial material by wave action, points to the conclusion that there are gold-bearing formations somewhere in the St. Elias Range. It is known that metamorphic and crystalline rocks do occur in this range, and this is suggestive of the conclusion that some of the auriferous formations of southeastern Alaska find their extension in these high mountains. Additional weight is given to this point of view by the fact that the western extension of these mountains is found to be gold bearing, to a limited extent at least, along the lower reaches of the Copper River Valley and its tributaries. The writer does not wish to convey the impression that this range will necessarily become a locus of commercial placers, for the following facts would argue against such a conclusion: (1) Though considerable prospecting has been done in this region, especially along Alsek River, whose valley crosscuts the range, gold has been found only in small quantities; this evidence is, however, purely negative; (2) the extensive glacial erosion and the great deposits of glacial drift, as well as the presence of many large glaciers, would not seem to present favorable conditions for the concentration of gold in placers.

COPPER RIVER BASIN.

Unconsolidated Pleistocene[a] gravels and sands are extensively developed in the Copper River basin, and many of these are auriferous. In relatively few of these deposits has the gold been sufficiently concentrated to be of commercial importance. The Chistochina district, in the northern part of the basin, where developments have been going on steadily during the past year, is the only one which has produced any considerable amount of gold. What would seem to be the eastern extension of the gold-bearing series has been found in the headwaters of the Tanana, but it has not yet been proved to carry commercial values. Gold has also been found to the west of the district, but up to the past summer not in commercial quantities. Rumors of important discoveries on White and Slate creeks, which are said to lie in the upper Sushitna basin reached Valdes late in the summer, and parties are said to be now en route to these diggings with dog teams. These placers are reported to be drained by streams flowing into East Fork of the Sushitna, and to lie 200 miles from tidewater. What is known concerning them is too vague to permit of speculation in reference to their importance, but their position would indicate that they lie in a zone which elsewhere has been found to be auriferous.

Little has been heard of the placer fields in the southern part of the Copper River basin. These, which embrace Nizina River, the Tiekel, and the Tonsina, while they have given sufficient indications to attract mining men, as far as known have not yielded gold in commercial quantities during the last year.

COOK INLET REGION.

The Turnagain Arm placers, which have been exploited since 1895, lie in the drainage basins of streams which empty into the head of Cook Inlet both from the north and the south. The district may be reached by a ten-days' ocean journey to Tyonok or Homer, and thence by small steamer to Sunrise. Most of the placers are within 10 to 20 miles of tidewater. There is little to add to the statements concerning this district in last year's report.[b] The improvements have been of a

[a] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: Prof. Paper U. S. Geol. Survey No. 15, 1903.

[b] Brooks, A. H., Placer gold mining in Alaska in 1902: Bull. U. S. Geol. Survey No. 213, 1903, p. 45.

character requiring heavy investments of capital. Several hydraulic plants have been, or are being, installed.

A large deposit of gold-bearing gravels is reported at the upper end of Tustumena Lake, in the central part of Kenai Peninsula, the promontory which separates Cook Inlet from the Pacific. These placers, which are from 20 to 30 miles inland, are said to be of sufficiently high grade to be workable by hydraulic methods, and a plant was installed during the past summer.

KUSKOKWIM AND MOUNT McKINLEY REGION.

The large area which is blocked out by Cook Inlet on the east, the Tanana and Yukon on the north and west, and Bering Sea on the south, and which is drained chiefly by Kuskokwim River, has been but little explored. It has been traversed by a few of the parties of the Geological Survey,[a] but much of it is practically unknown. Spurr reported evidence of mineralization in the Tordrillo Mountains and colors of gold in streams which head in these mountains. Prospectors, too, have entered this region, and now and again come reports of the discovery of rich placers, but up to the present time these have not been verified. Gold has long been known to occur on the upper waters of Mulchatna River, and the easterly fork of Nushagak River, emptying into Bristol Bay, but has not yet been found in workable quantities. These placers are said to yield $4 to $5 a day to the man, but their inaccessibility makes them of no commercial value. In 1900 the news of the discovery of gold near the lower Kuskokwim caused a small stampede from Nome. The scene of the find, which proved to be of no importance, was on one of the small streams which flow into Kuskokwim Bay from the east.

The latest reports of placers in this field locate them in the vicinity of Mount McKinley. Several parties of prospectors ascended Kantishna River, a southwestern tributary of the Tanana about 100 miles from the Yukon. These men report the presence of auriferous placers in the Kantishna Basin, near the foot of the mountains. The writer, who traversed this region in the summer of 1902, is unable to substantiate this report. Of the streams which flow into the Kuskokwim from the Alaskan Range few, if any, even carried colors. In some of the streams of the Kantishna drainage system, however, some colors were found, and there was other evidence of mineralization. It seems at least possible that this field may yet produce placer gold.

SEWARD PENINSULA.

Seward Peninsula, from the standpoint of production and of early increase of production, is still the focal point of Alaskan mining inter-

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[a] Spurr, J. E., A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, pp. 31-264. Brooks, A. H., A reconnaissance in the Mount McKinley region (in preparation).

ests. In 1902 the output of all the camps of the peninsula was about $4,500,000, and was probably about the same in 1903, but the statistics have not yet been compiled. This will bring up the value of the entire gold production of the peninsula since 1899 to over $20,000,000.

Though placers are widely distributed in Seward Peninsula, yet probably somewhat over four-fifths of the gold mined has come from two districts, the one lying immediately adjacent to Nome, and the other tributary to Council City. These facts must be taken as evidence rather of the greater developments in these two camps than of the greater richness of their placers. Though there are probably few placers in the peninsula in which the gold is as concentrated as in those of Nome and Ophir Creek, yet there are many undeveloped or little-developed prospects which give promise of yielding very large returns. It is certain that the field is far from having reached its maximum output, for in relatively few of the districts have mining methods been introduced which would give large returns. During the excitement of the years 1899 and 1900, the pick and shovel, with the rocker and short sluice box, held sway, and these primitive methods are still in use on the majority of the creeks. With their aid many a broken-down miner and prospector has retrieved his fortune, but capital is often chary of entering a field where such methods are in use, because they are suggestive of pocket mining, and large enterprises are in many cases delayed. Then, too, the general public has so often undergone losses in this field through ill-planned or downright swindling mining schemes, that it looks with well-merited suspicion on new ventures. With the successful execution of some extensive mining operations this conservatism is being rapidly overcome, and mining men of experience and reputation are finding it less difficult to secure backing for legitimate undertakings.

Mine operators are now thoroughly alive to the fact that an abundant and reliable water supply is the first requisite to large mining operations. The experience of the past three years has settled the question of depending on local and periodic supplies of water. To the experienced hydraulic miners of other regions it may seem strange that this lesson had to be learned again at Nome. It should be remembered, however, that Nome was first developed by men who were trained in the early days of the Klondike, when gold was taken out by the crudest methods. There were many who believed that it would be impossible to build and maintain ditches at anything but a ruinous cost, but this has been disproved. There are now nearly 100 miles of ditches in successful operation on the peninsula, and an equal mileage has been surveyed and is partly under construction. Experience has shown that, except for the difference in wages, the construction and maintenance of ditches is not more expensive in the Nome region than in many more favorably located districts. The original cost can be roughly approximated at from $1,000 to $2,500 per mile. It has been proved that, at the present high cost of fuel, it is usually cheaper to obtain water by ditches than by pumping.

The fuel problem is a serious one, as coal at Nome still commands about $25 a ton, and is never below $20. Gasoline and petroleum engines are extensively used. Gasoline retails at about 25 cents a gallon. During the last season petroleum tanks were built at Nome which were filled directly from tank steamers and were connected by a pipe line with some of the placer camps of the vicinity. This introduction of petroleum, handled in a large way, may revolutionize the fuel question. Another proposition is to convert into fuel the thick mat of vegetation which covers the surface of the tundra. This material, which is a form of peat, burns readily when dried, but its utilization as fuel has not been attempted on a commercial scale. On the north slope of the peninsula a small body of lignitic coal has been developed which, though not of high grade, has found ready market in the neighboring mining camps.

The deeply scoured glacial valleys of the Kigluaik Mountains, which lie about 40 miles north of Nome, afford an abundant water supply, which has been and will be an important factor in the development of placers both north and south of the mountains. Several ditches have already been built to these mountains. The same highland belt also contains much undeveloped water power, and plans have been formulated to convert this into electric energy and to supply camps all over the southern part of the peninsula with both light and power. The promoters of this enterprise believe that they can thus, by the use of pumps, successfully compete with the water-supply ditches.

The idea that hydraulicking gravels in this northern region was not practical from a commercial standpoint has been effectually dispelled. Even where the gravel was frozen solid, which is not by any means universally true, it is possible, by using sufficient head, to break up the frozen alluvium. Moreover, after the thick coating of muck and vegetation, which is nonconductive, is removed, thawing takes place rapidly during the long days of the arctic summer.

While hydraulic mining in this northern latitude contends with many difficulties, these are by no means so great as is ordinarily believed. Wages are $5 a day with board, the halcyon days for the pick and shovel men of $1 to $1.50 an hour having long since passed. Freight rates to Nome last spring were $15 a ton, including lighterage. Later in the season a combination was formed among the ocean vessels, and the rate was doubled. During the season of 1903 there were 26 steam vessels, small and large, and 7 schooners, which carried about 75,000 tons of cargo to Seward Peninsula ports.

The cost of water transportation between coastal points fluctuates greatly. The figures secured from half a dozen sources indicate a rate of from \$7 to \$15 a ton per 100 miles by steamer, with an average of about \$10. Freight is carried at much lower figures by small gasoline sloops and schooners, and these are particularly well adapted to this work because they can anchor close to the beach and can enter the mouths of the larger rivers. During the past season there were four small steamers with 50 to 200 tons capacity and half a dozen gasoline sloops and schooners of from 5 to 15 tons burden engaged in the coastal transportation.

Overland transportation with horses is very expensive, but varies greatly. According to best reports it varies from \$10 to \$16 per ton a mile, and will average \$13. The railways carry small lots of freight for about \$3 per ton a mile.

Navigation opens in the spring between May 25 and June 15. Surface mining operations can usually be carried on through the months of June, July, August, and often until the first of October. It is fair to assume that three months of sluicing can be counted on if a reliable supply of water is available. It should be borne in mind that this season is not so very much shorter than in many a placer camp in western United States. Taken all in all the conditions of mining are not so unfavorable as is often represented.

Reference has been made to the transportation facilities on the peninsula, which are still far from adequate for the mining industry. The only important improvement made during the past season was the construction of the Solomon and Council City Railway. About 10 miles of this well built standard-gauge road has been completed, together with terminal facilities, and plans are under way to push the construction next season. The road to Council will have a length of about 50 miles, and extensions are planned by the same company. This is really the first attempt to permanently solve the transportation problem. The Wild Goose Railway, which is narrow gauge, extends from Nome to the head of Dexter Creek, by way of Anvil Creek Valley, and has benefited the mining interests very much. Some wagon roads have been constructed on the peninsula, but most of the teaming is done across country or along the beach and stream bottoms, and, as has been shown, is enormously expensive.

The question is often asked, What minimum limit of value can profitably be exploited in this northern field? There are so many factors which have to be considered that no categorical answer can be given to this query. A placer which is close to tide water can be mined much more economically than one at a distance, where it costs \$10 to \$15 per ton a mile to transport equipment overland. Again, a low-grade gravel can often be worked, if it is near a bonanza, because the same ditch may supply water to both properties. After ditches have once been constructed and paid for by the yield from very rich ground, the water they supply may be utilized profitably to exploit deposits of lower grade. Statements in print are not infrequent from which it would be inferred that only bonanzas can profitably be exploited in the Nome region. Pay streaks which have yielded \$30 to \$40 and even \$100 per cubic yard are not uncommon, but these do not form any considerable percentage of the auriferous gravels which carry values. Much profitable mining is done in gravels which will not average over \$3 and \$4, and if the facts were known it would be found that probably much ground of lower grade is even now being worked. The cost of mining is being rapidly reduced, and it is fair to presume that eventually values of \$1 and possibly 50 cents per cubic yard can be mined with profit.

Some plants have been installed for dredging with bucket dredge or with steam shovel, but these enterprises have not yet yielded any considerable amount of gold. Probably the most successful of these plants so far are those which have been operated on rich portions of the beach, where the material handled was entirely loose and no difficulty was experienced in disposing of the tailings. Beach mining is still carried on, but is almost a thing of the past. The gravel plain, or tundra placers, which lie within a few miles of Nome, have not received the attention which their importance is believed to warrant. Extensive prospecting with churn drills has demonstrated the presence of gold in these deposits, a conclusion which had previously been arrived at from purely geologic lines of reasoning, based on the investigations of the United States Geological Survey.[a] In the reports of 1899 and 1900 it was pointed out that old beach deposits would probably be found in this tundra belt, and this theory has since been substantiated by the discovery of an old beach deposit which has been mined at a profit. It was also shown that auriferous gravels would most likely be found at other points in the tundra, which while of lower grade might profitably be exploited. These latter deposits have been mined along the courses of some of the streams with the aid of steam shovels and dredges, but in general it can be said that entirely successful methods of exploitation have not yet been elaborated.

Underground or drifting operations form another phase of mining at Nome, which has yielded large returns. This has been carried on to a limited extent in the tundra belt, but only during the winter, when operations were not hampered by the surface drainage. The more important drifting has been on the high-bench gravels in the divide between Anvil, Dexter, and Dry creeks. Attention was called to these high gravels in the Preliminary Report of 1899,[b] but they were not exploited until 1900, and have since then yielded large returns. The

[a] Compare Schrader, F. C., and Brooks, A. H., Preliminary Report on the Cape Nome Gold Region: Special Reports on Alaska, U. S. Geol. Survey, 1900; and Brooks, A. H., Richardson, G. B., Collier, A. J., and Mendenhall, W. C., A Reconnaissance of the Nome and Adjacent Gold Fields in the Seward Peninsula in 1900: Special Reports on Alaska, U. S. Geol. Survey, 1901.

[b] Schrader, F. C., and Brooks, A. H., op. cit.

gravels are from 40 to 200 feet thick, and are usually frozen, so that neither shafts or drifts require any timbering. There are some 20 shafts and several miles of underground workings in the gravels. The pay streaks, of which there are frequently two or more, one above the other, usually run in narrow channels, so that no great amount of stoping is required. The sinking and drifting in the frozen ground is all done with the aid of steam thawers, and many of the mines are provided with steam hoists. Pumping has not been found necessary, as the workings in the frozen ground are practically dry. This mining can be carried on throughout the year, but the operations are often confined to winter months, when miners wages are 50 per cent lower than in summer. The winter accumulation of gravel is washed out in the spring, when water is plentiful. Some of the high-bench placers have proved very rich, and as no large investment is required for plants they are very profitable. Similar high-bench gravels occur at other localities, and some of these are known to be auriferous, so it is fair to assume that other high-bench placers will be discovered.

Briefly considering the results of the past year in the peninsula, it is found that the extensive developments were confined to the Nome and Council City districts, and consisted chiefly in the introduction of mine machinery and equipment. Hydraulic lifts have been installed on Glacier and Anvil creeks in the Nome district, and many claims are being worked by hydraulic sluicing. Water for these operations is furnished by the Miocene and some smaller ditches, as well as by two large pumping plants. The coming season will witness the construction of a number of additional ditches in the Nome district, some of which have already been begun. One of these, to supply the placers on Hastings Creek, will be built to Flambeau River, a distance of about 15 miles. Another is planned to furnish water to the Cripple River mines. The drift mining on the high benches, already described, has been actively pushed. In the Eldorado basin some mining is being done on Venetia Creek, and across the divide to the north Iron Creek and other tributaries of the Kruzgamepa have become important gold producers.

The Council City or Ophir Creek district is second only to Nome in importance. A narrow-gauge railway connects the camp with navigable waters on Niukluk River. Several ditches are in operation, and the equipments include three hydraulic elevators, several inclines, and derricks. One steam shovel and one dredge were in operation on the bars of Niukluk River. The Koksuktapaga Basin includes many promising placers, but their exploitation has not been commensurate with their importance because of the lack of transportation facilities.

Two steam dredges were operated last season in the gravels of Solomon River, and sluicing was done on a number of tributary streams. A ditch has been projected, while the building of the Solomon and

Council City Railway promises to be of the utmost importance for the region. At Topkok the completion of the 12-mile ditch has renewed the mining activities, which have lain dormant while it was in construction. This will furnish water for sluicing a large amount of gravel, not only in the Daniel Creek basin, the immediate objective point, but also in adjacent creeks.

In the Kugruk basin Harris, Homestake, Northfork, and Dahl creeks, as well as the main river bed, were worked in the past season, but operations are not so extensive as they would be if the region were more accessible. The Kotzebue region, lying to the northeast, is the subject of a paper by Mr. Moffit which is printed elsewhere in this volume.

The streams flowing into Grantley Harbor from the north have long been known to be gold bearing, but as the gravels are not of very high grade their exploitation has been dependent on the installation of a hydraulic plant. Surveys for a ditch have been completed, and it is expected that a plant will be installed during the coming season.

In the Bluestone region Gold Run, Alder, and Bering creeks were worked. Several small ditches, the longest 2 miles in length, supply the diggings on the Alder and the Bluestone. The high benches have been exploited with promising results in some instances, and a large ditch from the Kigluaik Mountains to provide hydraulic power for the whole region is projected.

QUARTZ MINING IN SEWARD PENINSULA.

While it is no part of the purpose of this paper to discuss the auriferous quartz ledges, yet, in view of the great interest in this matter it seems worth while to add a note on these. Quartz veins which carry from a trace to $8 or $10 in gold are not uncommon in the peninsula, but only very few have been found whose values are high enough to give promise of profitable exploitation under the present economic conditions. In the Solomon River country a 10-stamp mill has been installed to work a free-gold quartz from a lode which has been opened up. The lode, which includes three distinct veins, has been developed sufficiently to insure ample ore for running the mill, and the enterprise seems assured of success. Other quartz veins of a similar character in this region are being prospected, and some carry values and give promise of being at least as valuable as the one already developed.

In the Nome region proper many ledges have been staked and a few trenches and a pit sunk, but no attempt has been made to systematically and properly prospect any ore body. Samples have often been gathered at haphazard, so that the assay returns do not necessarily carry conviction. In the Ophir Creek region also many quartz veins have been located, but, as in the Nome region, no systematic prospecting has been done.

During the placer mining, large surfaces of bed rock are often stripped, disclosing at several localities the presence of a large number of small quartz veins which on assay are found to carry values. These veins are found both following and crosscutting the foliation. In some instances observed by the writer well-defined fissure veins crosscut the country rock and sent out offshoots which penetrate the walls along lines of cleavage to a distance of several yards from the main vein. These offshoots the prospectors term "blanket veins," and entirely overlook their subordinate character.

In one class of veins the gangue is chiefly quartz and in another largely calcite. In veins of the second class, the gold seems to be free, while the first promises to run into a base ore below the surface weathering. The first class of ore carries considerable arsenopyrite. It seems entirely possible that deposits may yet be found where a zone of country rock has been so permeated by these veins that the entire belt may be regarded as an ore. The values would, however, have to be much higher than in most of those now known to make an ore of commercial value. Large quartz veins, mineralized with pyrite and often auriferous, are not uncommon in Seward Peninsula, but few of these carry commercial values.

On the whole, it can be said that the outlook for quartz mining in Seward Peninsula is far more hopeful, now that more ground has been stripped, than it was a few years ago. It is well worth while to make careful search for lodes, but the greatest conservatism should be exercised when such lodes have been found. A vein must be well opened and thoroughly tested before any equipment is installed, and only after ore enough has been exposed to pay for the mill is it time to think of establishing a milling plant.

The excitement last fall at Nome about quartz mining promised the usual harvest of ill-advised, to say nothing of stock-jobbing, enterprises. The staking of many of the quartz claims has been of such a character that, where veins of value are opened, nearly every claim will run the gauntlet of law suits, and must be expected to pay the usual tribute to experts and attorneys.

THE YUKON BASIN.

Placer mining was carried on in all of the old camps of the Yukon and its tributaries during 1903, and the Fairbanks district on the Tanana has been added to those of commercial importance. An account of the Fairbanks district by Mr. Prindle will be found elsewhere in this bulletin. In but few creeks have any large enterprises been inaugurated, but in many there has been considerable improvement in mining methods. The annual output of the Alaskan Yukon can be estimated at between $800,000 and $1,000,000, which is likely to be materially increased with the opening up of the new Fairbanks district and the more systematic exploitation of the older ones. This output is chiefly distributed in small amounts, running from a bare grub stake of $1,000 to $20,000. Few attempts have been made to work groups of claims by improved methods.

The general backwardness of the Yukon field compared with that of Nome is, of course, in a large measure due to the differences in values, but must also be assigned to the isolation of the region. So long as developments are dependent on the present inadequate transportation facilities the region will be handicapped. With the uncertainties of the river-steamboat service, the entire absence of roads, and the scarcity of trails, the placer miners of the Yukon district have had to face conditions which would have utterly disheartened less resolute men.

Freight rates from Seattle to Yukon River points are from about $40 to $65 per ton, and the first up-river steamer from Bering Sea can not be counted upon before the 1st of August. The cost of the summer freighting from the banks of the Yukon to the mining camps, which is all done by pack horses, can be roughly estimated at $10 per ton a mile; while the winter rates, when the traffic is carried on by means of horse and dog sleds, are from $2 to $3 per ton a mile. It must be remembered that some of the placer camps are from 40 to 50 miles distant from water transportation, and that this haulage greatly increases the necessary outlay of time and money for installing a mining plant. There are scores of creeks, if not hundreds, in the Yukon country, which will be worked when the transportation problem is solved.

The construction of roads is properly a function of a territorial government, but as Alaska has no representative government, and is administered to all intents and purposes as a colony, its mining interests must look to Congress for legislation, and probably appropriations, for road construction. Their cost could, however, be met by a tax on the properties which they would benefit. It has been suggested that the yearly assessment work required by law on each claim could well be commuted in part to a money tax, to be spent on roads. It is estimated that roads could be built in the Yukon country at an average cost of $1,000 to $1,500 per mile. Many a mining camp in the region has already spent on the transportation of its supplies more money than the cost of a wagon road. It is roughly estimated that 700 miles of wagon roads in the Yukon and Copper River regions would put nearly every placer camp within reach of reasonable transportation facilities. A million dollars might well be spent in such a manner, for there would be a certainty of an increase of the gold output sufficient to warrant such an expenditure. The building of roads in the Klondike district by the Canadian government has much accelerated the development of the placer mines in that district.

The writer would make the following provisional suggestions for the location of Government roads to develop the placer fields as they are now known: (1) A road from Eagle to the Tanana, the Chistochina, and to Valdes, on the coast, a distance of approximately 400 miles. This probably should follow the present well-established trail, which is used as winter and summer mail route. The most important part of the road would be that between Eagle and the camps of the Fortymile region. An alternate route would be to Fairbanks, on the Tanana, from Copper River by way of the Delta River Valley, a distance of about 300 miles. (2) A road to extend from Circle, on the Yukon, through the Birch Creek and Fairbanks district to the Tanana, a distance of about 150 miles. (3) Rampart, on the Yukon, to be connected with the mouth of Baker Creek, on the Tanana, by a road which would open up the Minook and Baker districts, a distance of less than 50 miles. (4) A hundred miles or so of road to be built in the Koyukuk region to connect the gold-bearing creeks with the head of steamboat navigation on Koyukuk River. It is believed that these roads would form a system of main arteries by which most of the placer fields could easily be reached, and that the production of the mines would thereby be so much increased as to fully justify the expense. In case a railway were built to the Yukon, this plan should be somewhat modified, but there would still remain an urgent need of roads.

During the year 1903 work steadily progressed in the Fortymile district, though the dry season made the output less than it would have been had there been ample water supply. On Chicken Creek, one of the oldest of the district, work was extended to an examination of the benches and was rewarded by finding good pay gravel 275 feet above the water level. Much work is being done by drifting with steam thawers in the frozen ground, a method now carried on throughout the year. Use is being made of both steam and horse hoists. On Wade Creek a steam hoist is in operation, and bed-rock drains have been put down on several claims to enable working by the open-cut system rather than by drifting. On Walker Fork a steam scraper and bucket conveyor are being used on one claim. Most of the claims are worked by open cuts. Some winter work is being done on the bar at the mouth of Franklin Gulch. At the so-called "Kink," an ox bow meander of the North Fork of Fortymile, and about 50 miles in an air line from the Yukon, a strong company is engaged in turning the course of the river, so as to leave exposed about 2¾ miles of its bed. This it is proposed to mine with a steam shovel.

On American Creek a large plant has been installed, including a flume, giving a 150-foot head and power to work two hydraulic elevators. Scarcity of water prevented the extensive operation of this plant. On Seventymile River two hydraulic companies were prospecting in the past season, but no sluicing has been done. A small hydraulic outfit was operating at the falls on Seventymile, and a little grub-stake mining was done on this stream, as well as on Woodchopper, a few miles to the northwest, where a steam thawer was used.

In the Birch Creek district, where there was ample water, Miller Creek was worked in a small way, as was Eagle Creek, which carries the purest gold of the district. On Deadwood Creek, where ground sluicing has been resorted to, the bed is largely worked out, but good values have been found on the benches. On Mammoth Creek a steam shovel is being used, while on the Mastodon some experimenting is being done with machinery and the benches here are beginning to receive attention. There were about 500 men in the entire Birch Creek region in the summer of 1903.

The Rampart region includes several creeks where operations are being carried on. A small hydraulic plant has been installed on Hunter Creek and others are in process of erection. On the Hunter the pay gravel is said to be on a bench 20 feet above the creek and is covered by 20 feet of muck. The gravels are frozen, but when a face is exposed it thaws out at the rate of a foot in 24 hours. When stripped the sun's rays thaw it to a depth of 10 feet in two weeks.

The dozen creeks which were worked in the Koyukuk diggings have done well during the past season, having produced upward of $300,000. The heavy rains interfered greatly with the work on some of the creeks, especially Hammond River. Provisions and equipment are still very expensive. The transportation charges are $100 per ton from Seattle to Coldfoot, which is nearly 100 miles from some of the placers. There were about 300 men in the district, many of whom came out in the fall. Wages are from $8 to $10 a day.

As this article goes to press, well-authenticated news comes from Alaska of a "stampede" to the White River region. It probably will take a year to find out whether this is based on the actual discovery of placer gold, or is simply another one of those wild scrambles which are perennial in the northland. The new placer field is reported to lie partly on the Alaskan, partly on the Canadian, side of the boundary, but has not been more definitely located. The writer, who explored the Tanana and White River basins in 1898 and 1899, found evidence of the presence of mineralized zones in a belt of schists which should cross the White River Valley about 100 miles from its mouth. Traces or gold were found[a] both in the bed rock and the stream gravels, but not in commercial quantities. It seems altogether possible that somewhere along this belt workable placers may be found. In the fall of 1903 the discovery of gold placers in the Tanana basin was reported to the writer by prospectors who had been examining the region in which these mineralized schists form the bed rock.

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[a] Brooks, A. H., A reconnaissance in the Tanana and White River basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 485-483.

This discovery, so far as the writer is able to determine its position, must lie near the district to which the stampeders are now directed. So far as anything is known of the region, there is at least some basis for the opinion that placer gold may be found in it.

White River is navigable only for small boats, and then only with great difficulty. A small launch could be used on the Tanana above the Fortymile trail crossing. The region can be conveniently reached with pack horses from Dawson, Fortymile, or Eagle, but there are no trails. Grass is usually abundant in the summer months. White River would be exceedingly difficult to cross with horses, except close to its source.

THE PORCUPINE PLACER MINING DISTRICT, ALASKA.

By Charles W. Wright.

GENERAL DESCRIPTION.

The placers of Porcupine Creek and vicinity, discoverd in 1898, are now coming into prominence as gold producers. Porcupine Creek, a stream about 5 miles in length, enters Klehini River from the south 12 miles above its junction with the Chilkat. Geographically it lies just north of the fifty-ninth parallel of latitude and approximately at 136° 20′ west longitude. The camp is situated at the mouth of the creek, 35 miles in a straight line northwest of Haines Mission, on Lynn Canal, but by the river route the actual traveling distance is about 45 miles.

The surrounding region may be described as a high plateau, dissected by numerous deep and narrow valleys, so that its general aspect is rugged and mountainous. The average elevation of the summits is about 5,000 feet above sea level, the mountain slopes being rounded and glaciated, with no abrupt benches or terraces. The valley of the Klehini is a flat-bottomed gravel flat, averaging one-fourth mile in width. The creeks, such as the Porcupine, are characteristic mountain streams, cutting deep canyons into the hillsides, and many of them are fed by glaciers.

Of the creeks tributary to Klehini River, Porcupine Basin contains the only deposits of gravel which have proved remunerative up to the present time, though prospects have been found on Glacier Creek, 3 miles to the west, on the Canadian side of the provisional boundary. The recent boundary decision throws Glacier Creek into Alaskan territory, and this will probably lead to the early development of its placers by the United States citizens who have claimed the ground for several years.

This gold field was formerly reached by the Dalton trail, but this is now seldom used. Most of the freight is taken up the Chilkat in Indian canoes to a cache opposite Wells, at the mouth of the Klehini, and thence by wagon to Porcupine City, a distance of 10 miles.

GENERAL GEOLOGY.

A few miles north of Klehini River is the edge of a belt of intrusive rocks 80 miles or more in width, striking northwest, and composed principally of diorite. Adjacent to this on the south is a zone 8 miles in width occupied mainly by folded and metamorphosed black shales and limestone, which trend parallel with the general northwest-southeast course of the diorite contact. Fossils of lower Carboniferous age were found in a stratum of limestone on Porcupine Creek. The upper part of the Porcupine cuts into a belt of quartz-diorite 2 to 4 miles in width, also striking northwest-southeast, parallel with the Klehini Valley, beyond which toward the southwest no observations were made. This intrusive mass extends eastward to Cottonwood Creek on Salmon River, where it disappears. Several greenstone dikes were observed crosscutting the slate country rock, but the relative age of these and the diorite could not be determined, as the two were not found near the contact. An interrupted zone of mineralization carrying large amounts of iron sulphide and intersected by narrow veins of quartz and calcite, also mineralized, occurs in the sedimentary series, and from this zone the placer gold has probably been derived.

SOURCE OF THE PLACER GOLD.

It has been generally believed by the discoverers and operators of Porcupine and Nugget creeks that the gold contained in their gravels has been transported from some region outside the district. The supposed necessity of this view is urged from the coarseness and worn condition of the nuggets and from the failure to find coarse gold or more than small amounts of the free metal in any of the local veins.

The distribution of the placers is, however, distinctly against this view and favorable to a local origin. If the occurrence of gold in the gravels is due to glacial or water transportation there is no reason apparent for its concentration in one stream and its absence from adjacent gulches. This localization and the fact that pay gravels are not found in the upper portions of the gold-bearing creeks, beyond the area of mineralization or where they enter the diorite intrusive belt, strongly suggests that the gold has been derived from the surrounding country rock.

Besides the creek gravels, there are important auriferous bench deposits filling abandoned channels a few hundred feet above the present creek bottoms. These not only furnish workable placers, but have also contributed some of their nuggets to the gulch gravels through the tributary streams which have cut into the deposits and effected a reconcentration of their gold. This suggests an explanation for the occurrence of rich deposits in potholes and the irregular distribution of gold in the gravel beds. These high benches will be more fully discussed in the complete report on this placer district.

DEVELOPMENT.

The Porcupine placer diggings date from the summer of 1898, when they were discovered by three prospectors en route to the interior over the Dalton trail. After the rush to this creek in 1898 and 1899 there was but little development until 1900, when several of the claim holders bonded or leased their properties, while others formed companies in order to obtain means to operate on a large scale. The peculiarities of occurrence here require a still further combination of interests for economic exploitation, and negotiations are now being made to bring the entire creek under a single management. The only claims being developed at present are the Cranston and Discovery, on Porcupine Creek, and the Chisholm and Woodin claims on McKinley Creek. To work the creek gravels it is first necessary to divert the stream into a flume built to one side of the channel, then to install a derrick to remove the large granite bowlders, some of which weigh several tons and have to be blasted. After this a hydraulic plant must be built.

On the lower claims very little work has been done owing to the depth of the bed rock. The first property worked was the Cranston claim, about 1 mile above the mouth of the creek. Here a bench deposit, which is said to carry good values, is being hydraulicked into a sump cut into the bed rock 40 feet below the surface, from which a bucket elevator, operated by water power, lifts the gravel to the sluice boxes above. At the Discovery claim the gravel deposit is about 12 feet deep and is reported to carry high values. The creek has been turned through a large flume and at present an elevator is used to lift the creek gravels, but eventually they will be worked through ground sluices.

On McKinley Creek, an eastern branch of the Porcupine, which flows in a canyon-like valley, the beds of stream gravel are very narrow. On the Chisholm claim, not far from the mouth of the creek, the placers are being worked by the ground-sluicing method. A long flume has been built along the side of the creek, and is so regulated that the water can be turned back into the creek channel from time to time and the smaller gravels washed downstream, thus removing the upper wash and concentrating the gold in a shallow deposit on bed rock from which it is easily recovered.

The operators of the Woodin claim, one-half mile above the Chisholm claim, are hydraulicking a bench deposit of a channel 150 feet above the creek. One troublesome factor here is the occurrence of a capping of gravel cement 3 feet thick. This can not be disintegrated by the hydraulic nozzle, which throws a 200-foot stream of water, and it is difficult to break it even with hammer and pick. The occurrence of a bed of glacial mud also entails the loss of much fine gold in the sluice boxes.

Placer gold is found in workable deposits from the mouth of Porcupine Creek to McKinley Creek, its eastern tributary, a distance of 3 miles, and from this point for a mile or more up McKinley Creek. The total production of the Porcupine basin since its discovery is estimated to be $450,000.

Beyond the divide at the head of McKinley Creek lies Salmon River, fed by numerous glaciers. In character its valley corresponds to the Klehini, with its vast gravel bed over one-half mile in width. The gold discoveries here are of more recent date than those of the Porcupine, and actual development work was first attempted during the summer of 1902. Fine colors may be panned from almost any place along Salmon River, but the coarse gold is all found in a few of the tributary streams on the north bank. Nugget Creek, 20 miles from the mouth of Salmon River, is the center of placer digging, and, on the creek, Discovery, two claims above the mouth, is the only holding which has received much attention. The gravels on this stream are worked by the same method that is used on the Porcupine, though the creek is much smaller and less difficult to control. On the north side of Salmon River between Nugget and Cottonwood creeks, a distance of nearly 2 miles, there is a wide bench deposit 50 feet above the present river, on which eight claims have been staked. From several pits an average of 25 cents per cubic yard is reported. Plans are being made to mine this extensive gravel bank and also to install large dredges to work the bed of Salmon River. It is believed that these deposits will yield favorable returns.

On Bear Creek, a west fork of the Chilkat, is a third placer camp, 40 miles north of Chilkat Inlet. Since its discovery in 1900 the camp has been almost abandoned, largely through difficulties arising from American ownership of claims along the creek, which is situated on the Canadian side of the provisional boundary. As it is now in Alaskan territory, claims have again been staked and operations will begin in the spring.

Further prospecting and investigation of the surrounding region may reveal other valuable placers, and possibly quartz ledges as well. If it can be assumed that the Porcupine mineral zone is a continuation of that extending along the coast from Windham Bay to Berners Bay the belt should cross Lynn Canal diagonally from Seward City to the vicinity of Davidson Glacier, so that the west shore of Lynn Canal, opposite Sullivan Island and northward, would appear to offer favorable ground for prospecting.

GOLD PLACERS OF THE FAIRBANKS DISTRICT, ALASKA.[a]

By L. M. Prindle.

INTRODUCTION.

In the report of the Peters and Brooks expedition of 1898,[b] the conditions in the Tanana country were described and prospectors were advised to investigate the streams tributary to the Tanana from the north and heading opposite the gold-producing creeks of the Fortymile and Birch Creek regions.

In July, 1902, gold was discovered on a tributary of one of these streams by Felix Pedro, and the creek was named after him. The neighboring creeks were staked during the fall and following winter, and some development work was done. Stampeders came in over the ice from Dawson and other points on Yukon River, but the momentum with which they came carried them beyond and out of the country with only an unfavorable impression of it. Some were caught by the springtime on the Goodpaster, were obliged to wait till the breaking up of the ice, and finally reached the region by water. During the summer of 1903 prospectors were coming and going, and about 200 men were working on the various creeks, most of them handicapped by the high prices of all supplies and the lack of money for the development of their claims. Notwithstanding the unfavorable conditions, this district produced from $30,000 to $35,000 during the summer of 1903.

GEOGRAPHIC POSITION.

On its way to the Yukon the Tanana receives several tributaries from the north. The most important of these from east to west are Volkmar, Goodpaster, Chena, and Tolovana rivers, and Baker Creek. They all head far back in the Yukon-Tanana divide, and flow in westerly and southwesterly courses. The area to be considered lies between Chena and Tolovana rivers and is drained by their tributaries. It is 140 miles southwest from Circle, 200 miles in a straight line west from Eagle, and perhaps 200 miles above the mouth of Tanana River. This region forms a portion of what is known as

[a] Abstract of a more complete report in preparation.

[b] Brooks, Alfred H., A reconnaissance in the Tanana and White river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 488.

the Fairbanks district, and present interest is directed mainly to the valleys of a few small streams, which head close to one another just

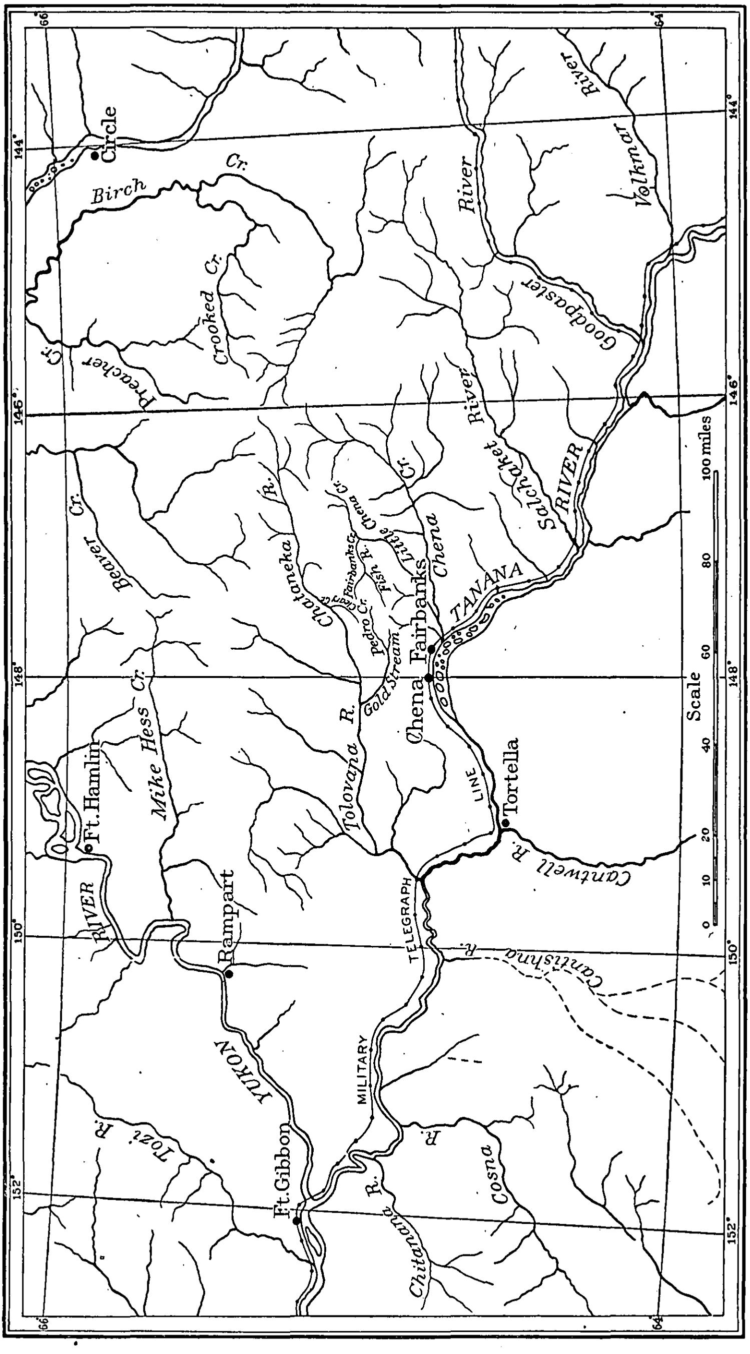

FIG. 1.—Sketch map of the Fairbanks district, Alaska.

within the hill country, about 12 miles north of Tanana River. Their geographic position is indicated on the accompanying map (fig. 1).

ROUTES OF APPROACH AND SOURCES OF SUPPLY.

The district can be reached by trail from Eagle and Circle, or by Yukon and Tanana rivers to Chena or Fairbanks, and thence by trail to the diggings. The distance from Circle to the Tanana is about 150 miles, and this is the shorter and better trail from the Yukon, and is generally preferred to that from Eagle by way of the Goodpaster. It can be traversed by pack train in the summer and by dog team during the winter months.

Fairbanks, situated on a slough of the Tanana, and Chena, about 9 miles below Fairbanks, are the nearest sources of supply, both places possessing stores. Fairbanks is accessible only by the smaller steamers like the *Koyukuk*, a boat 120 feet long by 24 feet in width, with an average draft of 22 inches. Chena is on the main river and can be reached by the larger steamers. The total population of both places, together with that of the creeks during the present winter (1903–4), is probably about 800. Both are connected by trail with the diggings. The distance from Fairbanks to the nearest creek where mining is in progress is about 10 miles, and the trail is said to be somewhat shorter and drier than that from Chena. Freight may be shipped by way of Yukon and Tanana rivers to either place. Passenger rates from Seattle to Chena or Fairbanks by way of St. Michael, Yukon and Tanana rivers, during the past season, were $150 first class and $100 second class; freight rates, $80 a ton. The rates from the Tanana to the creeks vary from a few cents a pound in the winter to about 25 cents a pound during the summer season. A telegraph office has been established by the Government about half a mile above Chena, and telegraphic communication thus is made possible with other portions of Alaska and the outside world. It is probable that in the near future an office will be established at Fairbanks.

There is very little timber large enough for mining purposes on the creeks, but a sufficient quantity is to be found a few miles away in the lower valleys of the larger streams and in the valley of the Tanana itself. Three sawmills are located at Fairbanks and have a total daily capacity of about 50,000 feet.

Feed is good in portions of the main valley and on the timbered slopes. Grass was found growing luxuriantly along the trail from Fairbanks to the creeks, and as late as the 11th of September had been untouched by frosts. On the creeks where work is being done there is but little horse feed.

GENERAL DESCRIPTION.

The Fairbanks district lies within the area of the Yukon Plateau, which extends from the northern base of the St. Elias and Alaskan ranges to the base of the Rocky Mountains, far north of Yukon River, and its characteristics are those of the great province of which it is a part.

The country is composed of ridges and valleys. The broad-backed ridges have an altitude of about 2,500 feet above sea level, and to an observer at this height all seem to attain about the same general level with the exception of isolated dome-like elevations of somewhat greater height. They slope gradually toward the Tanana and break off more or less abruptly to the extensive lowland of the latter stream. This southern edge of the Yukon-Tanana block of the plateau is much dissected by numerous minor streams, whose valleys are sunk to a depth of 1,200 to 1,600 feet below the comparatively even sky line of the ridges. The narrow V-shaped gulches of their headwaters widen to open valleys, often bounded on the one side by precipitous slopes and on the other by long, gently sloping spurs from the main ridge to the stream valleys.

The moss-covered surface of the highest divides gives place to that of the dwarf birch and alder on the lower ridges, and the growth of small spruce on the slopes and stream bottoms is abruptly terminated by the willow-covered strip which follows the waterway. Along the upper slopes and spurs are scattering poplar and birch, which lower down cover the hillsides bounding the Tanana Valley.

GENERAL GEOLOGY.

As this region in its surface features closely resembles that on the Yukon side of the divide, so the rocks are similar in character and form a part of the series already proved to be of economic importance there.

The bed rock of the gold-placer diggings of the Birch Creek mining district is composed of an essentially schistose series of metamorphosed sedimentary rocks, varying from a comparatively massive quartzite to a quartzite-schist and mica-schist. These have been cut by intrusive rocks, most of which are of a granitic character. This same series of more or less completely schistose quartzites and mica-schists was found to extend southward from the Birch Creek region to the diggings of the Fairbanks mining district. Associated with these schists in the Fairbanks region are hornblende-schists, gneiss, and granitic rocks of probably intrusive character. The distribution of the igneous rocks has not yet been determined.

The area from the Yukon to the Tanana is closely folded and the rocks often exhibit beautiful illustrations of overthrust folds in a nearly horizontal position. The apparent dips are generally low and give the rocks the appearance of gently folded strata.

The strike is variable, but the general structure seems to run northeast-southwest. Quartz stringers occur in the schists, but the proportion of quartz in the gravels, as in the Birch Creek district, is small.

CREEKS AND DEVELOPMENT.

The creeks of present economic importance are Pedro, called Gold Stream below the point where Gilmore enters it, and Twin Creek, a tributary of Pedro; Cleary Creek, with its tributaries, Chatham and Wolf; and Fairbanks Creek. They are but a few miles apart, separated by broad divides, 1,000 feet or more above them, and flow in divergent courses—Pedro toward the southwest and west, Cleary toward the northwest, Fairbanks toward the east. Pedro and Cleary belong to the drainage system of the Chatanika, which lower down is called the Tolovana, and Fairbanks Creek flows into Fish Creek, a tributary of the Little Chena. Cleary and Fairbanks creeks are easily reached by comparatively good trails from Pedro Creek. The distance is about 6 miles from the mouth of Twin on Pedro to Discovery Claim on Cleary Creek, and it is about the same to the head of Fairbanks Creek.

Claims include 20 acres, are a quarter of a mile long, and, with a few exceptions, are staked lengthwise of the creeks.

Pedro Creek and its tributaries.—Pedro Creek flows in an open valley. It is limited on the east by a rather abrupt slope, and on the west by broad, rounded spurs, sloping gradually from the divide to the stream bottom, and occasionally showing a bench-like character in the vicinity of the stream. Toward the headwaters and along the tributaries the sides approach until the valley becomes sharply V-shaped. The stream flat or valley floor varies in width up to a maximum of about 1,000 feet, and the grade in the portion where work is in progress is about 100 feet to the mile. The stream itself carries perhaps 3 to 4 sluice heads of water, or about 200 miner's inches, in its meandering course over the willow-covered flat. The sides of the valley are clothed with a light growth of spruce, sufficient only for wood and cabin material. The tributaries are small and flow in narrow valleys. On the west are Deadwood, Twin, and Steamboat creeks; on the east, Nugget Gulch, California Gulch, and Gilmore Creek. The continuation of Pedro below Gilmore has, unfortunately, received another name and is known as Gold Stream.

The area of present interest includes the lower portion of Twin Creek, the 3 miles of Pedro from Twin to Gilmore, and 2 to 3 miles on Gold Stream.

Twin Creek heads in the triangular divide between the Fairbanks, Cleary, and Pedro drainage areas. It is about 3 miles in length and flows in a narrow V-shaped valley over the bed rock, composed, so far as known, of quartzite-schist and porphyritic granite. The creek was staked in September, 1902. Work has been done at the mouth and at a point about one-half mile above the mouth.

There is about 12 feet of material on the bed rock, half of it muck and coarse rock fragments, and the other six feet a mixture of more or less angular flattened fragments of quartzite-schist, mica-schist, granite, and occasional large pieces of vein quartz up to 200 pounds in weight. The pay dirt varies from 2 feet to over 4 feet in thickness. It is somewhat finer grained than the material above it and contains a sediment composed of sand and a large proportion of yellow clay, which makes panning rather difficult. The dirt is said to average about 4 cents to the pan, and to run from $5 to an ounce a day to the shovel. The gold is generally flat, and occasional pieces are found up to a half inch or more in diameter, worth from 50 cents to $2.50. Sufficient work has not yet been done to give definite information in regard to the average value and distribution of the pay dirt.

Pedro Creek for 2 or 3 miles below Twin keeps for the most part close to the rather steep slope bounding the unsymmetrical valley on the east. The stream bottom widens on the west and merges into the spruce-covered hillside, which rises gradually to the divide between Pedro and Cleary creeks.

The bed rock, so far as seen in this part of the creek, was found to be a quartzite-schist. This is mantled over with 10 to 25 feet of muck and gravel. The muck averages, perhaps, 4 feet in thickness and is underlain by gravel to bed rock. The gravel is composed mostly of flattened fragments of schist, with occasional pieces of gneiss, granite, and vein quartz. The gravel containing the gold varies from 2 to 7 feet in thickness, and gold is also found in the bed rock to a depth of about 2½ feet. The pay dirt is characterized by a yellow color, due to a considerable quantity of the fine yellowish sticky clay, and ranges from 5 to 20 cents to the pan, with occasional pans of much higher value. The gold is of a bright color and occurs generally in small, flattened pieces. Very fine gold is sometimes present, and coarse, lumpy pieces up to a value of $14 have been found. Garnet and rutile are frequently associated with the gold.

Prospect holes have been sunk during the winter, but most of the developments were made in the summer. The claims are worked by open cuts, and the low grade of the creek has necessitated the construction of bed-rock drains up to about 800 feet in length. Ground sluicing is commenced by May 20 and shoveling in by June 22. Work can be continued till about the middle of September. Ground is prepared by draining and stripping off the 4 feet or more of muck, after which the gravel becomes thawed and is ready for shoveling in.

During the past season wages were in some cases as high as $1 an hour for a man and $25 a day for a team. The expense of working probably absorbed from 50 to 60 per cent of the production.

Gold Stream, the continuation of Pedro below Gilmore Creek, was not visited. From the information available, however, it would seem that the conditions there are similar to those on Pedro Creek except that there is more ground to be worked by drifting methods. So far as could be learned, less development work had been done than on Pedro Creek.

Cleary Creek and its tributaries.—Cleary Creek flows in a northeasterly and finally northerly direction to the Chatanika. Its general characters are similar to those of Pedro Creek. It flows in an unsymmetrical valley bounded on the east by a rather steep, wooded slope. On the other side a bench a quarter of a mile or more in width rises gradually from an elevation of 15 to 20 feet above the creek flat to the foot of the wooded slope on the left.

The tributaries of importance are Chatham and Wolf creeks. Chatham is about a mile in length, heads in the divide opposite Twin Creek, and flows in a northerly direction in a narrow valley, which has a stream flat about 300 feet in width at its mouth.

The headwaters of Wolf Creek have formed an amphitheatral depression in the divide between it and Fairbanks Creek. The main creek is about 1½ miles in length, and flows in a rather open valley, which expands to a flat a quarter of a mile in width, merging with that of Cleary about a mile below the mouth of Chatham.

Below the mouth of Wolf Creek the valley of Cleary widens, rather steep, wooded ridges approach it closely on the west, the stream flat on the east becomes more thickly wooded, and rises gradually until at a distance of about a mile from the stream it merges into the base of the wooded ridges. Cleary Creek, 6 miles below Wolf, flows into the Chatanika.

The bed rock is mostly mica-schist and quartzite-schist; hornblende-schists occur, and a granitic rock of apparently intrusive character is found near the head of Chatham.

Work is in progress on Chatham, Wolf, and the portion of Cleary from Chatham to a point a half mile or more below the mouth of Wolf. Claims are being prospected along Chatham, and, at the mouth, mining is carried on by the open-cut method. Sufficient work has not been done to determine the average thickness of the gravels or the average value and extent of the pay dirt. The material on bed rock varies from 4 to 20 feet in thickness, and the covering of muck constitutes in some cases a considerable proportion of this. The gravel is composed mostly of schist, and has been found to yield values ranging from 1½ cents to, in exceptional cases, 40 cents to the pan. The gold is generally fine, but nuggets have been found up to a value of $5. The gold near the head of the stream is rough.

On Wolf Creek the covering on bed rock is from 4 to 10 or more feet thick. The gravels are composed of quartzite-schist and this is the rock which outcrops on the rim of the amphitheater at the head of the creek. The open-cut method is used and very little ground is found to be frozen. The gold is generally in the lower portion of the gravel and down to 2 feet in the bed rock. It is mostly of a bright color, and that found at the head of the creek is very rough and angular, and feels gritty in the handling. It has the appearance of having traveled but a short distance.

On the main creek considerable work has been done. The depth to the bed rock of mica-schist and quartzite-schist varies from 18 to 40 feet, including from 4 to 30 feet of muck, "chicken feed" gravel, and pay dirt. The pay dirt here, as in the other localities, contains the yellowish clay which often has to be scraped from the rock fragments in order to save the pay. Nuggets have been found up to a value of $19. Some of these have considerable quartz attached and some are black in color. Most of the development thus far has been on the west side of Cleary, opposite the mouth of Wolf Creek. The method employed here is drifting, and a plant has been installed consisting of a 6-horsepower boiler and accessories, capable of thawing by 5 steam points about 300 eight-pan buckets in ten hours, and at least one sluice head of water, or about 50 miner's inches is required for sluicing. During the past summer, for a few days, the stream was running less than that. In the early part of September from 3 to 4 sluice heads were available.

The bench to the left of Cleary is being prospected, but the depth to bed rock of over 30 feet renders this a slow process.

Fairbanks Creek.—The valley of Fairbanks Creek lies just over the divide to the east of Wolf Creek. Its upper portion lies between the drainage areas of Pedro and Cleary creeks. It flows in an easterly and southeasterly direction, a distance of about 9 miles to Fish Creek, a tributary of the Little Chena. In its upper portion it is narrow and V-shaped; lower down its unsymmetrical valley is bounded on the south by a steep slope with short, abrupt spurs, and on the north by broad spurs a mile and a half in length, sloping gradually from the ridge 1,400 feet above the valley to the creek bottom. The creek is small, carrying only a few sluice heads of water, and flows through a willow-covered flat 100 to 300 feet in width, with a grade of about 100 feet to the mile. For the last two or three miles it meanders across a broad flat to Fish Creek. The spurs to the north are thickly covered with a growth of small spruce and some poplar. A very small proportion of the spruce is large enough to saw into 8-inch boards.

Moose, Crane, Alder, Walnut, and Deep creeks are the main tributaries from the north. They are about 1½ to 2 miles in length and are separated by the broad spurs from the main divide. Those from the south are short and flow in narrow canyons.

Fairbanks Creek is still in the prospecting stage of development. Some work has been done and pay has been found over several miles of its course. The bed rock, so far as known, is mica-schist, quartzite-schist, and gneiss. These are covered with a thickness of 14 to over 40 feet of muck and gravel. Muck may constitute a half of this, and is underlain generally by a light wash, and this by a sediment-bearing gravel in which the gold is found. The gravel is composed mostly of quartzite-schist, some mica-schist, gneiss, and occasional large pieces of vein quartz up to a foot or more in diameter.

The pay dirt is said to run from 2 to 7 feet in thickness and to contain values averaging from 2 to 15 cents to the pan. The gold is generally bright and occurs in granular or flattened pieces, some of which have been found worth $1.50.

As the ground is deep and frozen, prospecting is a time-consuming task. Holes are sunk by the use of wood fires, hot rocks, and hot water. Sometimes a combination is used, and where there is danger of thawing the walls too rapidly, hot water is preferred. It is difficult to thaw much more than 2 feet a day by any of these methods, and their use means an expenditure of energy far in excess of the results attained, yet many miners are forced by lack of capital to work by these methods, and much patient work under adverse conditions is being accomplished. One boiler with steam points was in operation; another had just reached the creek, and a third was met on the way, both of which were expected to be in operation within forty-eight hours.

With the advent of the boiler, work can be done more easily and quickly, and a brief description of the method may not be out of place. Boilers at present in use on the creeks vary from 2 to 6 horsepower, and are capable of supplying steam to 4 or 5 points. Steam is generated by the boiler, passes through an ordinary steam pipe, and is delivered to the points. These points are pipes from 4 to 5 feet in length, attachable at one end to the steam pipe and at the other end provided with a small opening through which the steam rushes with greatly increased penetrative force. They correspond to the nozzle attached to fire hose, and the whole system is similar, with the exception that the thawing machine is adapted to the transmission of steam rather than of water. The blunt ends of the points are placed in position against the frozen surface and the steam turned on. Shafts may rapidly be sunk to bed rock by this method and the ground then drifted out laterally. Care must be exercised to prevent the too extensive thawing of the ground with the consequent "sloughing" or falling in of material from the walls.

SUMMARY.

The creeks above described are the only ones in the Fairbanks district which up to the present time have given favorable results. The conditions of occurrence on all of them are essentially the same. No foreign wash was observed, and it would seem that the gold has been derived from the rocks in which the creeks have cut their channels.

These rocks are mostly schists, often containing small quartz stringers, and the fact that igneous rocks are associated with them suggests the possible relationship of these to the mineralization.

The pay is generally found at a considerable depth, and, with a few exceptions, in frozen ground. The creeks are small, carrying hardly sufficient water for extensive operations, and their grade is low. Timber for mining purposes has to be freighted generally for several miles from the lower valleys. Trails along the ridges are good, and where they traverse the wooded areas have been well cut out, but the sight of heavy loads hauled by horses on sleds over the swampy ground along the creeks is an eloquent illustration of the need of good roads.

Although no large values have yet been discovered, the gold seems to have a considerable distribution on the creeks where it has been found and is known to occur at some localities in sufficient quantity to pay for working under existing unfavorable conditions. The Fairbanks district deserves consideration, and with better means of communication and supplies at more reasonable prices the development will be greatly hastened.

THE KOTZEBUE PLACER-GOLD FIELD OF SEWARD PENINSULA, ALASKA.[a]

By Fred H. Moffit.

GENERAL DESCRIPTION.

The Kotzebue placer-gold field is in that part of the northeastern portion of the Seward Peninsula which lies to the south of the eastern extension of Kotzebue Sound, and is nearly 150 miles northeast of Nome. In a rough way, the more important camps may be included in a rectangular area, about 40 miles from east to west and 20 miles from north to south. Deering and Kiwalik are the chief distributing points for provisions and supplies, but during the past season steamers have landed parts of their cargoes intended for the more western camps at the mouth of Rex Creek, west of Deering. The region offers few attractions to the prospector. Low, tundra-covered hills, natural breeding places for mosquitoes and black flies, surround him on every side. Traveling, difficult on the higher ground, is almost impossible over the lowlands bordering the sound and on most of the streams. The only fuel for cooking or heating is that afforded by the low willows scattered along the bottoms of the valleys.

The coast line forming the northern boundary of the field is but 30 miles south of the Arctic Circle, and in consequence of its position the region is subject in summer to much damp weather and in winter to severe cold, with strong winds, more trying to the traveler than the lower temperatures but quieter atmosphere of the interior. The area containing the gold-producing streams is limited in an east-west direction by the one hundred and sixty-first and one hundred and sixty-third meridians, west longitude, and in a southerly direction all of the camps where gold is mined are within 20 miles of the coast, except those on Bear Creek, which are nearly twice that distance.

This area forms the eastern part of the Fairhaven mining district, including the drainage into Kotzebue Sound, beginning with Good Hope River on the west and ending with Buckland River on the east.

[a] This paper is an abstract of a more complete discussion which is shortly to appear in a paper entitled "A Reconnaissance of the Northeastern Portion of Seward Peninsula, Alaska."

Three principal streams flow through the district—the Inmachuk, Kugruk, and Kiwalik rivers. All these have a general northerly course and drain an area of between 1,500 and 2,000 square miles. Of the three the Kugruk is the largest and economically the least important, since very little gold has been taken from it. Kiwalik River, the second in size, is of special interest because its tributary, Candle Creek, has produced more than three times as much as the combined output of the other creeks. The Inmachuk and two of its tributaries, Old Glory and Hannum creeks, have afforded much the larger part of the remainder. Besides these Bear Creek, which empties into Buckland River, and the Alder Creek beach diggings should be mentioned, as well as Chicago Creek, a tributary of the Kugruk, on which a coal or lignite bed was worked during the past winter.

The topography of the country south of Kotzebue Sound is generally of low relief and monotonous appearance. Here and there, as in the vicinity of the Asses Ears, a prominent elevation south of Good Hope Bay, so named by Kotzebue in 1816 because "its summit is in the form of two asses ears," and on the divide between Kiwalik and Buckland rivers, more elevated masses of limestone or eruptive rocks reach a height of from 1,500 to 2,500 feet above sea level.

The field may be reached from Nome either by overland trail or by boat through Bering Strait and Kotzebue Sound, the distance in the first case being over 150 miles directly across the peninsula, and in the second case about 300 miles. Of the two the water route is now generally preferred, but can be used only for about three months in the year, since navigation is closed by the ice during the remaining nine months.

GEOLOGIC SKETCH.

The rocks of the Kotzebue gold field are almost entirely micaceous and graphitic schists of uncertain age and thickness, interstratified with occasional beds of limestone and overlain by an extensive flow of recent cellular lavas.

The highly metamorphosed rocks must have suffered an immense amount of erosion and were reduced to an almost level plain with here and there low hills of limestone and sometimes of granite rising above it. Over much of this plain was then poured out a thin sheet of lava, which overflowed several thousand square miles of territory, filling up the depressions and surrounding the higher points. On account of the lava and overlying tundra, outcrops of the schist are not plentiful and are generally found where the streams have cut their way through the eruptive sheet, forming canyon-like valleys bordered by rims of broken lava blocks.

Both schists and limestones are much folded, showing that they have been subjected to great pressure, and the schists have been further modified by the formation of a complicated series of quartz veins and lenses, fragments of which form a considerable portion of the gravels.

In the southwestern part of the field, in the neighborhood of the Asses Ears, is an elevated area of white crystalline limestone resting on or, as is much more probable, intruded by masses of very coarsely crystalline granites, one of which forms the "Ears." At the eastern border of the field the schists are interrupted by a great mass of eruptives, with a central core of granites and diorites flanked by andesites and lavas. The andesites are more widely developed than the granites and surround them on all sides, so that in approaching the higher elevations of the divide one meets first the cellular lavas, then andesites, and finally the granites, extremely coarse and in places with little or no quartz.

A characteristic feature of these mountains is the terraced appearance which they present when viewed from a distance, produced by the benches of broken blocks of the country rock.

GOLD OCCURRENCES.

For convenience in description the principal streams where gold has been produced may be divided into two main districts—the Inmachuk River drainage area and the Candle Creek area, belonging in the Kiwalik River drainage system. Of these two districts, viewed from the standpoint of production in the past, Candle Creek is by far the more important.

Inmachuk River.—The Inmachuk River is between 25 and 30 miles in length. It rises in the limestone area of the western part of the field, flows toward the northeast to the flats bordering Kotzebue Sound, and then meanders slowly in the same general direction to the sound. At Record City the eastern fork, known as Pinnell River, joins the main stream from the south.

The most productive portion of the Inmachuk begins near the mouth of Pinnell River and extends down the stream for a number of miles. The valley is much broader than those of the tributaries, and in this portion is occupied by a series of broad flats, having in places a width of more than a quarter of a mile.

The gravels occasionally reach a thickness of 6 to 8 feet. They are invariably frozen, except in the channel of the river, and are often covered by an ice bed. The bench and creek claims on the Inmachuk have been more extensively prospected than on the other streams, with the result that in a number of places a well-defined pay streak is known. At two localities lines of holes, extending across the valley, have been thawed down to bed rock, and at a number of places lines of holes have been sunk part way across. This work is carried on with the aid of thawers, the boilers ordinarily furnishing steam to 4-foot points set twice each day. The consumption of fuel in work of this kind is large, and greatly increases the cost of mining.

Hannum Creek, which flows into the Inmachuk above the mouth of the Pinnell, has produced a small amount of gold during the last two years. This stream flows through a narrow canyon-like valley surrounded by a rim of lava and sheeted over with gravels, consisting mainly of schist with smaller amounts of quartz, limestone, and lava, which appear in places as broad tundra-covered flats one-fourth to one-half mile long.

The gold is irregularly distributed along the bed rock of the channel, or "spotted," as the prospectors say; with it is associated some pyrite and a very small amount of galena.

Old Glory, on which the original discovery of gold in this region was made, is a short creek about 6 miles in length, rising in the limestone area north of the Asses Ears and joining Pinnell River 1¼ miles above its junction with the Inmachuk. The valley of Old Glory is cut in a series of schists with occasional interbedded limestones; it is broader than that of Hannum Creek, and is covered with a sheet of wash gravel, largely quartz, which extends well up on the slopes. Near the bottom of the valley the gravels have been much disturbed by the sliding of rock, gravel, and tundra from the sides. These gravels differ further from those above in the much larger amount of schist which they contain and the decrease in rounded quartz pebbles. No pay streak is known, the creek being "spotted," as is Hannum Creek.

Candle Creek.—In the eastern district Candle Creek, which has produced more than three times as much as the combined output of all the other camps, joins Kiwalik River about 9 miles above the town of Kiwalik on the sand spit at the entrance to Spafarief Bay. The creek is nearly 16 miles long. It flows in a northeasterly direction through a broad V-shaped valley with gentle slopes and rounded tundra-covered hills, which are always wet and make difficult traveling for men and horses.

Sixty-six claims, containing 20 acres each, are said to have been staked on the creek, besides a considerable number of bench claims on either side of these. The gravels of Candle Creek are almost entirely schist with a small amount of quartz. On some of the bench claims the gravels have a thickness of 8 feet, exclusive of "slide" and tundra. Near the stream they are generally overlain by a bed of ice. Owing to the low grade of the channel the use of bed-rock drains has not been possible on this creek, and the China pump is universally employed for keeping the pits clear of water. The cost of mining is considerably increased for this reason, since one extra man and sometimes two are required to work the pumps.

During the last two years the channel has been nearly worked out, and attention is now turned toward the bench claims, on which the future of the camp largely depends. These bench claims are known to carry gold, and in one or two instances have yielded large returns, but the successful treatment of the deposits depends on securing a supply of water of sufficient head and volume to remove the overlying tundra and ice economically and to work the gravels on a considerable scale.

Bear Creek.—Bear Creek, which empties into Buckland River between 40 and 50 miles to the southeast of Candle City, is about 17 miles long, and rises in the eruptive area east of Kiwalik River. During the past season some 40 men have been at work on the creek. The output is derived chiefly from two small tributaries, Sherdon and Cub creeks, and that portion of Bear Creek which lies between them. On account of the difficulty of obtaining supplies, all of which must be brought overland from Candle City, none but the richest of the claims have paid for working under present conditions, and many of the prospectors report that they have not made wages.

Alder Beach.—These diggings are located near the mouth of Alder Creek, which flows into Kotzebue Sound about midway between Kiwalik and Deering. The gold-bearing gravels, being shallow and of no great extent, have furnished work for only a few men. The gold occurs on bed rock; it is fine and little worn, and is clearly derived from the neighboring schist.

The output from Alder Beach diggings for the past two years is reported to be between $12,000 and $14,000.

CHARACTER AND ORIGIN OF THE GOLD.

The gold production of the Kotzebue field from the year of its discovery, 1901, to the present is estimated to be not far from $415,000. Of this amount some $325,000 came from Candle Creek, about $12,000 from the Alder Creek diggings, $10,000 from Bear Creek, and the remainder from Old Glory, Hannum Creek, and Inmachuk River. The production of Hannum is very small.

Gold from the Inmachuk district is dark and heavy, assaying about $18 to the ounce; almost no black sand is present, but considerable gray sand or pyrite is seen in the pan and the boxes always contain a large quantity of rounded hematite pebbles which the miners call "ironstones." The gold frequently contains a little quartz and is sometimes seen in the form of fine veinlets in the ironstones. Small pieces of rutile are occasionally found with the heavy concentrates and have been mistaken for cassiterite. Dr. Cabell Whitehead, of the Alaska Banking and Safe Deposit Company, has informed the writer that about 27 ounces of tin were recovered in cleaning gold brought to Nome from Old Glory Creek, so that the tin ore, cassiterite, must be present on that stream. On the upper part of Hannum Creek, a small quantity of galena is associated with the gold and ironstones. Much of the gold from the Inmachuk and its tributaries is coarse and rough. Pieces of the value of $2 or $3 are not uncommon, but no large nuggets have been found.

Candle Creek gold resembles very much that from the Inmachuk, but is usually somewhat darker and is said not to assay as well. The minerals associated with the gold are the same as those found on the Inmachuk. Many of the ironstones are nearly always present and a decrease in their amount is regarded by the prospectors as an unfavorable sign. So dark is the gold that it is not an uncommon sight to see a miner, when panning, bite a nugget in order to make sure of its being gold and not one of the ironstones. One nugget worth $62.10 and a second, $36, have been taken from the creek.

Bear Creek gold, assaying over $19, is flattened and much brighter in color than that from any other part of the field. With the gold is found considerable black sand, which is entirely removed by the magnet, and is undoubtedly derived largely from magnetite in the granites and andesites forming the eruptive mass in which the stream rises. The presence of black sand constitutes a second difference between this gold and that from Candle Creek or the Inmachuk district. Gold from Sherdon Creek is much coarser than the fine, flaky gold on Bear and Cub creeks, but the Cub Creek gold occurs throughout the whole thickness of the gravel, differing in this respect from Sherdon and Bear creeks, where it is found on bed rock. Cub Creek gravels also show a large amount of a heavy, red, cherty rock, which sticks in the pan or riffles and causes inconvenience in sluicing.

The gold from the Alder Beach diggings is flaky and bright. It occurs on the shallow bed rock and includes some wire gold, showing that it can have traveled but a very short distance before reaching its present resting place.

There can be little doubt that the gold of the Alder Beach, Candle Creek, and the Inmachuk region has had very much the same history as is ascribed to the other deposits of Seward Peninsula—that is, that the gold is of local origin and is concentrated from an original supply widely disseminated in small quartz veins and stringers and impregnated zones of the bed rock. This is shown both by the character and occurrence of the gold itself.

The valuable gravels are all derived from the weathering of rocks which have been subjected to intense pressure, heat, and other influences of such a nature as to change entirely their original character and fill them with an intricate network of small quartz veins and lenses known in some cases to be gold bearing. The concentration due to the action of running water on the vast amount of material derived from the decompositon of these gold-bearing schists, amounting to a vertical thickness of hundreds and possibly thousands of feet, has without much doubt given rise to the rich gold deposits now found in the gravels. So constant is the association of the gold with the schists that the prospectors refuse to waste time in the search for gold in a place where the schist is not found.

It is further probable that in nearly every case the gold has traveled but a relatively short distance from its original source; its rough, unworn appearance, the absence of any large amount of fine, bright, flaky gold, the occurrence of wire gold in one instance, and the presence of considerable quartz in the nuggets, all tend to establish this conclusion.

COAL.

The discovery on Chicago Creek of what appears to be a good-sized bed of lignitic coal has been of considerable interest to prospectors in the neighboring country, where small willows constitute the chief supply of fuel. Chicago Creek, which is tributary to Kugruk River, is about 9 miles from the coast and lies between Candle City and the mining camps on Inmachuk River. The coal occurs at a point somewhat more than a mile from the mouth of the creek and was discovered by prospectors who found pieces of float in the stream gravels and traced them to their source, which they located for mining purposes. During the past winter a slope was driven into the coal for a distance of 150 feet or more, and it is said that a crosscut of 60 feet was made without finding the walls, thus seeming to indicate that the deposit lies in a horizontal position and has considerable thickness. The coal is solidly frozen so far as uncovered and contains a large percentage of ice, which causes it to check and crumble on being thawed. It burns quickly with a bright flame, leaving a small quantity of fine, white residue like wood ash. The miners regard two tons of this coal as equivalent in value to about one ton of Wellington coal, which ratio is also expressed by the prices of the two, since Wellington coal sells for about twice as much as the native product. For use in boilers the imported coal is preferred, although costing over $80 per ton at the camps, but for cooking purposes, as well as for heating, the Chicago Creek coal is satisfactory and may perhaps prove to be of some local importance.

QUARTZ VEINS IN MAINE AND VERMONT.

By George Otis Smith.

INTRODUCTION.

During the past field season two localities in northern New England were visited where there is some slight activity in the exploration of quartz veins containing precious metals. While separated by approximately 135 miles, these two districts, the one in western Maine and the other in southern Vermont, possess some points of similarity. Furthermore, the veins occurring here are believed to be typical of ore deposits throughout this general region, and since they are the most promising deposits being prospected within this area they may properly be discussed together. It is believed that the results of reconnaissance observation as here presented may be taken as fairly representative for this class of veins as they occur in northern New England. In the one case development work has not been carried to sufficient depth to warrant very definite conclusions, yet in the other locality the explorations have continued for scores of years with little change in the character of the veins as exposed.

MAINE.

The mining property in Maine upon which the most development work has been done the past year is situated in Milton Plantation, in Oxford County. The region is one of considerable topographic diversity and borders upon what might be termed the mountainous portion of western Maine. A group of high hills which here encroaches upon the valley of Androscoggin River includes Mount Zircon, the most prominent height of the vicinity, and Mount Glines, a somewhat lower knob, on the slopes of which the mining work has been done. The country rock appears usually to be granitic. This granite as observed in the vicinity of the quartz veins is characterized by shear structures and banding of the constituent minerals. The resultant gneissoid texture trends about 30° west of north. This granite appears altogether distinct in its textural characters from the granite quarried on the Maine coast. The latter rock is known to be of Paleozoic age and it seems probable that the gneissoid granite here discussed is older.

The granite from Mount Glines, when examined microscopically, is found to contain both biotite and muscovite, the dark mica being somewhat altered to chlorite. The feldspars are only slightly altered and the quartz is clear. Garnet, zircon, and rutile are accessory constituents.

The northernmost of the quartz veins prospected on Mount Glines is a well-defined fissure vein striking about N. 25° E. with a southern dip varying from 65° to 70°. This trend cuts the banding of the granite at an angle of over 50°, although locally the granite close to the fissure exhibits a schistosity parallel to the vein. In the case of both this and the other veins the evidence all points to the occurrence of two distinct periods of deformation of the rock, an earlier, in which shearing produced the gneissoid texture of the granite, and a later, to which must be attributed the fissuring of the granite together with the occasional production of some degree of schistosity in the rock adjacent to these fissures.

Exploration work has been done on the above-mentioned fissure vein, so that some of its characters may be observed. In the shaft (No. 1) the vein is composed of quartz, together with varying amounts of talcose material. This material when studied under the microscope is seen to be simply altered wall rock. The feldspar is almost completely altered, probably by hydration, into masses of kaolin and sericite. The quartz that remains in the original grains is clouded with lines of minute cavities. The muscovite is present in this altered phase of the granite, but its flakes have been bent by the movement which the rock has evidently experienced. Small veinlets of clear, secondary quartz cross this material in all directions.

The gangue of the vein is largely white quartz, clear in color and compact in texture. With this is associated the stringers of greenish material already described. This occurs mostly near the walls, and from its mixture with quartz gives the vein in places the appearance of pegmatite, this being a structural resemblance only, as the feldspar characteristic of pegmatite veins is lacking here. The sulphides, galena and pyrite, occur in scattered bunches in the vein, which varies from 4½ feet to less than 2½ feet.

While this vein is plainly a fissure vein, its walls are not at all points well defined, owing to the occurrence of other fracture planes which intersect the main fissure walls at slight angles and cause the irregularities in width of the vein mentioned above. The walls are not slickensided and in places the distinction between vein material and wall is obscure. There is therefore in this vein no evidence of movement later than that at the time of the formation of the fissure, when the masses of granite described above were separated from the walls and more or less crushed and then incorporated in the vein filling.

Seventy-five feet lower on the slope a tunnel has been driven in on this same vein. Here it is even more irregular in width. A seam of pyrite one-half inch in width was exposed in the working face of the tunnel when visited in July, 1903.

Several smaller veins have been located on the same slope of Mount Glines, but these are not worked. The No. 6 vein is being developed by a shaft. This vein is similar in composition to No. 1, and a thickness of over 6 feet is exposed. It strikes N. 20° E. and is nearly vertical, dipping to the north. The walls of this vein are not so sharply defined as those of the other vein, being in part due to approximately parallel shear planes developed in the granite walls. The ore minerals are galena and pyrite, occurring both in bunches and in a fairly distinct streak, 4 inches wide, near the northern side of the vein. This band of sulphides dips to the northwest, crossing the vein at an angle of about 45°, and this dip agrees with that of veins of quartz seen in other parts of the main vein.

Open fissures also occur in the vein, and all of these, like the small veins of quartz and the streak of sulphides, cross the general structure of the quartz gangue, which is nearly vertical, while the others are characterized by the northwest dip. These relations are considered as evidence of a fissuring subsequent to the formation of the large fissure and the crystallization within it of the gangue minerals. The conclusion suggested by this hypothesis is that the ore-bearing solutions were of later origin than the solutions from which the major portion of the quartz was deposited. This assignment of a later date to the ore minerals than to the most of the quartz gangue is important, since it follows from the application of this hypothesis that in this region thick veins of quartz are not of themselves necessarily indicative of the presence of ore unless they show evidence of the later fracturing that preceded the introduction of the ore minerals.

The ore exposed by the development work on Mount Glines is very irregularly distributed within the veins. This lack of natural concentration detracts from the value of the ore. Any estimate of its value should not disregard the proportions in which the metallic sulphides are mixed with the gangue minerals. Usually the nature of this admixture is such that the greater part of the quartz would need to be handled with the ore minerals. An assay of anything less than a complete sample taken across the entire width of the vein therefore would have little direct bearing upon the economic value of these veins.

Assays from the Mount Glines property have been reported as indicating values ranging from \$7.50 to \$49.68 per ton, it being stated that the ore increases in value with depth. These assays were doubtless made of picked material. At the time of the visit to this property, No. 1 shaft, which had been sunk to a depth of 35 feet, was half full of water. A sample was, however, collected in the upper part of the shaft, where the vein is 2½ feet in width. This sample was of selected quartz, the selection being such as could readily be made in ore sorting, and the assay of this sample, made by Dr. E. T. Allen in the Survey laboratory, is given below under A.

At vein No. 6, the sample was an average across the vein, where 6 feet of quartz is exposed in the shaft, including the narrow streak of galena and pyrite described above. The assay of this sample is given under B. The calculated value per ton of the material of which the two assays have been made would be, at average market prices of the contained metals, 63 and 55 cents, respectively.

Assays of ore from the Mount Glines mine, Oxford County, Me.[a]

	A.	B.	C.
Gold	None.	None.	Trace.
Silver .... ounce..	None.	None.	3.50
Copper .... per cent..	0.16	0.18	3.33
Lead .... do....	0.25	0.08	47.95

[a] Assays A and B, by E. T. Allen, U. S. Geol. Survey; assay C, by Milton L. Hersey, city and provincial analyst of Montreal.

Contrasted with assays A and B is the assay C, made for the Mount Glines Gold and Silver Mining Company. The value of the ore as calculated from the assay is given as $49.68.

This sample was taken, it is reported, from the No. 1 vein at a depth of about 35 feet. In comparing this assay with the assay of the sample from the same shaft, as given above under A, it will be noted that the value is almost wholly in the copper and lead. Again, the high percentage of lead shows that the sample sent to Mr. Hersey was almost 55 per cent pure galena. This indicates the method employed in collecting the sample, which, indeed, is comparable to a low grade of coarse mill concentrates rather than to ore as mined. This assay is to be regarded as that of a cabinet specimen of galena, rather than of an ore body. In determining the possible value of a quartz vein the only assays that can be used as a basis for calculation are assays of average samples across the vein, like B in the table given above, or of samples like A, of selected ore picked with no more discrimination than is possible in the ordinary sorting of ore by miners.

Development work has been continued on the Mount Glines property and the streak of sulphides is reported to have increased in width and in percentage of copper. At present nothing more definite can be stated concerning the value of such quartz veins than is given above. All the assays indicate that the ore is in no sense gold bearing, and even in the best assay the silver content is no greater than is to be expected in a galena ore. Whether these veins contain copper and lead in profitable amounts will depend upon future developments, but the economic value of the veins can be determined only by assays of samples which fairly represent the vein or such portions of the vein as must be mined and milled. The management of the property is wise in not having had mill construction precede the underground prospecting. The erection of a quartz mill is not necessarily indicative of the value of a mining property.

In the town of Pittston, Kennebec County, Me., prospecting for gold veins has been carried on for many years. A visit was made to the property locally termed the "Pittston gold mine," which is about 3 miles east of Kennebec River. The development work here is in pegmatitic veins, sheets, and masses in the mica-schist of the region. At some places in the schist traces of sulphide are seen, but in the pegmatite there is little evidence of any minerals other than the quartz, feldspar, and mica commonly found in pegmatite. Gold is said to have been found in the quartz, and a quartz mill was erected several years ago on the shore of Nehumkeag Pond, about 1 mile from this property, and some of the ore was treated. It does not appear probable that the work was profitable. For the purpose of having an assay made by the United States Geological Survey chemists, a sample was collected from the principal opening in the pegmatite. Acting upon the advice of the owners in the collection of this sample, the quartz was selected as far as possible. The sample was thus in reality a picked sample, yet the assay showed no traces of either gold or silver. These results, therefore, do not appear to justify further development of this pegmatite in the hope of its having value as a gold ore.

VERMONT.

In southern Vermont there has been some interest of late years in gold mining. One of the localities concerning which much has been published in the local press is in the extreme southern part of the State, next to the Massachusetts line. This excitement has so far subsided this past year that little comment is necessary. The search for gold in the town of Readsboro dates back about twenty years, when the finding of a small nugget of gold led to the location of a vein reported to be of economic value. A few years ago the interest was revived and prospecting encouraged by the results of assays which appear to have been, to say the least, of doubtful accuracy. Ores claimed to carry values of $30 to $40 were found to yield less than one-tenth that amount by assays conducted at a distance by reputable assayers. The influence of disturbing local conditions was illustrated by an assay of a bit of grindstone which is said to have yielded over $25 in gold to the ton. It was not thought necessary to visit this district.

Another district, farther north, which seemed more deserving of investigation, was visited. The towns of Plymouth and Bridgewater, like Readsboro, are on the eastern slope of the Green Mountain Range. The ridges and foothills of this region are deeply trenched by the narrow valleys of the swift mountain streams, and the rocks are well exposed everywhere. Schistose rocks predominate, which were mapped by the earlier Vermont surveys as talcose schist and slate. Steatite and serpentine, as well as some granular quartz, also occur.

In the town of Bridgewater gold was discovered over fifty years ago, and within ten years of this discovery at least two quartz mills were built to treat the ore from the quartz veins in the vicinity of Bridgewater Center.[a] The early work was characterized by extravagant expenditure and the lack of reliable statements. It can safely be stated, however, that more money was expended in mill building than was secured from the ore treated. This kind of work has continued spasmodically, and even to-day the outlay in development work in progress appears out of proportion to the ore in sight.

The veins in Bridgewater have a north-south trend, and apparently all belong to one general system which extends across the western part of the town. The southernmost productive locality is on Otta Queecha River, immediately west of Bridgewater Corners. On the Otta Queecha property a small bunch of very rich ore was uncovered nine years ago, which is reported to have yielded between eight and nine hundred dollars in gold. Since the discovery of this pocket the property has produced very little and is not worked at the present time. This locality was not examined.

Next north on this veined zone is the Taggart vein, on which work has been done at various times, beginning with 1859. Ten tons of the ore crushed and amalgamated are reported at one time to have yielded 374 pennyweights of 21½-carat gold. The Taggart vein is located on the old Thompson farm, 1 mile west of Bridgewater Center. It has been opened at several points, chiefly in the gulch of a small stream. These openings were visited at the upper exposure in the stream bed itself, where the quartz vein has a width varying from 8 to 18 inches. The strike of the vein is 5° to 10° east of north, and it dips to the east at an angle of about 70°, being apparently parallel with the schistosity of the country rock. The quartz of this vein is white and compact, and barren in general appearance except for the small stringers of galena which it contains. The quartz is well cemented to the wall rock and there is no evidence of fracturing of the vein. Below the stream level at this point the vein thickens to nearly 3 feet, and here the ore was taken out that was reported to yield $32 in gold to the ton. This opening extended to a depth of 6 feet, but is now filled in. From a small pile of quartz and galena remaining at the edge of this

[a] Information concerning this early work is given by A. D. Hager, Vermont Geological Survey, Final Report, vol. 2, 1861, p. 844.

opening a sample was taken which was assayed by Doctor Allen in the Survey laboratory, with the following result:

Assay of sample of quartz from Taggart vein, Bridgewater, Vt.

Gold	None.
Silver	1.27 ounces.
Copper	6.19 per cent.
Lead	6.26 per cent.

This indicates a value of over $6, but the sample represents the richer part of a small ore body. The absence of gold is suggestive in view of the high gold values claimed for this vein. Quartz has been mined from other parts of the Taggart vein, but it is said that whatever value it may have contained was lost in the process of milling. Four mills were constructed at various times in this vicinity for the purpose of separating the gold from the quartz.

There is also at this locality what may be a cross vein, with a trend of N. 50° W., in which galena is reported to have been found, but the ore was soon cut off by a fault in the wall, so that this vein can not be traced very far. The country rock is here full of stringers of quartz, so that locally it is more of a mica-gneiss than a schist.

Farther north in the same town is the Shatauguay group of claims. Little could be learned concerning this property, except that development activity at the time of the visit was being confined to mill construction and road making. A well-equipped quartz mill is being built, but the openings that will furnish the ore were not shown by the manager of the property. Two small prospects were examined in the vicinity, where small amounts of sulphides are found scattered in the country rock, which here is a soft, white, sand rock, locally termed "porphyry." It seems reasonable to consider the Shatauguay veins as forming the continuation to the north of the same zone as that containing the Taggart and Otta Queecha veins.

In Plymouth, the next town south of Bridgewater, mining interest extends back over forty-five years. At Plymouth Five Corners a mill pond was once drained and worked for placer gold. Sluice boxes and rockers were used, and the result is variously reported at from $9,000 to $13,000. Some recent prospecting for quartz veins has been done, and reports of success have been given out. At the locality itself, however, there is little faith in these reported discoveries.

Near Tysons Furnace, in the southern part of Plymouth, the Rooks Mining Company conducted operations about twenty years ago on an ambitious scale, but apparently with no profit from the mine. This property is located about 1½ miles north of the village, and was visited, although none of the old openings were in condition to allow examination. The country rock is schist, but in the accumulation of material lying on the tunnel dump and around the old buildings no ore was seen that showed anything more than moderate impregnation of quartz with sulphides.

In southern Vermont the only gold known to have been mined at anything like a profit is that found in the gravel deposits of Plymouth. Hager reports the largest nuggets found here to have had values of $14 and $9. To what extent even the Plymouth work was profitable is doubtful, in view of the inexperience of those who engaged in this gold washing between 1855 and 1861. The origin of this gold in the alluvial deposits can not be stated. The presence in this vicinity of steatite and serpentine probably representing altered basic igneous rocks is naturally at once noticed in this connection. The possibility of this derivation for the gold was suggested by Hager in 1861,[a] and the statement of a prospector quoted "that he did not think he ever washed a dollar's worth of gold 5 miles east or west of the line of serpentine and soapstone beds, or $5 worth 1 mile east or west of them." In this part of Vermont abandoned stream channels and other features due to diversion of streams in the past are so common and apparent as to be readily noticed by the traveler. These changes in the old drainage complicate somewhat the task of tracing the alluvial gold back to the rock from which it was derived; but in any search for gold veins these drainage features must be taken into account.

The essential feature in the question of the occurrence of gold in Vermont is the economic value of the deposits. No better statement of this can be made for the benefit of the public than that made by E. Hitchcock,[b] in 1861: "We trust that too much is known on this subject at the present day to leave any to indulge in extravagant speculation, or to make investments without reason."

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[a] Op. cit., p. 848.

[b] Vermont Geol. Surv., Final Rept., vol. 1, p. 533.

PRELIMINARY REPORT ON THE ORE DEPOSITS OF TONOPAH, NEVADA.[a]

By J. E. SPURR.

LOCATION, CLIMATE, AND POPULATION.

Tonopah is situated in Nye County, Nev., near the Esmeralda County line. It lies south of Belmont, and about 60 miles east of Sodaville, which is on the Carson and Colorado Railroad. The camp is reached by semidaily stage from the latter point.

The climate is arid, with rare rains and occasional snows. The present water supply is pumped from wells in a water zone some 4 miles north of the town.

At the present writing the camp has an estimated population of 5,000. It has electric lights, waterworks, two newspapers, and has attracted enterprising men from all parts of the country.

DISCOVERY AND DEVELOPMENT.

Tonopah was discovered in 1900 by J. L. Butler, who was on a prospecting trip. He gave his samples to Mr. T. L. Oddie, of Belmont, who had them assayed for him. These samples showed values of from \$50 to \$600 to the ton. Mr. Butler gave T. L. Oddie, W. Brougher, and several others interests in the original eight claims which he located, now the property of the Tonopah Mining Company.

In doing the location work 2 tons of ore was sorted out and shipped to Selby's Smelting Company. This netted about \$600, and from that time the property has paid for its own development.

In December, 1900, a few leases were let, and in the spring of 1901 over a hundred more. Before the end of 1901 the lessees are said to have extracted ore to the value of about \$4,000,000. In January, 1902, the leases having expired, the Tonopah Mining Company commenced development work, in which it is still engaged.

[a] The writer has spent about five months in field work at Tonopah and four months at Washington studying material collected at Tonopah. A satisfactory final report on the district calls for more detailed office study, microscopic examination of thin sections, chemical investigation, etc., which will now be carried on, and the completed report issued as soon as possible. Since, however, there is an urgent call by the mining public for some immediate information concerning the region, the Director has authorized the writer to issue a preliminary report containing an outline of the results to date.

Following is a table of the weight and value of the ore shipped, taken from smelter returns: [a]

Weight and value of ore shipped to April 1, 1903.

Year.	Weight.	Gold.	Silver.
	Pounds.	*Ounces.*	*Ounces.*
1901	5,067,852	9,780.95	623,487.83
1902	22,836,355	27,003.84	2,408,946.60
1903 (to April 1)	3,481,443	4,212.96	399,186.30
Total	31,385,650	40,997.75	3,431,620.73

Total value, $2,662,401.25.[b]

There are now[c] on the dump close to 25,000 tons of ore, of an average value of $50 per ton.

Subsequently ledges were cut in a number of different localities, such as the Montana Tonopah, Mizpah Extension, California Tonopah, West End, etc. Some of these are low grade, while some show high values. All are in the development stage.

Besides the Mizpah the only mine in the Tonopah district proper which has actually made shipments of importance, so far as the writer is aware, is the Montana Tonopah, where ore was discovered in depth by prospecting under the later andesite capping after the discovery and earlier development of the Mizpah vein. The shipments[d] of the Montana Tonopah to and including July 15 of the present year (1903) are as follows:

Shipments from the Montana Tonopah mine to July 15, 1903.

Shipment.	Pounds.	Total value.
First shipment, May 5:		
First-class ore	29,128	$6,596.39
Second-class ore	23,331	2,472.76
Second shipment, third-class ore for mill test	21,200	749.25
July 15	29,019	4,381.81
	15,664	715.61
Total	118,342	14,915.82

Shipments have been made by both companies since these data were collected.

[a] For this table and the preceding information the writer is indebted to Mr. T. L. Oddie, manager, at Tonopah, of the Tonopah Mining Company.

[b] Estimated by the writer.

[c] May, 1903.

[d] Courtesy of Mr. C. E. Knox, president Montana Tonopah Mining Company.

The values in the ores are entirely gold and silver. The proportion of gold to silver is usually remarkably uniform, and is the same in both the oxidized and the sulphide ores, namely: The gold is to the silver, by weight, as 1:90 or 1:100, making the values about two-sevenths gold and five-sevenths silver. In some of the excessively rich ores the proportion of gold becomes greater, occasionally making up half of the total value.

TOPOGRAPHY.

That the mountain range in which Tonopah is situated is of volcanic origin is shown by its topography. It consists of a series of eroded mesas and detached or connected hills. These mesas and hills are irregularly distributed, with no definite valley systems between. They are separated by patches of sloping or rolling country, largely covered with "wash," or débris worn from the hills. The mesas are the remnants of volcanic flows; the isolated or connected irregular hills are denuded volcanic necks.

An excellent topographic map of the country immediately around Tonopah, on the scale of 800 feet to an inch, has been made by Mr. W. J. Peters, of the United States Geological Survey. On this it is seen that the general elevation of the slight valley-like depression in which the town of Tonopah lies is about 6,000 feet above sea level, while the top of Butler Mountain, which is the highest mountain near the town, is 7,160 feet.

GENERAL GEOLOGICAL HISTORY.

Pre-Tertiary formations.—In the immediate vicinity of Tonopah the rocks are all Tertiary volcanics or sedimentary tuffs belonging to the volcanic period, and composed partly of ash and partly of silt derived from the erosion of the lavas. Eight or nine miles south of the camp, however, there is limestone, very likely of Cambrian or Silurian age, and in this granitic rock is intrusive. Limestones and granites occur also several miles north of Tonopah, and at intervals between there and Belmont. At Belmont the limestone, into which granite is intrusive, is known to be Silurian.

At Tonopah itself occasional limestone fragments and more abundant fragments of a fine, even-grained pegmatite occur in the volcanic breccias. They are blocks which were hurled out from the volcanoes at the time of their eruption. Thus it is shown that at an uncertain depth below the present surface the ascending lavas broke through rocks of this character.

Early andesite eruption.—The oldest rock outcropping in the immediate vicinity of the camp is a hornblende-andesite, or, rather, was such, for no fresh portions have been found and the rock has been altered so as to acquire an aspect in general very different from its original one.

Subsequent to the eruption of this rock fractures were formed in it, and these became the channels for circulating solutions, probably ascending hot waters, closely connected with the volcanism. The waters were remarkable for intensity of action. The rocks which they traversed have been chemically transformed, the chief process being silicification, so that they are now found more or less completely altered to quartz and sericite (fine muscovite). Along fracture zones the rock has been replaced almost entirely by quartz carrying silver and gold, and these constitute the veins by which Tonopah is known. Some parts of the hornblende-andesite, on the other hand, show chiefly calcite and chlorite, with pyrite, as alteration products; but such phases have not yet proved to lie immediately adjacent to important veins, and, as a rule, do not seem to be indicative of the proximity of the best class of ore.

Later andesite eruption.—There is evidence that these events were followed by a considerable period of erosion, long enough to bring the veins to the surface. Then another eruption of andesite occurred. This later andesite, which was abundant in amount, differed from the earlier andesite in containing, as dark minerals, pyroxene and biotite rather than hornblende, and it also differed in some structural and textural points. It is probable that this andesite came up through the hornblende-andesite in places, and also flowed over it, completely covering it and its contained veins.

Rhyolite and dacite eruptions.—Following probably another period of erosion and volcanic rest, eruption was vigorously renewed and there were outbreaks at many closely adjacent points. The lavas were rhyolites and siliceous dacites, closely related to one another. Some vents emitted one, some the other rock. This period of volcanism was long and a number of different lava flows of dacite and rhyolite alternated or mingled. The eruptions were often explosive, as is shown by the considerable quantity of pumiceous and fragmental material in the volcanic breccias of this period.

Lake sediments.—During this volcanic epoch a large fresh-water lake formed, of unknown, but probably great extent. In it were deposited white, finely stratified ash and tuff, and some beds are entirely made up of late Tertiary infusoria. In places the sediments of this lake, exposed near Tonopah, are several hundred feet thick.

It is probable that this lake was partly filled by sediments and then drained by an uplift. Near the top of Siebert Mountain (a white tuff mountain southwest of Mount Brougher) there is what appears to be a river channel belonging to this post-elevation epoch, containing rounded waterworn pebbles of rocks such as now outcrop to the north and east of Tonopah, and fragments of silicified wood, showing the presence of vegetation at that time. This uplift may be ascribed to volcanism, for it was soon followed by renewed outbursts of lava.

Eruption of basalt and intrusion of later dacites and rhyolites.—Above the tuffs on Siebert Mountain is a thin sheet of slaggy basaltic

GEOLOGIC MAP OF TONOPAH MINING DISTRICT.

rock, the first of the upwellings of the next period of volcanic activity. Soon afterwards great columns of dacite and rhyolite made their way to the surface. The eruptions from these vents must have been chiefly explosive, and the products light and scanty and easily swept away, for no trace of them has been found in the immediate vicinity of Tonopah. The volcanic necks, however, have been laid bare by erosion, and on account of their superior hardness to the tuffs and breccias, in which they were intruded, now stand up as low detached mountains. Brougher Mountain, Butler Mountain, Siebert Mountain, and Golden Mountain are all dacite necks of this period, while a group of rhyolite eminences, consisting of Oddie and Ararat mountains and Rushton Hill, represent necks of very nearly the same period as the dacite.

Faulting of the region.—At about this period occurred an event of great scientific and economic interest—the faulting. A considerable number of important and complicated faults have been found in the region. Their age, as denoted by their relations to the different formations, seems nearly uniform. All the rocks up to and including the stratified tuffs have been displaced by the faulting, and on Siebert Mountain the thin sheet of basaltic rock overlying the tuff has been faulted with it. But these faults invariably stop at the contact of the dacite necks, which are not affected, and the same is probably, though less certainly, true of the rhyolite necks above noted. Indeed, the dacite certainly (and the rhyolite less certainly) has been intruded as dikes along the faults.

The geological map (Pl. I) reveals some important points. It shows that the area of observed complicated faulting is in general coextensive with the region of late dacite intrusion. This region, which occupies the southeastern portion of the district, is downsunken in comparison with the unfaulted or little-faulted region on the northwest. Near the dacite necks the observed faults are rather more numerous than elsewhere, and in many instances it may be established that the blocks adjacent to the dacite have been downsunken in reference to blocks farther away. From these intrusive necks the faults run in a roughly radiating fashion and seem to follow no regular system of trend. Detailed study of the contact phenomena of the dacite shows that the minute faults in the tuffs at these points generally have their downthrown side next the dacite. From these facts the following conclusions have been reached. The faulting was chiefly initiated by the intrusion of the massive dacite necks (the rhyolite necks were probably not so bulky). After this intrusion and subsequent eruption there was a collapse and a sinking at the various vents. The still liquid lava sank, dragging downward with it the adjacent blocks of the intruded rock, accentuating the faults, and causing the described phenomena of downfaulting in the vicinity of the dacite. This sinking of volcanic centers after eruption has been well established by students of volcanism.

The economic interest in this faulting lies largely in the circumstance that the veins in the early andesite have been cut and displaced thereby.

Recent erosion.—To complete the geological history, we have to conceive of the considerable period of erosion which stripped from the surface a great thickness of volcanic material, leaving the resistant volcanic necks standing out as hills, and laying bare the present surface. Certain blocks of limited extent had been raised by the faulting above the level of the rest, and here the surface of erosion reached the early andesite and uncovered the rich veins contained in it; and it is the discovery of these veins which has made the subject of the geology of the still covered region of such lively interest to miners.

Sequence of formations and events.—The following, then, is the sequence of events as deciphered for the vicinity of Tonopah:

Sequence of formations and events in the vicinity of Tonopah.

Early andesite.
  Fracturing.
  Vein formation. (Primary minerals, quartz, valencianite, stephanite, pyrite, chalcopyrite?) Values good; gold and silver, silver predominant.
Erosion.
Later andesite.
Probable erosion.
Dacite.
Dacite breccia.
Rhyolite breccias, flows, and dikes, intermingled with slightly stratified or interstratified pumiceous or tuffaceous fragmental material.
  Vein formation. (Primary minerals, quartz, pyrite.) Values relatively low; gold and silver, gold apt to predominate.
Erosion.
Tuffs, with an occasional thin rhyolite flow.
Elevation of tuffs.
Tilting.
Basalt.
Chief faulting. (Affects everything preceding.)
Rhyolite (white) intrusion (probably Ararat, Oddie, Rushton hills).
  Vein formation. Primary minerals, quartz, chalcedony, calcite, siderite, pyrite.) Values low; gold and silver, gold apt to predominate.
Erosion.
Dacite intrusion (Butler, Brougher, Golden, Siebert mountains).
  Mineralization (chalcedony, manganese). Values slight to insignificant. Mud veins.
Erosion.
Glassy rhyolite flow (slopes of Oddie and Brougher).

DESCRIPTION OF THE ROCKS OF THE REGION.

Distribution and characteristics of the early andesite.—This was originally a hornblende-andesite, containing probably some biotite and pyroxene. In the immediate vicinity of Tonopah it outcrops only, so far as observed, on Mizpah Hill and Gold Hill, but it has been discovered under younger rocks in a number of different mines, such as the Montana Tonopah, the North Star, the Ohio Tonopah, the California Tonapah, the Wandering Boy, the Fraction, and probably the West End and MacNamara, the Midway, etc. Nowhere is it in even an approximately fresh state, but, as before noted, it has altered largely to calcite and chlorite, and (more commonly in the vicinity of the veins) to quartz and sericite. In the former condition it has a fairly deep-green or blue color, while in the latter phases it is lighter green or blue, and very often nearly white, or assumes, near the surface and along faults or fractures, a pale, yellowish, brownish, or reddish color. This common quartz-sericite type has the appearance of rhyolite rather than of anything else, and does not at all resemble andesite, while the calcite-chlorite phase has more nearly the rightful aspect of a highly altered andesite.

It is difficult always to distinguish this early andesite with certainty on account of its many different phases. It is most likely to be confounded with the later andesite on one hand and with certain types of rhyolite on the other. The main points of difference will be outlined shortly.

Distribution and characteristics of the later andesite.—The later andesite outcrops over a considerable region in the northern part of the district. The upper portions, and in some cases the whole, of the following shafts are in it: Montana Tonopah, North Star, Midway, Golden Anchor, Little Tonopah, Boston Tonopah, Halifax, etc. It varies greatly in state of preservation, being frequently found nearly fresh, and again highly decomposed. In its fresher phases it is a dark-colored, hard rock, with large crystals of pyroxene, feldspar, and biotite. It has usually been more or less altered, and as secondary minerals calcite, chlorite, serpentine, etc., have been formed, giving the rock a dark-green color. Frequently, also, the altered rock has a deep-blue color. Near the surface the red of the oxidized iron combines with these colors to produce a characteristic rich purple. In some places the rock has been thoroughly altered to calcite, chlorite, and pyrite, with other secondary minerals, and again has been so completely leached as to be soft and white.

In these highly altered phases the later andesite becomes with great difficulty distinguishable from the early andesite, and where it is fine grained the resemblance may become almost exact.

For the distinction of the two rocks in general it may be noted that the early andesite is characteristically finer grained than the later andesite, and that in the former the feldspar crystals are slimmer and rectangular, while in the latter they are stouter and often of complex shape. In some of the hornblende-andesite (though not generally) the long dark crystals of altered hornblende may be distinguished, while in the later andesite the crystals of biotite are usually plainly visible, even in the considerably altered phases. The characteristic later andesite has a coarse, mottled appearance, and even when highly altered and bleached it has a dull clayey luster, which is rarely seen in the early andesite. Rocks which are highly siliceous from alteration are apt to belong to the early rather than the late andesite.

Distribution and characteristics of the rhyolites.—There have been several different rhyolite flows and intrusions, some before, some mainly subsequent to the faultings; and the rocks have a variety of appearances which defies any description in common. The lava of Oddie, Rushton, and Ararat hills is a characteristic siliceous white rhyolite. The Rescue shaft is mainly in this rock, and two long tunnels, the North Star and the G. & H., have been driven in it into Mount Oddie.

Besides this, however, there is a formation of fine-grained gray or red, largely glassy rhyolite, which covers a still larger area. A large body of it occupies the northern portions of the district, where it is intrusive, with a sinuous contact, into the later andesite. It continues from here, along the western edge of the district, to the vicinity of the Ohio Tonopah, and occupies a considerable part of the basin inclosed between Butler, Brougher, and Siebert mountains. The formation here occurs as complicated dikes cutting the dacite-breccia formation, and as sheets underlying the tuff, or, to a less extent, intercalated in the tuff. In the rest of the district it is practically absent. It is in general between the dacite breccia and the stratified tuff in point of age, is older than the faults, and is therefore displaced by the fault movements. In the northern portion of the district a number of shafts are located on or near the contact of this rhyolite and the later andesite. Among these may be mentioned the King Tonopah, Belle of Tonopah, Miriam, Silvertop, Little Tonopah, etc. In the western portion the Ohio Tonopah and the New York Tonopah each encountered a considerable quantity of this rhyolite mixed with dacite breccia, while the Fraction Extension is entirely in this rock, after having passed through the overlying tuff.

This finer grained gray or red rhyolite has many different aspects. Fine brecciation, with bright red, gray, and white colors, is frequent; in other cases it is dense and characterless. The best test of it is the detection of the small quartz crystals that dot the glassy groundmass, which distinguishes the rock satisfactorily from the andesites. Sometimes, however, these quartz crystals may be rare and small. Near the contacts of the rhyolite (intrusive into the earlier rocks) there has also frequently been alteration—silicification, the formation of pyrite, etc.—and then the rock may become almost identical in appearance with the early andesite which has been similarly altered. The best method for distinguishing the rhyolite from andesite in this case is the tracing of the connection with the less-altered rhyolite farther away from the contact.

Distribution and characteristics of the dacites.—The bold knob north of Butler Mountain, known as Heller Butte, is made up of what is regarded as probably the oldest dacite exposed at the surface. It is a compact, relatively coarse-grained rock, finely brecciated, and carrying included fragments of older rocks, notably the later andesite. It is surrounded and probably overlain by the softer dacite-breccia formation. The Tonopah City shaft after passing through the dacite breccia has continued in solid Heller dacite to a total depth of over 500 feet. East of Butler Mountain, on the edge of the district, another strip of this dacite is exposed, also surrounded by the dacite breccia. It is regarded as probably intrusive.

The *dacite-breccia* formation, on the other hand, is essentially a surface formation, and not intrusive. It consists of flows of often very pumiceous and friable dacite, dacitic mud flows, and some rudely layered or even stratified fragmental material. In places it is very thick. It is exposed over a large fraction of the southern portion of the district, around Butler, Brougher, and Siebert mountains. The Ohio Tonopah and the New York Tonopah shafts passed through considerable thicknesses of this formation, and the Fraction No. 3 is entirely in it. The Fraction Nos. 1 and 2, and Wandering Boy, and the West End, passed through this formation at the surface and reached the underlying formations.

The *later intrusive dacite*, which makes up Butler, Brougher, and Golden mountains and the central portion of Siebert Mountain, has usually a characteristic appearance. It is darker than the rhyolite of Mount Oddie, has a slight purplish tinge, and contains more crystals (of feldspar, quartz, and mica) embedded in the glassy groundmass. The Big Tono shaft, at the east foot of Mount Brougher, starting at the outward-pitching contact of this rock and the intruded dacite-breccia formation, goes down several hundred feet in the former. The Molly, starting near the dacite contact on Golden Mountain, passed through several hundred feet of this rock, then through the inward-pitching contact to a slight thickness of loose material belonging to the dacite-breccia formation, and so into the later andesite.

PERIODS AND NATURE OF MINERALIZATION.

Mineralization subsequent to the early andesite intrusion.—The most important veins of the Tonopah district, and all those that have been proved to be of immediate economic importance, occur in the early andesite, and do not extend into the overlying rocks. Hence, when the early andesite is not exposed at the surface, the later rocks form a capping to the veins, and this capping must be passed through before anything can be learned of the presence or the nature of the veins beneath. This circumstance shows pretty plainly that the vein deposition took place before the eruption of the later andesite, and immediately after that of the early andesite (for the period of erosion between the two andesites seems to have exposed the veins at the surface, showing that they were formed before this period, or early in it).

Indeed, there is every evidence that the veins were formed by ascending hot waters succeeding and connected with the early andesite intrusion, and that these waters had apparently become inactive by the time of the later andesites.

The mineralization at this period was extraordinarily active, as the profound alteration of the early andesite testifies. Among the known veins formed at this period those of the Valley View, Mizpah, and Montana Tonopah groups are the most important, though certainly there are others which have not yet been discovered. These veins carry gold and silver, in the proportion of about 1 part of gold to 100 of silver, by weight. They are unusually free from base metals—no lead, arsenic, etc., has been detected. In some places there is a very little copper, in others none. The gangue is quartz, with frequently a mineral which is a variety of orthoclase feldspar (valencianite). The sulphide ores, so far as developed, show primary stephanite, with probably some polybasite, scant pyrite, and comparatively rare chalcopyrite. Secondary sulphides coating the cracks in these ores are ruby silver, argentite, and probably pyrite and chalcopyrite. The oxidized ores show abundant silver chloride, with occasional bromides, etc., and sometimes free gold.

Mineralization subsequent to the early rhyolite intrusion.—Along the borders of the gray or red glassy rhyolite intrusions, especially in the northern portion of the district, there has been, as before noted, considerable alteration and mineralization, which must be attributed to a cause similar to that which produced the veins in the early andesite—namely, the action of hot ascending waters immediately succeeding and genetically connected with the rhyolite intrusion. This alteration is in the form of silicification and the formation of pyrite, and has acted on the rhyolite as much as the intruded rock. Quartz veins have been formed, in the majority of cases relatively small. These veins contain precious metals, but usually very irregularly distributed. High assays, especially on the surface, may even be obtained, but it is likely that some of these are the result of the well-known process of increase of values at the surface during oxidation. Specimens of the veins have a general resemblance to those of veins of the early andesite, and show pyrite, often finely disseminated in a quartz gangue. Some of these veins have been found to be of considerable size; therefore it may often be difficult to distinguish them from the andesitic veins without study of the rock in which they lie. Chemically they appear to be characterized, so far as yet developed, by very low average values and by the frequent but not regular preponderance of the gold values over those of silver.

Mineralization subsequent to the later rhyolite intrusion.—It has been described how the white rhyolite of Oddie, Rushton, and Ararat hills is probably later than the dense, usually gray rhyolites referred to above. For example, the top of Ararat seems to be a plug or neck of white rhyolite forced up into the earlier gray rhyolite. This later white rhyolite shows near its contacts, and to a less extent away from these, in itself or in the intruded rock, veins which are ascribed to causes similar to those which probably brought about the preceding mineralizations—namely, ascending heated waters following the lava intrusion, genetically connected with it, and, like the previous similar processes, dying out after the lapse of some time. These veins, which are in places very large, are of calcite, siderite or ferriferous calcite, chalcedony, etc. They contain some pyrite and sometimes give low values in the precious metals, gold preponderating.

Mineralization phenomena may also be observed in some places near the contact of the Oddie Mountain rhyolite, where there is silicification and the formation of pyrite, with quartz veins of various sizes, sometimes containing calcite. These veins are generally small, but may be large. Galena and chalcopyrite have been exceptionally found in them. They carry low values in gold and silver, the gold being apt to predominate.

Mineralization subsequent to the dacite intrusions.—Finally, the contacts of the large dacite necks (Butler, Golden, and other mountains) are accompanied in many places by the deposition of chalcedony, manganese, etc., in cracks and crevices. These are not usually in veins, or when so are small and irregular. Considerable values in the precious metals have been claimed in some cases, but it is the writer's experience that the content of these metals is insignificant.

Résumé.—To sum up, no fewer than four periods of hot-spring action, accompanied by more or less vein formation and mineralization, have been noted at Tonopah. Each of these periods was consequent upon a lava intrusion, and the mineralization was the result of a process which is known to accompany and follow volcanic eruption at the present day. In general, the values found in the veins of these different periods increase with increasing age. Also, the general phenomena indicate that the younger veins were formed nearer the surface than the older ones. Although ascending hot waters are not known to deposit more than traces of metals at the surface, it is supposed that an important precipitation takes place at some depth; so in the case of Tonopah it may be that the later periods of mineralization have produced some rich ores, but that erosion has not yet had time to expose the level at which they lie, whereas in the case of the oldest period this has been accomplished. At Gold Mountain, about 4 miles south of Tonopah, veins belonging to the rhyolitic period and having the same characteristics as some of these veins at Tonopah contain considerable values in gold and silver, while at Tonopah no such values have been discovered in this class of veins.

At Tonopah, therefore, the earliest and most important class of veins can be found only in the earlier andesite. The rhyolite veins, on the other hand, may occur in the rhyolites, as in any of the older rocks; indeed, they must also occur sometimes in the early andesite itself. The mere fact of a vein lying in the early andesite, therefore, is not always evidence that it belongs to the early andesite period. In some such cases it may be extremely difficult, if not impossible, to tell to which period it belongs.

The later andesite is in many cases thoroughly decomposed and altered, and there has been extensive formation of pyrite, calcite, etc., in it, especially in the regions where the richest veins have been found. The nature of this alteration is such as to indicate copious percolating waters as the agents, and to suggest that the waters may have been heated. It is quite possible that some of the small sulphide-bearing veins, which are frequently found in the later andesite, may have been formed contemporaneously with this alteration. These veins are nonpersistent, and the values contained are small. Physically they resemble the rhyolitic veins, and as they have been noted chiefly in the general vicinity of rhyolite, which is intrusive into the later andesite, they have been classed with the undoubtedly rhyolitic veins. It is possible, however, that a moderate mineralization, similar in quantity to that which succeeded the rhyolite eruptions, followed that of the later andesite.

FIG. 2.—Horizontal plan of portion of Mizpah vein, as developed on the 250-foot level, Mizpah mine, east of the Brougher shaft.

VEIN GROUPS OF THE EARLY ANDESITE MINERALIZATION.

The only productive veins thus far discovered in the Tonopah district proper are those of the early andesite period. On account of the later volcanic rocks which cover the early andesite in most of the district, these productive veins outcrop only in a very small area, outside of which little is known as yet. It is probable, however, as indicated by the great amount of alteration in the early andesite, that the vein formation has been extensive, and that the veins at present known are only a small portion of those that will eventually be developed.

The veins already discovered all belong to the type of "linked veins." Their physical characteristic is that they branch and reunite in both a horizontal and a vertical direction (fig. 2). There is generally in each group a main or master vein from which the smaller veins branch. These smaller veins again may subdivide and so finally die out. The main vein and its branches may together be termed a "vein group."

Veins probably of the early andesite period have been discovered in various mines outside of Mizpah Hill, where the first discoveries were made. Among these later developments may be mentioned the California Tonopah, the MacNamara, the West End, the Ohio Tonopah, and other workings. But it is only the veins on Mizpah Hill

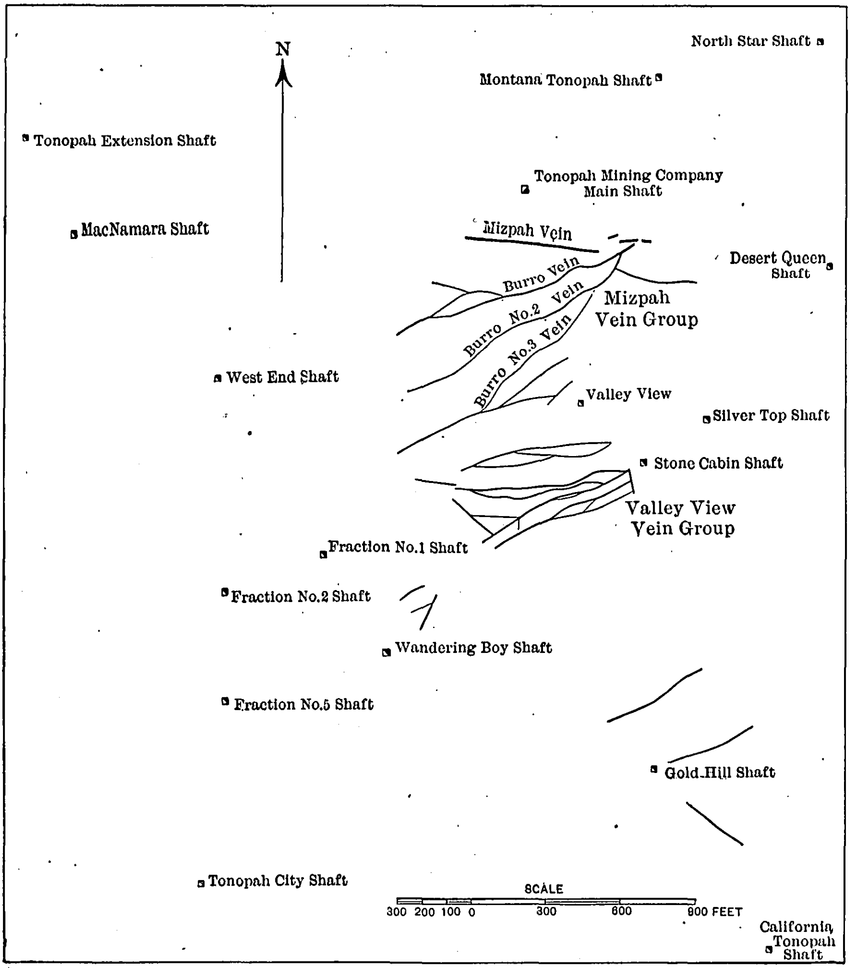

FIG. 3.—Map showing outcropping veins at Tonopah.

that have been sufficiently developed to give information concerning the vein system. On Mizpah Hill there may be recognized at present three main groups of veins—the Valley View group, the Mizpah group, and the Montana Tonopah group. These are all strong and distinct (fig. 3).

The Mizpah group lies in the center, between the other two, and was the first discovered. The trunk vein of the group is called the "Mizpah" vein, and crosses Mizpah Hill in an east-west direction, showing a strong outcrop. This outcrop is cut off both to the east and to the west by heavy faults, so that it is adjoined on the east by the rhyolite of Oddie Mountain and on the west by the later andesite. From the Mizpah vein a succession of branches depart, running chiefly in a southwestern direction from the eastern end of the outcrop, and each successive branch diverges more than its predecessor from the strike of the main vein, so that the whole group is like a section of the spokes of a wheel, the spokes uniting some distance east of the main shaft. The chief of these branches are known as the Burro No. 1, No. 2, No. 3, etc. They are strongest near the main vein, and those which diverge most from the strike of the latter are weaker than those which are more nearly parallel to it. The intersections of the branches with the main vein and with one another usually pitch to the east at a moderate angle. These easterly pitching intersections are significant, since they have the same general course as certain shoots of especially rich ore in the same vein, and correspond also in direction to some post-mineral fracturing and faulting. The main vein has in general a steep northerly dip, which is locally overturned so as to dip steeply to the south.

The Valley View mine shows a group of veins of the same general type as the Mizpah, but with minor differences. The main Valley View vein as exposed in the workings has, like the Mizpah vein, a northerly dip, but is very much flatter. It is very large, and the rich ore in it is unequally distributed, occurring in shoots or bunches. As the large vein approaches the surface it splits into several somewhat smaller veins, which assume a nearly, or quite, vertical position. This vein group is in general very nearly parallel to the Mizpah group; the linked character, forking and reuniting, is quite as well marked as in the Mizpah group; and there is some radiation in the strike of the veins, although not so much as in the former case. The Valley View veins are affected by post-mineral faulting, like the Mizpah vein.

The Montana Tonopah group shows a strong main vein running east and west and dipping north at a moderate angle. A number of lesser veins have been cut in the workings, and although development at the time of the writer's examination was comparatively slight, it is probable that most of these veins will eventually unite with one another or with the trunk vein. The indications are that the branches lie mostly on the north side of the trunk vein and diverge in trend from it, opening out to the east. These branches as a rule dip more steeply than the main vein, and will, therefore, also tend to unite with it vertically. The Montana Tonopah veins are, like the others, displaced by considerable post-mineral faulting.

In all these veins the union of two branches to form one is generally attended by corresponding enrichment, and, conversely, the place where a small branch vein leaves the main one is generally impoverished, often to a much greater degree than the size of the branch vein would seem to warrant. The recognition of this fact by the miners has led to the use of the highly descriptive term "vein robbers," for these small branches.

From the above it will be seen that the chief developed Tonopah veins have a decided east-west trend. From the fact that there is a predominant north-south trend in some of the chief veins of California and the western part of Nevada, east-west veins have been looked upon with some prejudice in Tonopah, many miners being inclined to doubt the value of the veins on account of their strike, and others forming the theory that they were simply the offshoot of a great undiscovered north-south vein which would prove to be vastly richer than these; but the Tonopah field is in an entirely different region, geologically, from California, and this objection seems to the writer to have little weight. In Idaho, where the geological conditions are perhaps more like those of Nevada than they are in California, the usual trend of the veins is east and west.

Minor veins run northwest and northeast and even north and south, but so far as yet observed the east-west veins are the chief ones, and it seems likely that the mineralization will be extensive in an east-west belt rather than in a north-south one.

OCCURRENCE OF ORES IN THE VEINS.

Physical character.—The veins of the Tonopah district are usually strong, straight, and well defined, yet they are not fissure veins. They have at first sight all the appearance of fissure veins, but a little close examination shows that they have been formed almost entirely by replacement of the andesite in which they occur. They seem to have originated along zones of especially strong fracturing in the andesite, formed during a period of movement subsequent to the consolidation of this rock. These zones of maximum fracturing, which are usually 4 to 6 feet wide, but may be much wider or narrower, became the chief channels of circulation for the mineralizing waters. It has already been stated, in describing the alteration of the early andesite, that the andesite near the veins has been silicified to a very great extent, and the veins themselves seem to be the final stage of alteration, the andesite being mostly or entirely altered to quartz. A slight detailed study of the veins gives abundant proof of this origin, for all stages in the development can be seen in different portions. In many cases the vein consists simply of a zone of more or less altered andesite, not essentially different, except perhaps for a somewhat greater silicification, from the andesite which forms the walls. This zone is cut by parallel fractures having the same strike and dip as the walls, and the walls themselves are nothing more than stronger fractures of the same kind. In the next stage, where part of this fracture zone becomes altered to quartz, the main wall fractures have been the most favorable, so that sometimes a hanging-wall streak of quartz and a foot-wall streak are found with only altered andesite between (fig. 4). Sometimes, also, either the hanging-wall or the foot-wall streak may be wanting. Next, streaks of quartz parallel with the walls may be found, or the quartz may form a network in the andesite. Thus the process may be traced to the stage where the whole of the andesite is replaced by quartz, forming a solid vein several feet in width. As a

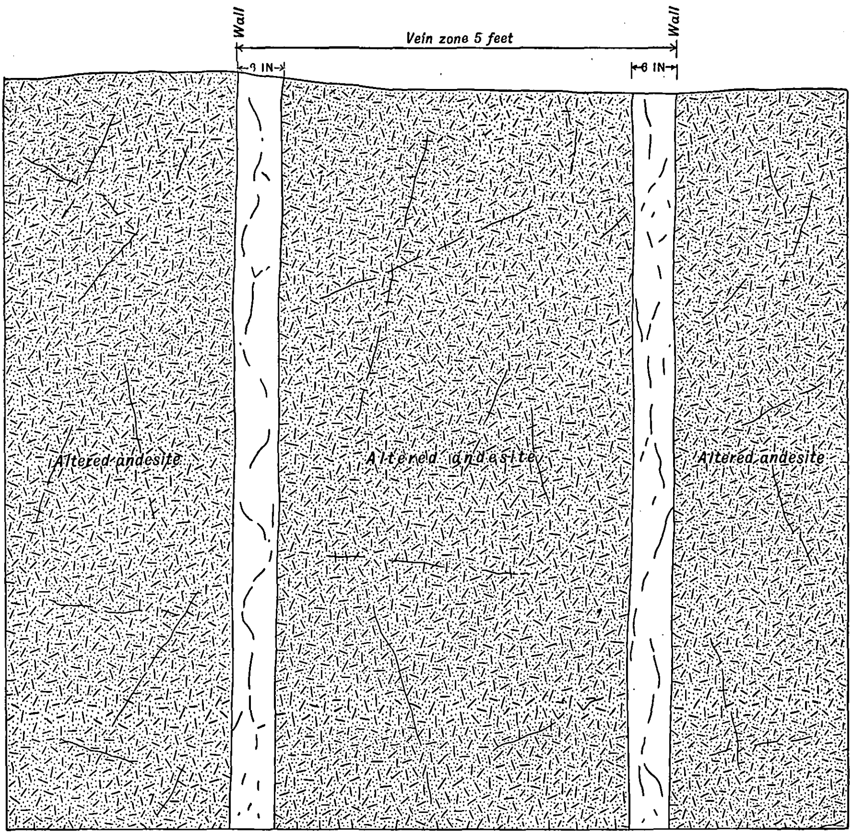

FIG. 4.—Detailed vertical section of one of minor Valley View veins at surface.

rule, however, there is more or less decomposed andesite forming part of the vein.

As exceptions there are found streaks of quartz, usually small, within the vein, which show crustification and comb structure, and thus bear evidence of having been formed in cavities. These cavities, however, were of irregular shape and were not fissures, properly speaking, but spaces of dissolution, and were the effect of the mineralizing waters themselves.

The largest example of a crustified vein is found in certain parts of the Montana Tonopah workings, where the cavities were sometimes 2 or 3 feet in diameter and gave rise to well-banded ores.

In the Montana Tonopah the chief vein shows in places a brecciation and subsequent cementation. Both the original material and the subsequent cement are of quartz and rich black silver ores, and seem to have been deposited under about the same conditions. The inference is that the strain which originally produced the fracture zones kept on during their cementation by the circulating mineralizing waters, and that in this case this strain resulted in the local shattering of the cement and the subsequent healing by similar materials.

Primary ores.—At the time of the writer's first investigation of Tonopah, in the autumn of 1902, only the oxidized ores of the upper levels of the Mizpah were available for examination. From a microscopic study of these he found that the original metallic mineral was still present in minute grains. It was black in color, and he supposed it to be a rich silver sulphide. Subsequent to this investigation the primary sulphide ores were found in the Montana Tonopah mine, and the correctness of the forecast above mentioned was shown. In the Montana Tonopah the ores are quartz veins carrying in places very large amounts of the rich black antimonial sulphide of silver, stephanite. This stephanite is undoubtedly primary. Besides the quartz, as gangue mineral, there is another having a milky appearance, but otherwise looking much like the quartz. This is a variety of orthoclase (valencianite). Some of the stephanite may contain some copper, making it a kind of polybasite. Chalcopyrite is very commonly present and is probably, in part at least, primary, although this is not certain.

Secondary sulphides.—Throughout the Tonopah district argentite and ruby silver occur in greater or less abundance, sometimes adding considerably to the value of ores, but they do not occur in such quantities as the stephanite ores or the oxidized products. Wherever found the argentite and the ruby silver are unquestionably secondary, having formed from the alteration of the stephanite. They occur along cracks in the primary sulphide ore and are occasionally found in the oxidized or semioxidized ore. The chalcopyrite above mentioned, as observed in the Montana Tonopah ore, seems to occur chiefly as small streaks cutting the original stephanite ore, giving it the appearance of being secondary to the latter. In some cases it occurs along cracks and is undoubtedly secondary. It is very likely that some at least of this mineral has been formed from the copper contained in the cupriferous silver sulphide. Some pyrite is also undoubtedly secondary. Pyrite, however, is relatively rare in these ores—much more so than in the country rock.

Oxidized ores.—In the Mizpah vein the oxidized zone extends nearly down to the 700-foot level. Observation shows, however, that the limit of oxidation is extremely irregular. For example, the oxidation extends much deeper along the vein than some distance away from it in the country rock. At 400 feet from the surface the Valley View veins show oxidized ore, while 100 feet higher the country rock away from the veins is unoxidized. In the Stone Cabin shaft the change from the oxidized to the unoxidized andesite came just below the 200-foot level, but at 400 feet the ore is partly oxidized. The reason for this appears to be that the quartz veins, on account of their brittleness, have been more readily fractured by strains than has the softer country rock, and so the veins afford channels for oxidizing waters coming from the surface. Strong fractures, such as those in the vicinity of faults, have the same effect as the open fractures in veins and carry down the oxidizing influences to a depth of several hundred feet. Where the rocks are protected above by relatively impervious formations the oxidation may be comparatively slight. Thus, in the Silvertop workings (near the Stone Cabin) the later andesite is unoxidized at a depth of 120 feet. Here it is protected at the surface by a deposit of fine-grained, stratified tuff.

In the oxidized zone of the veins the sulphides are mostly entirely altered or can be made out only with a microscope, yet in many cases the alteration is not complete and the purple color of the richer quartz is as a rule due to these finely disseminated sulphides. Most of the sulphides, however, are altered to silver chloride, with some bromides and iodides, and to iron oxide. Nearly all of the ore in the Mizpah vein, down to the lowest depths explored, is oxidized, while the ores of the Montana Tonopah are only slightly and exceptionally oxidized. In the latter case the veins and the inclosing early andesite have been protected from the atmosphere by several hundred feet of decomposed, soft, later andesite, whereas in the former case the veins outcrop at the surface and oxidizing waters sink readily into them.

In the process of oxidation and alteration of the metallic minerals there has probably been some transfer of material. Little is known of the primary or unoxidized veins, but some portions seem almost entirely barren and some very rich. It will probably be found that these rich portions form definite shoots or masses of ore in the relatively barren veins. In the oxidized ores the values are by no means uniform, but seem rather better distributed than in the deeper regions. The indications are that during oxidation some of the values have been distributed from the richer portions through the more barren portions, producing a larger supply of fair quality ore. It is also likely that during this process there has been some concentration of values, so that the oxidized ores as a whole may be found to be somewhat richer than the sulphide ores. It is possible, for example, that those portions of the veins which have been eroded furnished during the process of erosion a small share of their precious metals to the underlying portions of the vein, these underlying portions now having become the present oxidized zone.

It also seems probable that in places some relatively slight transfer and redeposition of the precious metals has taken place along the fault planes, which are later than the original veins and have displaced them. This action, however, is only exceptionally the case, and as a whole is insignificant. The main ore shoots of the oxidized portion of the Mizpah mine are regarded as primary, since evidence has been found that these coincide with the original ones and have been oxidized nearly in place; therefore it is improbable that the transfer of material during oxidation, bringing about local concentration or impoverishment, has been very great.

Ore shoots.—In the oxidized portion of the Mizpah vein the richer ores lie in roughly defined, broad shoots, which pitch east on the vein. At least three of these shoots, parallel to one another and with poorer ore between, have been recognized. In the unoxidized ores of the Montana Tonopah there is evidence of the existence of similar shoots or bunches, but enough exploration work has not been done to enable the writer to describe them more closely.

APPLICATION OF GEOLOGICAL PRINCIPLES.

From the short description of the occurrence of the veins which has been given, it is seen that it is of the first and highest importance to distinguish and determine, so far as possible, the position of the early andesite. As has been noted, this early andesite is likely to be confounded with the later andesite and with some forms of altered and silicified rhyolite, especially that gray, glassy rhyolite which occupies a considerable area in the northern corner of the district. As is seen on the accompanying map, the actual area where the early andesite outcrops is very limited, and in other portions of the district it is covered by later rocks or is cut through and displaced by them. These later cappings may consist of the biotite-andesite, the various rhyolites and dacites, the volcanic breccias, or the stratified tuff formation; or they may consist of two or more of these, superimposed one on the other. Those later rocks which are intrusive rather than in the form of flows (including some of the siliceous rhyolites, some of the dacites, and probably even some of the later andesites) can not be expected, however, to give way to the early andesite in depth. A shaft sunk in a dike or volcanic neck is very apt to continue in this same rock indefinitely downward (see fig. 5).

Of the different rocks which cap the early andesite and the included veins, the oldest, the later andesite, is regarded as the most favorable for prospecting; and, in the light of present knowledge, a belt of this rock lying east and west of Mizpah Hill is probably especially favorable. On the other hand, although the veins indicate a general east-west trend of mineralization, it is by no means proved that the outcrops on Mizpah Hill occupy the center of the mineralized belt and show the greatest mineralization. It may eventually be proved that the strongest portion of this belt lies north or south of the locality known at present, which would make the whole width of the belt considerable. The whole later andesite region is worthy of careful yet cautious prospecting. The localities where the later andesite is intruded by the rhyolite ought, as a rule, to be avoided in this prospecting, for such places are not so favorable as those where the andesite is undisturbed. Such places, however, are likely to be preferred by many mining men, since they are apt to show some of the smaller and poorer veins of the later rhyolitic mineralization. Again, the region of faults should be avoided, for these faults have affected the ore-bearing veins, and if veins are found near them they are difficult, and sometimes almost impossible, to follow. The rocks along fault zones are often decomposed and the decomposed material may

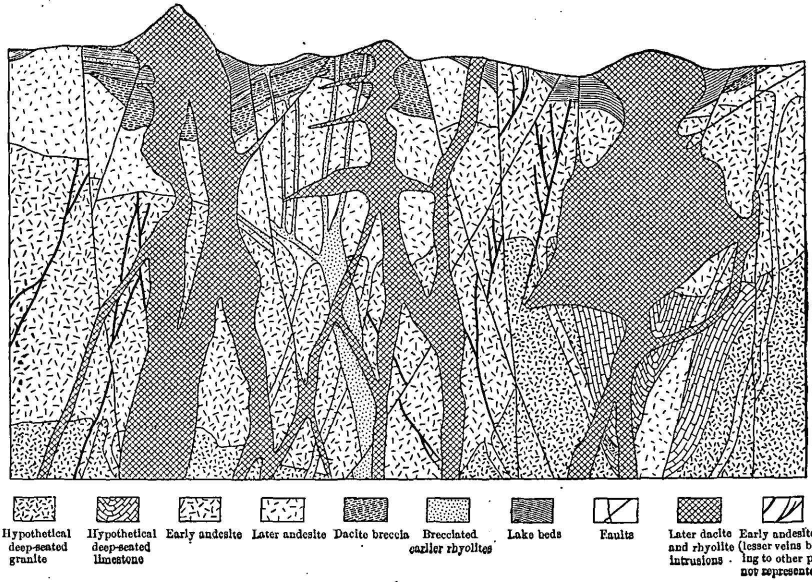

FIG. 5.—Ideal cross section of Tonopah rocks. (This section does not represent any particular place, and is simply intended to illustrate the geological conditions, as described in the text.)

have the appearance of what is known as "vein matter." From this material real or fictitious assays may be obtained, and such a locality may appear to the miner as more hopeful than less altered rock which does not look like a vein and does not show any assays. Some of the principal faults are shown on the accompanying map, but certainly not all of them have been detected, and underground developments will probably reveal many more.

Concerning the dacites and rhyolites of the later intrusions, the volcanic necks and the dikes should, as a rule, be avoided by prospecting operations. The greater parts of the principal low mountains and hills in the vicinity, such as Butler, Brougher, Siebert, most of Golden, etc., are regarded as offering very little hope for prospecting, and even near the rhyolite hills, like Rushton, Oddie, and Ararat, there has been a displacement of the veins, for the hills are essentially intrusive. The writer is aware that the proximity of the rich veins of Mizpah Hill to Oddie Mountain has caused this mountain to be regarded with great favor, but the fact that the veins are in this position has no connection with the mountain; they are there rather in spite of the mountain than by virtue of it, and it would certainly have been much better for mining operations if the rhyolite had not been erupted and the mountain formed.

Most of the dacite breccias and some of the brecciated rhyolite are in the nature of flows, and may be sunk through by shafts to lower formations, such as the later andesite or the early andesite. Much of the fine-grained, brecciated rhyolite, however, is intrusive, so that, as a rule, this rock also is not a good place to sink, except with caution.

The tuff formation, of course, is always sedimentary and can be sunk through to reach the underlying formation, which may be any one of the older rocks.

To sum up, then, the later andesite is the most favorable of the capping rocks; the pumiceous dacite breccia with interstratified, coarse, tuffaceous rocks is next, while the brecciated rhyolite should be prospected very cautiously to see whether it is intrusive. The tuff may be pierced to discover the underlying rock where the geological relations do not make this plain, while intrusive dacite and rhyolite necks should be approached very cautiously indeed.

It must be understood that these characterizations apply only to the immediate vicinity of Tonopah, or the Tonopah district proper. On account of the sudden rise and fame of the camp the name Tonopah has spread far beyond its limits, and has been applied to mines lying in quite other districts, sometimes 50 or 60 miles away. Here, and also in neighboring districts which have not borrowed the name Tonopah, the geological conditions are different. In the Gold Mountain district, for example, about 4 miles south of Tonopah, the veins lie in rhyolites and tuffs and evidently belong to the rhyolitic period; yet they carry in some cases considerable values in gold and silver.

The position of the early andesite away from the outcrops can be foretold to only a limited and uncertain extent, for in dealing with a complex of volcanic flows and dikes like that in Tonopah there is no rule which governs their distribution and by which their position in an unknown locality can always be defined with certainty. Therefore, the prospecting should be done cautiously and the district should be developed from the known region as a center; thus little by little a greater knowledge of the geological detail will be gained. On account of the lack of certainty of results in this work, in many cases it would probably be more economical, both of time and of money, to explore with a diamond drill rather than with shafts. Certainly the sinking of a two- or three-compartment shaft in an unproved portion of the district is often unwise.

The early andesite once located, the question of finding the veins remains, and after that the question of finding pay ore within the veins. The geological evidence goes to show that the mineralizing waters which produced the early andesite veins were unusually active, and a large amount of vein formation is indicated. It is beyond question, therefore, that the veins thus far found are only a fraction of those which exist in the vicinity. These veins will be chiefly unoxidized, since they are protected from oxidation by capping rocks. In them undoubtedly large portions—probably much the larger portions—will be relatively barren quartz, in which shoots, chimneys, or irregular bunches of rich ore may be expected to a considerable depth.

These quartz veins, carrying silver and gold and occurring in Tertiary andesite, belong to a larger group of veins occurring in similar andesite and found along a north-south zone. These veins are exemplified by the Comstock in Nevada and by the important district of Pachuca in Mexico. Probably Pachuca is the nearest analogue, and its description, as given by the Mexican geologist, Ordoñez, may be of value in considering the characters of the Tonopah veins. Judging from these districts it is possible that in depth a rather larger proportion of the baser metals, such as copper, and possibly lead and zinc (although no traces of the last two have as yet been found in the veins), may come in, and that the values in gold and silver may decrease somewhat. This, however, if it happens, should do so at a considerable depth.

ORE DEPOSITS OF SILVER PEAK QUADRANGLE, NEVADA.

By J. E. Spurr.

INTRODUCTION.

Description.—The Silver Peak quadrangle is mostly in southwestern Nevada, adjacent to the California boundary; one corner of it lies in California. There are no railway or telegraph stations within the quadrangle; the nearest is at Candelaria, about 40 miles to the north of the old mining camp of Silver Peak.

The area includes the Silver Peak Range and the valley which lies east of it, together with some portions of outlying mountains, such as the Palmetto Mountains in the southern portion of the quadrangle and Lone Mountain in the northeast portion.

The climate, vegetation, water supply, and other conditions are those typical of the Great Basin region, in which the quadrangle lies. There is no permanent standing or running water of any importance, and for water supply the occasional springs have to be depended on. The valleys and lower mountain slopes are covered by sagebrush only, while on the upper slopes are nut pine (piñon) and other small trees or shrubs.

There are at present only a few hundred people within the quadrangle, and the occupations of all of these are connected with the mining industry. Although there is no very great amount of actual mining going on, some prospecting is being done. The region has been considerably mineralized. It is constantly attracting outside attention, and it is very possible that it may become the seat of a profitable mining industry if the conditions and cost of production can be so adjusted that a balance can be reckoned upon in favor of the mine operator.

GEOLOGY.

The general geology of the region has been examined for the Survey by Mr. H. W. Turner, whose report has not yet been published. His work shows that the chief rocks are Paleozoic limestones, granitic rocks of pre-Tertiary age (granites, diorites, etc.), with abundant Tertiary sediments, and Tertiary lavas, such as rhyolites, andesites, and basalts. As is the case in all this desert region, the Pleistocene wash from the mountains, which floors the valleys and fringes the mountains, forms a conspicuous geological feature.

Ore deposits.—Ore deposits are known to exist in several different parts of the Silver Peak quadrangle. The chief districts are the Silver Peak district proper, near its central part, occupying the mountain spur known as Mineral Ridge, west of the camp of Silver Peak; the Lone Mountain district, in the northwestern corner, most but not all of which is within the quadrangle; the Windypah or Fesler district in the southern part of the Silver Peak Range; and what may be called the Palmetto district, on the northern slope of the mountains of that name. Not all of the Palmetto district is within the quadrangle.

All of these districts, and indeed all the ore deposits known, occur in close connection with large intrusive bodies of pre-Tertiary granitic rock. The ore bodies sometimes occur within the granitic rock, but more usually in the Paleozoic (Cambrian and Silurian) limestones into which it is intrusive, within a broad belt following the intrusive contact. They do not occur in the Tertiary rocks.

SILVER PEAK DISTRICT.

The Silver Peak district, which is the oldest and the most important, contains abandoned silver mines and gold mines which have been considerably worked but are still regarded as promising. The silver prospects were discovered in 1864, but were shortly left idle, and in 1867 they were opened up again and worked till 1869. It is currently reported that the profits were very small. A 10-stamp mill was finished in 1866. A lixiviation process was used, the ores being leached with salt. They have not been worked since.

The principal properties thus far developed, both silver and gold, belong to Mr. D. C. Blair, of New York. A 30-stamp mill for working the gold ores of the Blair mine was finished at Silver Peak in 1867, and was worked for two years. The mine was then idle till the early eighties, when it was leased for two or three years. Another long period of idleness ensued, and in 1893 another lease was given for one year. Immediately after this the mine became involved in litigation, which has only very recently been settled. Mining and milling in a small and intermittent way, meanwhile, has been conducted on a number of the veins, generally of minor importance, outside of the Blair properties.

It is estimated by persons who have been familiar with the history of the mining here that the silver mines have produced a gross value of $200,000, most of which came from the Pocatello and the Vanderbilt, while the Blair gold mine is estimated to have produced $1,080,000.

From the important Mary mine, situated near the Blair gold properties, Mr. John Chiatovich, the owner, has taken out and milled ore worth $46,000; other mines have yielded $7,000 or $8,000.' The Valcalde Brothers have also taken out and milled several thousand dollars' worth of ore from properties controlled by them.

The Drinkwater group of mines, which is the most important part of the Blair gold properties, and which has produced practically all of the million dollars' worth of ore, as above stated, may be taken as typical of the gold veins which, though widespread and numerous, show a wonderful similarity of character. On the surface two adjacent veins outcrop, the Crowning Glory and the Drinkwater, the former the larger, the latter containing the greater quantity of good ore. The quality of the ore still left standing (only the richer portions having been removed for milling) has been more or less carefully determined a number of times. An exhaustive and careful sampling by Mr. George M. Maynard, of New York, gave the average assay value of the measurable reserves of the underlying Crowning Glory vein at $5 for a tonnage of 107,370, making a total value of $537,550. For the measurable reserves of the Drinkwater vein the average value was $9.18 for a tonnage of 4,558, and a total value of $42,118; making $579,668 for the measurable reserves of both mines. Mr. Maynard estimated the probable reserves of the mine at nearly as much, making a total value of measurable and probable reserves of approximately a million dollars.[a] Since Mr. Maynard's examination, several years ago, a considerable amount of new development work has been done which increases markedly both the measurable and the probable reserves.

Geologically, the veins of the Blair mines are interesting. Properly speaking, they are hardly veins, but flattened lenses of quartz occurring in a definite zone 100 feet or more in thickness. The lenses wedge out and disappear both horizontally and vertically, and their place is taken by overlapping lenses. The wall rock is a schist, derived chiefly from the metamorphism of an original limy shale or limestone. Frequently, also, the wall rock is a very siliceous granitic rock (alaskite) made up essentially of quartz and feldspar. This alaskite occurs in the schist in lenses similar to the quartz. There is, moreover, every transition between the alaskite and the quartz, and the schist has been, so to speak, saturated with this siliceous material, which forms seams and tiny lenses in it. The auriferous quartz lenses in the mine in many places run laterally into quartz-feldspar rock (alaskite). As a rule the values grow insignificant with the coming in of the feldspar, but occasionally high values may still be found.

The general conclusion is that here a series of fissile shales and thin-bedded limestones has been invaded by a very siliceous granitic intrusion which has metamorphosed the sediments to schists. The quartz has plainly the same origin and nature as the alaskite, both

[a] Communicated by Mr. Maynard.

being siliceous phases of a granitic magma. The gold in the quartz is usually free, sometimes associated with scattered galena. Greenstone or diorite dikes cut the veins or follow along them, but are of later age. Along the dikes there has been water circulation, resulting sometimes in impoverishment, sometimes in relative concentration, of the original values.

This zone of veins outcrops for a mile along the mountain side. At one point, some distance below the vein zone, free gold in fresh alaskite-pegmatite country rock was found.

In the main the other gold mines or prospects of the district have exactly the same geological relations.

LONE MOUNTAIN DISTRICT.

The ore deposits of this region are situated within a moderate distance of two masses of intrusive granitic rock, one of which makes up Lone Mountain Peak proper, while the other lies in the lower mountains to the south. The properties visited by the writer include the Paymaster, Esperanza, Utopia, and Alpine, the Weepah district, and numerous other mines and prospects. The first three mentioned all belong in the same class, being small, nonpersistent quartz veins in Cambrian limestone and slate. These veins are generally, but not always, parallel with the stratification. They follow crushed zones or selvages formed by movement in the limestones, possibly attendant upon faulting. The ore in the veins consists of small amounts of rich silver-copper sulphides, with some galena, pyrite, and secondary minerals such as chrysocolla, limonite, and probably chloro-bromides of silver.

The Alpine mine is situated near the contact of the Lone Mountain granite with a series of metamorphic marbles and some interbedded schists. In the marbles are seams of ore parallel with the stratification. Small quartz seams containing galena are low-grade silver ores. These lead into bodies of mixed galena and argentiferous lead carbonate, which widen out into irregular pockets and constitute the ore that is mined. The ore bodies follow a certain horizon around a hill, with lesser seams above and below. Diorite sheets and crosscutting dikes are frequent but are not in any way associated with the ore.

The area of intrusive granite above noted as lying south of the Lone Mountain granite is marked by considerable contact metamorphism in the limestone and shale into which it is intrusive. On its eastern side this contact metamorphism has been accompanied by some mineral deposition. There was here noted, interstratified with schistose slates and crystalline limestones, a metamorphosed belt about 60 feet wide and traceable for a long distance. This zone is characterized by epidote, garnet, chalcopyrite, calcite, magnetite, specular iron, pyrite, and galena, with certain secondary minerals—chrysocolla, limonite, and others. Some of the material gives fair assays for silver, some shows gold, and some it is claimed contains a considerable quantity of tin, although this subject has not yet been investigated by the writer. Some silver ore from this zone was milled at Columbus twenty-five years ago.

Weepah is situated at the contact of the granitic mass last mentioned, on its south side. It was discovered in the early part of 1902 by an Indian, and was located by a rancher named James Darrough. The find caused some excitement, and at one time about 200 people were there. It was bonded to a company for examination, but was not further developed, and was deserted at the time of the writer's visit. The openings are very slight, consisting chiefly of a few pits showing bluish quartz mixed with limestone. From these were taken a few tons of ore showing high values in gold, with some silver, but the ore bodies could not be followed.

DISTRICT NEAR DYERS.

On the west side of the Silver Peak Range near Fish Lake Valley and 1 mile east of Dyers is a mineral district where some prospecting has been done, although at present it is deserted. In 1885 to 1887 this district was located and was the scene of a short-lived excitement, but was afterwards abandoned. Following the Tonopah discovery it was relocated, but no new work was done. One of the mines was relocated under the name of the West Tonopah, which is surprising, considering that it is about 50 miles from Tonopah as the crow flies. Nearly all the ores here are bedding-plane deposits, of the same type as many of those near Lone Mountain. They occur in the Silurian limestone, within a moderate distance of a small body of intrusive granite. Along the stratification occur bunches of quartz, which are discontinuous both in horizontal and vertical extent, fading out to absolutely nothing. The quartz contains black copper-silver sulphide, which, when oxidized, yields stains of copper carbonate, iron oxide, and silver chloride.

WINDYPAH OR FESLER DISTRICT.

This district, which has only recently been opened up, lies in the southwestern part of the quadrangle in the Silver Peak Range, east of Piper's ranch. An abandoned mine or prospect—the Good Hope—has existed for many years a number of miles northeast of the district, in the same geological position, but the camp mentioned was discovered in the winter of 1903 by J. G. Fesler. A great deal of prospecting has been done, but no actual mining. There is here a large body of granitic rock, intrusive into Silurian limestones, and the ores occur in both formations. The veins may be divided into three distinct classes: (1) Segregations in alaskite, which is here locally intrusive into the granitic rock. These show good gold values in segregated bunches of quartz and in the adjacent siliceous alaskite. The quartz lenses are limited in size and have not been proved to have any regular connection.

(2) Quartz veins in granite: These have formed along crushed or sheared zones. The amount of quartz is variable and the walls are ill defined. The mineralogical character is like the first class of deposits. The gold values are locally good, but all workings up to the present have been near the surface.

(3) Veins near the contact of granite and limestone: Noble silver-quartz veins containing rich black sulphide, carrying copper, silver, and gold. These veins are very persistent, following the contact for miles, though different parts may not always be perfectly connected. Where noted, they follow the contact of alaskite dikes, which are probably border phases of the granitic inclusions. They do not have well-defined walls, and probably are to be regarded as replacements of the limestone along the dike contacts. Frequently a dike has such a vein on both sides, though more or less intermittently.

PALMETTO DISTRICT.

Such prospects of the Palmetto district as fall within the quadrangle were examined. The principal one is the old MacNamara, located in 1880. Although assessment work has been faithfully done upon these claims, they have not produced any shipping ore. The vein is near the contact of limestone with a large intrusive body of alaskite which itself is probably a border phase of a large granitic intrusion just south of this place. The ore occurs as quartz replacing and penetrating limestone on the under side of an alaskite dike. The limestone near the alaskite shows contact metamorphism, becoming altered to garnet, epidote, etc.

As an example of other prospects in the vicinity may be mentioned the Paymaster vein, which is a short distance south of the MacNamara, and, like it, runs in a northeasterly direction. This Paymaster must be distinguished from the Paymaster already mentioned as occurring in the Lone Mountain district. It was located eight or ten years ago, but was abandoned and relocated in 1902. The lead seems to be a long band in a contact metamorphic zone of the intrusive granite mass, this band being marked by garnet, specular iron, and auriferous quartz veins or lenses.

AURIFEROUS SAND DUNES.

A conspicuous bunch of large sand dunes appears in the southern portion of the quadrangle in the middle of Clayton Valley. These have been sampled as gold ores, and some relatively good assays have been obtained. As a consequence of this some very careful sampling has been done, but with unsatisfactory results. It seems to be the general outcome of all investigations that, except locally, the sand of these dunes does not contain more than a trace of gold. The sample taken by the writer assayed a trace of gold and silver.

SUMMARY.

To sum up the ore deposits of the Silver Peak quadrangle it may be repeated that they are all connected with intrusive granitic rock and lie either within this granite or (more often) in the Paleozoic limestone into which this is intrusive. The age of all the deposits is pre-Tertiary. The ores have been formed in part directly as ultra-siliceous segregations from the granite; in part by the action of solutions from the granite on the adjacent limestones. The most important district, the gold district of Silver Peak, belongs in the first class, and the others mainly in the second class. These others, except the Windypah district, as before stated, were prospected and abandoned years ago, and owe their recent activity directly to interest produced by the discovery of Tonopah. Many of the veins in them are not highly encouraging. However, some of the mines in the Lone Mountain district have recently produced considerable shipping ore; for example, the Alpine has shipped over $70,000 worth within the last year. Some of the prospects within the Windypah district appear worthy of investigation. The Silver Peak district proper is a vast treasury of low-grade gold ores.

NOTES ON THE GEOLOGY OF THE GOLDFIELDS DISTRICT, NEVADA.

By J. E. Spurr.

INTRODUCTION.

Interest has been aroused in the new camp of Goldfields, Esmeralda County, Nev. This district is situated 23½ miles southeast of Tonopah and about 6 miles due east of the old mining camp of Montezuma. Recently some good values in gold have been found; several hundred people have gone there, and ore has been sacked for shipment from some of the mines.

The writer visited this district in June, 1903, shortly after it had been located, and while only a few men were working. Some good assays had been reported at this time, while other attempts did not succeed in finding much over a trace of gold. The district then was known as the "Grandpa," but the name has since been changed. The writer's visit was a flying one, and no close examination was made, but such notes on the geology as were taken may prove of interest.

GENERAL GEOLOGY.

Topographically the district shows a number of low ridges. To the west are basalt-capped mesas, leading up into the higher mountains in the vicinity of Montezuma. The part of the district examined consists of one of the ridges mentioned, which runs in a north-south direction; this was followed for a distance of about 2 miles. On the north end of the ridge the rock is a very much altered rhyolite, showing strong flow structure, a glassy groundmass, and porphyritic crystals of quartz, orthoclase, and biotite, which are, however, almost always decomposed. Near the north end of the ridge the igneous rock is chiefly alaskite (quartz-feldspar rock), sometimes of granitic structure, sometimes coarse and pegmatitic, frequently very fine grained. A variation of this is quartz-muscovite rock which, when fine grained, resembles somewhat metamorphosed quartzite. Some of these quartz-muscovite rocks seem to have been originally such, while in other portions the muscovite seems to have formed in little blades at the expense of original orthoclase feldspar. A process of endomorphism similar to that described by the writer in similar rocks at Belmont,[a] is

[a] Spurr, J. E., Quartz-muscovite rock from Belmont, Nev.: Am. Jour. Sci., 4th ser., vol. 10, 1900, pp. 351-358.

suggested; and since muscovite is, like orthoclase, essentially a silicate of aluminum and potassium, but, unlike it, usually contains a weighable amount of fluorine, the action of this gas is probable. In one of the thin sections a crystal of probable fluorite was detected. Another variation is pure quartz, which occurs in the alaskite in small blotches, lenses, and even in masses 2 to 4 feet in diameter. All these are intrusive into a dark siliceous rock (jasperoid), which is probably the result of the silicification of an original limestone. By analogy with the similar geologic conditions in other districts in the same general region—as at Silver Peak and Belmont—we may suspect that the limestone is of Cambrian or Silurian age, and that the alaskite may be correlated with the granitic rock intrusive into the limestones in those districts.

The relation between the rhyolite and the alaskite is uncertain. Some phases of the alaskite are not distinguishable in the hand specimen from the rhyolite, and since they have about the same composition one is tempted to consider the hypothesis that they are differently crystallized portions of the same magma; but the strong flow structure of the rhyolite and its usually glassy groundmass indicate that, even if this is so, they were formed under different conditions and at different times, and that the rhyolite was formed near the surface, the alaskite at a considerable depth.

Auriferous veins.—The chief veins or ore bodies being prospected at the time of the writer's visit are broad masses of white to purplish and reddish, iron-stained, cherty quartz, extending irregularly in a northerly direction (N. 10° to 15° W.). There are usually no well-defined walls to these, and the width of the mineralized zones varies from many feet in one place to nothing in another. As reported, the assays made up to that time are very irregular, some average samples giving $25 to $50, others only a trace. The values of these are all in gold, very little or no silver being present.

When examined under the microscope, it was found that the ore is only a highly silicified rhyolite, and the rhyolite country rock, wherever examined, is itself much silicified. There are many of these silicified reefs, usually forming the crests or combs of ridges on account of their greater hardness.

Near the southern end of the principal ridge described, an average sample of the alaskite from many different places was taken. This contains a trace of gold and 0.11 ounce silver. In the same place a sample was taken of a lens of feldspathic quartz, segregated in the alaskite. This gave a trace of gold and 0.05 ounce silver.[a] This quartz and other similar lenses, however, are of a different type from the reefs of silicified rhyolite which form the principal ledges.

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[a] Assayed by a special, careful method by R. H. Officer & Co., Salt Lake City.

REPORTED GOLD DEPOSITS OF THE WICHITA MOUNTAINS.

By H. Foster Bain.

The Wichita Mountains occupy portions of Caddo, Comanche, Kiowa, and Greer counties, Okla., and for the most part are within the area formerly known as the Kiowa-Comanche Reservation, which was opened for settlement in 1901. They consist of a core of crystalline rocks, including granite, gabbro, porphyry, and certain greenstone dikes, the whole partially encircled by a fringe of Paleozoic limestones. The gabbro and porphyry are pre-Cambrian. The granite and the dikes, which include certain rare and petrographically interesting types, are eruptive through the older crystallines, but their relations to the sedimentaries are not certain. Mr. Taff, who made a reconnaissance map of the region in 1901, correlates the granite with a pre-Cambrian granite of the Arbuckle Mountains. The sedimentary rocks include representatives of the Cambrian, Ordovician, and Carboniferous.

For many years there have been rumors of the occurrence of gold and other ores in the mountains, and upon the opening of the country many mining claims were staked out. The miners have come into serious conflict with holders under agricultural and Indian titles, and as the evidence was somewhat conflicting it was thought necessary to make a special investigation of the reported ore deposits. This was accordingly done in October, 1903.

The mountains extend as semidetached masses about 50 miles west and 30 miles north of Lawton, the principal town of the region. Their general trend is a little south of east. The most important mountains occupy the east one-third of the area and form the Wichitas proper. West of them is a great mesquite plain extending to Otter Creek, and beyond that an area of scattered granite and gabbro peaks extending some miles beyond Red River. Meers, the most important mining camp on the north side of the mountains, is at the foot of Mount Sheridan and about 20 miles northwest of Lawton. Craterville is on the south side about 2 miles north of Cache. From Craterville to Oriana, on the edge of the mesquite plain, the mountains are being prospected at many points. Near Mountain Park, Wildman, and Roosevelt, towns in Otter Creek Valley, there are numerous prospects.

At Lugart, near the junction of the two forks of Red River and about 12 miles south of Lone Wolf, there is an additional group of prospects.

The important camps in the area extending from Lawton to Lugart were visited, and samples were taken from the leading mines in each camp. In every instance an effort was made to get samples from the prospects on which the most work had been done or where the most encouraging results were reported. It was thought that if some of these prospects had a demonstrable value others might reasonably be considered worthy of further effort, but that if the best prospects had no value, the less promising ones were not likely to yield any profit.

It was found that five modes of occurrence were being prospected: (1) Certain well-defined quartz veins which cut both granite and gabbro; (2) greenstone dikes which apparently cut indiscriminately all the crystalline rocks; (3) contacts of the granite and the gabbro, particularly where, as often happens, the granite sends off into the gabbro long apophyses or dikes usually assuming an aplitic phase; (4) disintegration products of the gabbro; (5) in a very few cases simple shear zones in the granite.

Some of the classes of occurrences enumerated are of the sort which, in view of the relations of the rocks, might well be expected to warrant prospecting. For example, quartz veins very commonly carry gold and other metals in sufficient amount to make the material an ore, though it is also true that many of the largest and best-defined quartz veins known carry no values or values so low as to preclude the working of the vein. On the other hand, shear zones in granite seldom have been found to carry ore, and when present it is only in the immediate neighborhood of well-recognized ore bodies of other types and of considerable richness. Since, however, assays are reported to have shown values in all the situations noted above, samples were taken from both probable and improbable occurrences, and in many cases where there seemed to be no reason to suspect any values at all, the owner or person in charge was invited to select samples of what he considered his richest material. In all cases where the workings were accessible samples were carefully taken from across the entire vein. Occasionally these were taken in duplicate, and usually with hand specimens of the wall rock and of any horses or included rock present, so that the occurrence of the ore might if necessary be studied in detail. Having in mind the disappointment which has so often come from incomplete or inaccurate sampling, the utmost care was taken to get fair samples of the material which would be shipped if mining should be carried on. As already suggested, where any bias was introduced it was in the direction favorable to the miner, and arose from taking picked samples of the better grade rather than average samples of the vein. Whenever possible with a reasonable expenditure of time the owner or his representative was invited to be present while the samples were being collected. All the usual precautions were taken to prevent possible mixing or salting of samples. Over 300 pounds of samples were taken, and each was opened and identified by the writer in the laboratory of the United States Geological Survey, where Dr. E. T. Allen, of the Survey, made 71 assays of these samples. None of these assays revealed any gold.[a]

In view of the precautions taken in collecting the samples, and of the great care with which they were assayed, the uniform absence of even a trace of gold and the only occasional presence of a small quantity of silver, copper, or lead admits of one conclusion—that none of the prospects examined shows any ore in the proper sense of the term, and that none has any present or probable future value. The possible exceptions are the Hale and the Clark and Bennett prospects in respect to copper and lead. A picked sample from the Hale mine showed 0.35 per cent of copper and a similar sample from the Clark and Bennett yielded 3.63 per cent of lead. In neither case is any considerable body of ore exposed. At the mine of the Kiowa Copper Company samples of material sacked for shipment assayed 10.81 per cent of copper. The mine was not open to examination, but the best data available indicated that the ore seam was only from one-half inch to 1½ inches thick, and therefore the find is considered unimportant.

Whether future prospecting may reveal other occurrences which do have value can not, of course, be stated with certainty at the present time. It is believed, however, that the prospects examined were fully representative and that they have, in many cases at least, been developed enough to admit of a trustworthy judgment as to their value. In no case do they offer any encouragement whatever for additional prospecting.

In the granite mountains west of Otter Creek there are certain coarse pegmatites showing crystals of quartz 3 or more inches long. With the quartz crystals are some small, black, semivitreous crystals recognized by Doctor Hillebrand, of the Survey, as belonging to the columbite-tantalate group. It is hoped that further investigation may reveal the presence of some of the rare earths.

Molybdenite in small quantity occurs on one of the claims of the Shawnee Mining Company near Meers.

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[a] The complete list of samples and detailed report of the assay has been published as Senate Document No. 149, Fifty-eighth Congress, second session.

ORE DEPOSITS OF THE NORTHERN BLACK HILLS.

By J. D. Irving.

INTRODUCTION.

In the several steps of its growth, mining in the Black Hills has followed closely the lines of its development in other regions. First the attention of the early prospectors and those who followed them was given to the more easily accessible deposits—the placers. As the value of these became evident, search was made for the source from which the gold in the placers was derived. The old gravel deposits which lie at the base of the Cambrian series were then found, and for a number of years yielded very good returns to those who had located on them. The impregnated lodes in the schistose rocks were then discovered, and the mines which have now become the famous Homestake belt were gradually developed. The lead-silver ores mined at Carbonate then became productive, and still further search revealed the beds of refractory siliceous ore which have of late years become of such very great importance; then the Ragged Top ores were found, and finally a variety of smaller deposits was discovered. Areas where ore bodies were easily accessible at the surface were first prospected, and the development of the more remote and more deeply buried ores slowly followed.

To make the description of the ore deposits clear, the general geological character of the Black Hills will be briefly described, and then the different types of ore bodies will be separately treated.

GEOLOGY.

Geologically, the Black Hills differ in some respects from almost any other region in this country. Surrounded on all sides by flat and rather barren plains whose general aspect is monotonous and without special interest, the Black Hills rise as an island, presenting within their borders geological problems of great variety and interest, diverse types of ore deposits, and studies in land drainage. From the very isolation and circumscribed character of this uplift many of its problems are easily grasped and understood, and are without the usual complicated connections with the surrounding country that make most geological questions so difficult to comprehend.

In his classic work on this region Henry Newton[a] has described the Black Hills as an elevated area, roughly elliptical in outline, comprising a central core of metamorphic crystalline rocks about which are grouped in rudely concentric belts strata of later geological age, dipping away in all directions from the elevatory axis or region of the hills.

Were the strata which originally covered the core of schists which forms the center of the hills still present, we would have an elevated dome of very great height, rising far above the level of the surrounding country. The gradual erosion of these uplifted rocks, however, has gone on together with their upheaval, so that there remains a region only slightly higher than the surrounding plains. In the center is the uncovered area of schists, and at the sides the stratified rocks dip outward beneath the flat prairie land beyond. This central core of old crystalline rocks has in general a due north-south direction, but at its northern extremity it turns abruptly toward the northwest, forming a sort of geological cul-de-sac, shut in on three sides by upturned strata, but separated from the main portion of the core to the south by a narrow belt of Cambrian rocks and their included masses of porphyry.

Throughout this northern area erosion has not cut so deeply into the crystalline schists as farther south, so that besides the rude belt of inclosing strata, isolated patches of the old sedimentary covering lie on the higher hills within the area of schists.

In the northern hills four systems of rocks can readily be distinguished from one another. The lowest series is composed of metamorphic schists. It consists of a series of crystalline mica-schists, mica-slates or phyllites, chlorite-schists, and laminated quartzites. Together with these are found, in the southern portion of the Black Hills and in the region known as Nigger Hill, large intruded masses of granite, very coarse in its texture and sometimes containing deposits of tin. In the northeastern portion of the hills there is no granite present, but its place is taken by numerous dikes and great irregular patches of a dark-greenish hornblende rock, termed amphibolite. Bodies of this rock are particularly noticeable in the vicinity of Lead, and extend as far south as Custer Peak. It is possible that they may have had some connection with the occurrence of gold in the Homestake mine, but there is no definite evidence in favor of this theory. These rocks are strongly laminated and are everywhere tilted at a high angle. The lamination often crosses the planes

[a] Newton, Henry, Geology of the Black Hills: U. S. Geol. and Geog. Surv. Rocky Mt. Region, 1880, pp. 1-222.

of original sedimentary banding, as can still be seen in many places. Numerous closely spaced folds are also seen to exist in the series, but the high degree of alteration that the rocks have undergone has now almost completely obliterated their original structure.

Above the metamorphic crystallines are the rocks of the Cambrian system. This system is composed of a basal conglomerate or coarse bed of cemented gravel, a thick layer of quartzite, and a series of alternating limestones, limy sandstones, and shales with some quartzite—in all a thickness of about 400 feet. Above these and still farther out from the center of the hills there is a yellowish limestone showing purple spots and belonging to the Silurian age. This is about 80 feet thick and comprises the third system. Above it comes the fourth system, a series of very heavily bedded gray limestones, pinkish at the base and averaging about 600 feet in thickness. These are of Carboniferous age and cover the other rocks throughout the entire western portion of the uplift.

There are present, besides these sedimentary rocks, eruptive rocks of several different varieties. The most abundant of these are rhyolite, either fine grained and white as in the vicinity of the Homestake mine, or coarse grained and darker colored as at other localities; syenite-porphyries, occurring chiefly in the vicinity of Deadwood and Two Bit Gulch; monzonite-porphyries; and phonolite. The latter is generally a dark-greenish or bluish rock, sometimes very coarse but usually exceedingly dense and fine grained. Other intermediate varieties of eruptive rock are also present in different places. The eruptive rocks, when found in the schist series, usually occur either as dikes which are parallel to the lamination of the schists or as large and more irregular masses which have no definite form. When in the Cambrian rocks they are generally sills or sheets which have spread out laterally to great distances along the planes of sedimentation; while in the Carboniferous they are less regular in form, sometimes occurring in short, thick sheets, again in dikes, and still more frequently in very irregular masses.

Much discussion has taken place as to the probability that the phonolites which are present in the Black Hills indicate a recurrence of the types of ore deposits found in Cripple Creek. While there are certain cases in which tellurides of gold have been found in the Black Hills, associated with phonolites bearing some resemblance to Cripple Creek ores, the existence of phonolites themselves in this region does not indicate that there is likely to be found a second Cripple Creek. Phonolites occur in many localities in the world (in Europe, Mexico, and elsewhere), and are in most cases not associated with ore bodies. That they may indicate future mineral wealth in the Black Hills is possible, but not at all essential.

ORE DEPOSITS.

If the placer workings, which are distributed widely over the entire hills, be excluded the productive mining region of the northern Black Hills comprises only a limited area of about 100 square miles. It extends from the town of Perry, on Elk Creek, where the Clover Leaf mine is situated, northwestward to the town of Carbonate, on the east branch of Spearfish Canyon, while its widest as well as most productive portion lies between Terry Peak on the southwest and Garden City on the northeast.

Within this rather restricted region are closely grouped together as many as nine distinct types of ore deposits. They occur in each case in a particular geological series, and are, with one exception, not found in the rocks belonging to any other formation. Classifying them according to the rocks in which they occur, the following five divisions of ore deposits may be distinguished: (1) In Algonkian rocks; (2) in Cambrian rocks; (3) in Carboniferous rocks; (4) in eruptive rocks; (5) in rocks of recent formation.

In the crystalline schists and metamorphic rocks of Algonkian age are found the free-milling gold ores, some small deposits of tin, and a few trifling prospects of copper, which have not yet assumed any great importance. In addition to these there are certain deposits of graphite which have lately attracted some interest.

In the Cambrian rocks there are gold-bearing gravels which lie at the base of the system, the refractory siliceous ores which have of late years become of great importance, the lead-silver ores of Galena and vicinity, and some deposits of wolframite which have from time to time produced considerable quantities of this mineral.

In the heavy, gray limestones of the Carboniferous there have been found in the vicinity of Ragged Top Mountain high-grade siliceous ores, and at the town of Carbonate the same rocks have yielded large amounts of lead-silver ores closely resembling those of Leadville, Colo. A few deposits also occur in eruptive rocks.

In the latest rocks of all—the gravels which fill the beds of modern streams—have been found the placer deposits, and while they are now chiefly of historic interest as representing the earlier development of mining in the hills, they have in past years produced heavily.

ORE DEPOSITS IN METAMORPHIC ALGONKIAN SCHISTS.

Since the attention of miners has been diverted from the gold-bearing gravels, so frequently the first producers of a mining region, the free-milling ores which occur in the Algonkian schists have assumed an increasing importance in this region, until now they are the heaviest producers and constitute by far the most prominent factor in the gold production of the region.

There are in general two areas where ores of this character have been discovered. The first is the great Homestake belt; the second, the Clover Leaf or Uncle Sam mine, some distance southeast of the first.

As a report will soon appear by Mr. S. F. Emmons, discussing in detail the geological structure of the Homestake mine, the writer will give only a brief summary of this important ore zone, gathered in large part from previously published reports and in part from personal observations.

Homestake belt.—The Homestake belt is a term which has been applied to a series of mines operated on a great gold-bearing zone in the metamorphic schists in the vicinity of Lead, S. Dak. It comprises a group of mines which are known severally as the Homestake, Deadwood-Terra, Father de Smet, and Caledonia, but as the Homestake Company has exercised an increasingly important influence in the management, its name is now generally applied to the entire belt. The surface workings or open cuts from which the ore was first extracted in the early days of its history indicate in a broad, general way the location and trend of the lode. The Caledonia ore body is distinct from that operated in the other mines, and lies to the east of it. The Homestake ore body is not a true fissure vein, but is a broad, impregnated zone in the schists, which strikes approximately N. 34° W. and is slightly at variance with the general direction of the lamination of the schists. There seems to be a rough dip to the east, but the ore is so irregularly related to the rocks in which it occurs that the general inclination can not be given with any degree of accuracy. The ore body pitches noticeably toward the south, so that at the southernmost portion yet opened up it is much more deeply buried than at the northern end. Alternating with the lenses of ore, and also to the east of them, are many dikes of white, fine-grained rhyolite which have passed upward between the lamination planes of the schists and spread out in broad, flat masses in the nearly horizontal Cambrian strata that cap the hills to the west, north, and east of the ore zone. In places most of the stratified rock into which these porphyry masses have been intruded is now eroded, and on the summits of the divides which separate the open cuts little is left but the thick sheets of rhyolite. As the porphyry bodies which form these sheets were followed downward in the mine workings they became gradually thinner and fewer in number, the eruptive rock having apparently spread out as it came nearer to the surface and formed branching masses of a lenticular form. The first ore which was mined in the early days formed great irregular lenses included almost wholly within these dikes of porphyry, but as it was followed downward it seemed to diverge from the porphyry bodies, and in the deeper levels of the mine is apparently entirely independent of them. It is an interesting fact that in the lower levels a mass of phonolite of a dark-greenish color has been found closely associated with the wider portions of the ore zone. No definite foot wall or hanging wall to the ore can be detected, because it is in many cases difficult to distinguish the mineralized material from the barren country rock.

It seems probable that the Homestake lode, owing to its mineralized character, was a harder and more resistant ledge than the surrounding schists of the Algonkian, and that for this reason it constituted a reef in the old Cambrian seas before the sedimentary rocks above were deposited. That it was then mineralized and gold-bearing is proved by the presence of gold in the basal or lowest rocks of the sedimentary series which lie in the isolated patches about the outcrop of the ore body.

The ores of the Homestake belt taken as a whole can not be said to present any constant features which serve to distinguish them from the characteristic but barren rocks of the Algonkian series. Pyrite is by far the most invariable indication of mineralization, but it is notably absent from much of the ore. Quartz also occurs in a great number of cases. Perhaps the most usual type of ore would be that consisting largely of quartz and pyrite. Other minerals are dolomite, calcite, and arsenopyrite; these are also of very frequent occurrence, but no decrease in the values of the ore can be noted when they are absent. Again, garnet and tremolite appear in some portions of the ore in such abundance as to constitute the larger part of the gangue, but the ore here found does not differ in value from that having a wholly different appearance. It would seem that when the ordinary type of schists is mineralized the ore more closely resembles a schist, but when the amphibolite is mineralized the ore more closely resembles an amphibolite. Thus it will appear that although pyrite, quartz, dolomite, calcite, arsenopyrite, tremolite, and garnet frequently constitute, either separately or in combination, the gangue of the ore, no one of these minerals can be considered an indication of the presence of gold. In general, however, it may be said that the ores occupy a zone in the Algonkian rocks which presents a greater number of secondary minerals, a more constant occurrence of sulphides, quartz, dolomite, calcite, and arsenopyrite, and, finally, a more advanced degree of distortion and irregularity of structure than do the barren areas of the same formation.

From a careful study of the ores and the general structure of the Homestake belt, it appears first, that there have been several different periods of mineralization, at least one of which has preceded the deposition of the Cambrian rocks, as is distinctly shown by the presence of placer gold in the lowermost gravel beds of the Cambrian series; second, that there have been periods of mineralization which followed the entire deposition of the sedimentary rocks and were later than the intrusion of the dikes and bodies of rhyolite. It is probable that this belt has been the seat of much fracturing and crushing from very early geological time until the present, constituting a line of weakness along which mineralizing waters were permitted to circulate more freely than elsewhere. Impregnation of the country rock at successive periods with vein minerals and small amounts of gold has thus given rise to a workable zone of gold-bearing rock.

In the earlier days of the mine the ore was completely free milling and of higher grade than that now mined. It was highly oxidized, and contained little or no sulphurets. As the workings penetrated deeper, oxidized material gave place gradually to sulphides, and more and more of the values in the ores failed to yield to amalgamation. For a time the concentrates from the mine were sold to smelting companies, but experimentation on their treatment gradually led to the construction of a cyanide plant with a view to treating the more refractory portions of the ore.

It has been assumed by many who have written upon the geology of these ore bodies that the rhyolite-porphyries which occur in intimate association with them have enriched the ore, but there is no evidence to support this theory.

The Homestake mine has, since its opening, been an illustration of the manner in which a large body of low-grade ore handled on a large scale could be made to yield great profit. Its successful operation has been due chiefly to the care with which it has been managed and the great business ability of those who have handled it.

Clover Leaf mine.—The other mine which has been operated on Algonkian ores is known as the Clover Leaf mine (formerly the Uncle Sam), and is not far from Perry station, on the Black Hills and Fort Pierre Railroad. Compared with the Homestake belt its production is comparatively small, but it is of singular geological interest. The ore body is a large, saddle-shaped mass of quartz inclosed in the metamorphic schists, with its apex striking N. 64° W. and pitching to the southeast at an angle of 40°. The horizontal section of the quartz body as exposed on the 250-foot level has the appearance of the letter U, with slightly flaring arms. The northern arm strikes N. 40° W., the southern S. 75° W. This quartz body is thickest at the crest, and the lamination of the inclosing schist is parallel to its surface, curving around it so as to give to the mass the appearance of a folded lens at the crest of a southeast-pitching anticlinal fold in the Algonkian schist. Both of the arms of this quartz mass when followed out from the apex become much narrower than the main body, the northwesterly having an average width of 20 feet, the southwesterly of about 10 to 12 feet. The gold is contained chiefly in the quartz, in which it often appears free and generally associated with small particles of galena. The quartz and the encompassing schist are heavily impregnated with pyrite, which at the surface is completely oxidized. The ore is treated in a stamp mill and amalgamates readily.

Besides these gold-bearing lodes, deposits of tin occur in rocks of Algonkian age, notably in the southern portion of the hills and in the region to the west of Spearfish Canyon, known as Nigger Hill. The country rock in which these deposits occur is apparently a coarse muscovite-granite, and the cassiterite or tin oxide is scattered through this rock in irregular patches, increasing and decreasing in amount with little or no regularity. At the time of survey none of the deeper workings were accessible. In the earlier days of mining in the Black Hills, the tin ore attracted, as is well known, considerable interest, but the unfortunate character of the enterprises which were connected with its exploitation have much retarded its development. The cassiterite occurs also in placers as stream gravels which have been derived from the disintegration of the country rock containing the tin. The cassiterite in these gravels is but little rounded, and differs in its black color from the usual reddish-brown type of stream tin so commonly found in the vicinity of tin-bearing lodes.

A few small prospects of copper have been found at different places in the schist areas of the northern Hills, but they have not yet proved of sufficient size or regularity to attract serious attention.

MISCELLANEOUS DEPOSITS IN THE ALGONKIAN ROCKS.

At several localities within the productive mining region ores have been found which may properly be described with the Algonkian lodes. They are partially in eruptive rocks and partially in brecciated material composed of schist and porphyry, while at times they form veins which pass from schist into porphyry; at other points they pass from porphyry into Cambrian rocks. While none of these have yet attained any great importance, there are two that deserve special mention. The first is in Strawberry Gulch, where a large number of small mines have been intermittently worked. Much of the ore occurs in a decomposed porphyry in the form of thin auriferous limonite fillings in small fractures, or of impregnations in the country rock. In general, these pass downward into unoxidized pyrite, while in a few cases sphalerite and galena have been reported. The porphyry mass in which these ores are found is extremely large and so irregularly intruded into the schists that its relation to them can not readily be made out. Some of the ore obtained from the mines is reported to have been very rich, but it has so far been too irregular in its occurrence to form the basis of extensive mining. The second locality where ore has been found, which is chiefly in porphyry, is the Old Ironsides mine, near the mouth of Squaw Creek. Here, at the side of the creek, is exposed a sheet of mica-diorite-porphyry about 40 feet thick, with beds of Cambrian rock both above and below. Through these rocks run a series of vertical fractures striking about N. 85° E., along which silicification has occurred and from which telluride of gold has been introduced into the adjacent rock, often to considerable distances from a fracture. Some of the crystals of telluride—presumably sylvanite—are rather large. The deposition has occurred chiefly in the diorite-porphyry, but also to a minor degree in the Cambrian rocks. At the surface where the rocks are highly oxidized, gold may be seen along the fractures in a free condition. There are other places in which ore has been found in eruptives, either as fillings of fissures or as impregnations, but they are not of any economic value. The eruptive rocks as a whole have not been the loci of considerable deposits.

ORE DEPOSITS IN CAMBRIAN ROCKS.

As a producer of gold the Cambrian is second in importance only to the Algonkian system. In the rocks of Cambrian age, or those which lie immediately above the metamorphic schists, there are four varieties of ore: (1) the gold-bearing conglomerates or gravels, generally known as the cement deposits; (2) the refractory siliceous ores; (3) the pyritic ores; and (4) the lead-silver ores.

The gold-bearing conglomerates.—At the base of the series of Cambrian strata immediately above the upturned schists there is generally a bed of gravel. It varies in thickness from a few inches to more than 30 feet. Throughout a large number of areas where the Cambrian strata yet remain uneroded this conglomerate is generally about 3 or 4 feet thick, and passes upward into a hard, dense quartzite, which has a vertical range of from 15 to 30 feet. This quartzite is almost invariably present at the base of the Cambrian series. The gravel is generally thin, but attains a notable thickness in a few localities. One of these, in the vicinity of Lead, is of unusual economic importance, as here the gravel is gold bearing, and has produced very heavily in the past. The productive areas of this gold-bearing gravel are closely grouped about the Homestake belt. They are five in number. One, comprising the Durango and Harrison mines, is west of the Homestake lode, near the southern extremity of the present outcrop. The other four, east and north of it, include the Hawkeye, Monitor, and Gentle Annie. One of these lies just east of the Caledonia open cut; another on the divide between Blacktail and Deadwood gulches; the third on the divide between Blacktail and Deadwood gulches, and the fourth on the north side of Blacktail Gulch beneath a heavy capping of rhyolite which forms the high ridge beyond. The gold-bearing conglomerate occupies irregular depressions in the old schist surface, and was probably not uniformly distributed along an old shore line. It thins out to nothing along the strike of the Homestake lode, and allows the higher measures of the Cambrian to lap over onto the mineralized rock of the Algonkian. A general downward inclination of the schist surface toward the northeast may also be observed.

It is not possible to give exact boundaries to the original extent of these gold-bearing gravels on account of the dissected nature of the areas which now remain. The gravel is composed of rounded, waterworn pebbles of quartz and quartz-schist and a few fragments of softer schist, which seem to decrease in abundance as the distance increases from the Homestake lode, that is, from the old pre-Cambrian shore line. The gold-bearing portions of the gravel may be at once distinguished from those which are barren by the character of the material which cements the pebbles. In the gold-bearing portions this is chiefly oxide of iron when weathered, or pyrite when it has not suffered alteration. The nongold-bearing portions, on the other hand, have a rather sandy, quartzose matrix, or are in some instances slightly calcareous. The gold in the richest portions of the conglomerate—those first mined—is chiefly placer gold, for it is rounded and worn by attrition and is concentrated near the bed rock. It was undoubtedly derived from the erosion of gold-bearing lodes in the Algonkian rocks and mechanically deposited in depressions along the old shore line. Some of it has been dissolved by ferric sulphate, which has resulted from the oxidation of the pyrite, and has been redeposited from this solution in thin films in the laminæ of the underlying schists. This has also produced an enrichment of the lowermost layers of the conglomerate. Besides these two types of gold which occur in these conglomerates, it is also possible that gold was introduced with the pyrite which either cements or once cemented the pebbles. The introduction of pyrite was subsequent to the deposition of the conglomerates, since it penetrates fractures in the quartz pebbles and is probably a replacement of the original quartzose cementing material. Intrusions of rhyolite cut the conglomerate in many places, and are often heavily impregnated with pyrite. The close relation between these gravel deposits and the Homestake lode, together with their absence along its line of outcrop, seems to indicate that the Homestake zone projected above the level of the surrounding rocks and formed in the old Cambrian sea a reef about which these gravels were deposited. The greater portion of their gold was thus, with little question, derived from the disintegration of the old Homestake lode. They are not exactly equivalent to the gold-bearing sands in the Nome district of Alaska, but are somewhat exceptional, not only because they are the only representatives of what may be termed fossil placers, but because they were not uniformly deposited along the shore, having been confined to the vicinity of an outcrop of a large gold lode, and the detrital material from that lode being held in irregular depressions in the submarine surface in its vicinity.

Refractory siliceous ores.—Of all the ores occurring in rocks of ages later than the Algonkian, the refractory siliceous ores have thus far been the most important factor in the gold production of the northern Black Hills. They are widely distributed over a large area extending from Yellow Creek on the southeast to Squaw Creek on the northwest in a broad, irregular belt. This belt includes five productive areas, which will later be discussed. The country rock in which the ore occurs is a crystalline dolomitic limestone of fine-grained texture and varying like the ore in its degree of oxidation. It is termed "sand rock" by the miners. In its fresh condition it is a dense, gray, crystalline rock, showing innumerable small cleavage faces of dolomite that are generally interrupted by bands of greenish-black shale of varying width. When oxidized it has a deep-red color, but presents the same crystalline texture, while with very advanced alteration it passes into a red, earthy material termed "gouge." Chemical analysis of this rock shows it to be a dolomite of nearly normal composition, while the microscope shows that it is composed of either (1) irregular grains of dolomite with some scattered grains of quartz or (2) of clearly bounded rhombic crystals of dolomite. When the latter type of rock has been mineralized the rhombic crystals of dolomite are altered to silica and often beautifully preserved.

The dolomite beds which have so far been most extensively prospected occur at two positions in the Cambrian series. The first is immediately above the basal quartzite, from 15 to 25 feet above the schists of the Algonkian, and is known as the "lower contact;" the second is from 18 to 30 feet below the Scolithus or so-called "worm-eaten" sandstone that forms the top of the Cambrian series, and is termed the "upper contact." Many other beds of dolomite occur at intervening levels, and prospecting shows them to be very frequently mineralized. There has been as yet but little systematic search upon the latter beds, and it is very probable that they may become important ore horizons in the future.

The ore is an extremely hard, brittle rock, composed largely of secondary silica, and carrying, when unoxidized, pyrite, fluorite, and, at times, barite, wolframite, stibnite, and jarosite. It shows many cavities which are lined with druses of quartz crystals or contain cubes of fluorite in clusters. Some of the cavities show large crystals of barite. In some localities the siliceous ore is heavily charged with wolframite, so that in many instances it grades from beds of siliceous ore into flat bodies of almost pure wolframite. Occurrences of this kind are found in the Yellow Creek and Lead areas. When carrying large quantities of wolframite the ore usually contains great quantities of barite. The ore occurs in flat, banded masses in which the banding is continuous with the bedding planes of the adjoining strata. These masses possess a somewhat regular, channel-like form, and follow zones of fracture that vary for the separate districts in their general direction, but exhibit a very uniform trend within the limits of any single productive area. These channel-like ore bodies are known as shoots, and have a width of from a few inches to, in rare instances, 300 feet. The average width is perhaps about 30 feet, although all widths between 5 and 100 feet are of frequent occurrence. The length is in all cases many times in excess of the breadth, and in the case of the Tornado-Mogul shoot is about three-fourths of a mile. The vertical dimensions vary from a few inches to a maximum of 18 feet. The average thickness is about 6 feet. The shoots generally follow either single fractures which are parallel to their longer diameter or broad areas of parallel or intersecting fractures. The beds of rock that lie above the ore are generally shale of a more or less impervious character, but sills of eruptive rock not infrequently play the same rôle. On the lower contact the floor is sometimes of basal Cambrian quartzite, but in many cases varying thicknesses of dolomite intervene between the quartzite and the ore. In such cases the widest portion of the shoot is directly beneath the impervious rock of the roof, for the solutions have spread out and replaced dolomite for a great distance along the under surface of the impervious rock. The shoots have thus a wedge-shaped form in many cases, the broadest portion of the wedge being at the top.

The fractures.—When the ore that forms the body of a shoot has been removed the fractures by which the mineralizers have gained access to the rock replaced may be traced in the overlying, and where they are uncovered, in the underlying beds. These fractures have been rendered prominent by a slight silicification of the adjoining rock, which has often caused them to project from the softer shaly material; they are frequently iron stained. These silicified, iron-stained fractures are commonly known as "verticals." They may be observed in greater or less number in all the shoots of the refractory siliceous ore. The fractures are generally slightly warped surfaces along which a little movement has occurred, or they may be composite zones of fracture caused by the intersection of many small, irregular fissures. The displacement along such planes of movement is generally very small—not more than 2 or 3 inches—but it sometimes reaches 6 or 7 feet. They are usually without appreciable open space, for the walls have not generally been removed from one another for distances greater than one sixty-fourth of an inch. Some notable exceptions occur. The verticals frequently extend into the beds that form the roof of the ore bodies, but sometimes terminate in the ore-bearing beds themselves. They have also been traced through the lower quartzite into the Algonkian below, but on entering that formation their traces are lost in the vertical laminæ of the schists.

Productive areas.—The productive areas of refractory siliceous ore are five in number, and have been severally designated Bald Mountain area, Yellow Creek area, Lead area, Garden area, and Squaw Creek area. The last named was at the time of survey little more than a prospect, but it has since become an important producer. The Bald Mountain area is the most extensive and important. It is a northwest-southeast belt, about 1 mile in width and 4½ miles in length, the width being limited by the annular exposure of Cambrian rocks that surrounds the Algonkian nucleus of the region. The ore-bearing strata dip to the southwest and pass beneath the Silurian and Carboniferous limestones, while, except in a very few instances, they have been eroded from the Algonkian hills to the northeast. Hence, on the north, the ore bodies are exposed at the surface, but to the south shafts are necessary to reach them. At the southeast end this area is cut off from the Yellow Creek area by Whitewood Creek. At the northern end the Cambrian rocks are present in nearly their full thickness. With relation to the ore bodies, the area may be divided into two portions, the Ruby Basin district and the Portland district. In the former the shoots are larger in the lower ore-bearing beds; in the latter, larger in the upper.

The Garden area is situated at the head of Blacktail and Sheeptail gulches and an east tributary of False Bottom Creek. It is located on the northern, as the Bald Mountain area is on the southern, rim of the Cambrian outcrop. The beds dip to the northeast and the shoots so far mined have been on the lower contact. A rhyolite cap of great thickness and extent covers the country to the north and the Cambrian beds pass beneath it. The average trend of the ore bodies here is about N. 55° E., much more nearly east-west than in any of the other areas.

The Lead area is located on one of the Cambrian outliers that caps the hill north of Deadwood, and the ore bodies extend over the gold lode of the Homestake mine. A heavy sill of fine-grained rhyolite lies above the Cambrian on the tops of the hills. The ore bodies are exposed at the surface on the westernmost edge of this area, but lie beneath the shales to the east. The ore from this district is richer than that elsewhere mined, and contains great quantities of barite, wolframite, and in several instances large amounts of free gold. The Hidden Fortune mine is an instance of this kind.

The Yellow Creek area is situated a little more than 2 miles slightly east of south from the city of Lead. The ore shoots are in a thin capping of Cambrian strata on the divide between Whitewood Creek on the west and Yellow Creek on the east. The shoots lie on the basal quartzite about 15 to 26 feet above the Algonkian. Much wolframite and barite are also found in the ore from this area.

The Squaw Creek area lies near the mouth of Squaw Creek. Workings have been run upon some ore-bearing beds which pass rapidly beneath the Carboniferous limestones that cover the country to the north. The horizon is just beneath the scolithus or "worm-eaten" sandstone. Ore bodies of considerable size have recently been opened here and the district has become a productive one.

Value of the ores.—The gold contents of the ores in the Bald Mountain area run from $3 or $4 per ton to, in rare instances, $100. The general average for the ores in this district is about $17, those containing from $10 to $20 being of the most common occurrence. Ore carrying $35 per ton is considered high grade. Some of the ore from the Ben Hur mine has yielded upward of $60 per ton in gold. As compared with the ores of the lower beds, those from the upper contact are of slightly poorer grade, so that much of the ore is often left in the mines. The upper ores have also been reported to carry a higher relative proportion of silver, but although this is true in individual instances, in general, silver ores are as frequent in the lower as in the upper beds.

The three smaller areas of siliceous ore, Yellow Creek, Lead, and Garden, lying over or to the west of the Homestake ore body or its continuation, produce ores of uniformly higher grade than those from the Bald Mountain country. The mineralization is probably later than the igneous activity, for the verticals which supplied the ores often cut all varieties of eruptive rocks.

As igneous rocks cut strata of the Fort Benton Cretaceous and pebbles of the same rock have been found in the basal conglomerates of the Neocene, it would seem then that the mineralization occurred somewhere between Fort Benton and Neocene times, and it probably represents the final phase of volcanism that was concomitant with the elevation of the Black Hills. This occurred while the Cambrian was still deeply buried beneath its covering of later formations.

Lead-silver ores of Galena and vicinity.—The ores belonging to the fourth division of Cambrian ore deposits are similar in form and mode of occurrence to the refractory siliceous ores. They occur in the vicinity of the town of Galena.

At one time these ores filled an important place in the mineral production of the Black Hills. About twenty years ago a smelter was in operation and several mines were producing heavily, the Richmond or Sitting Bull mine especially having figured prominently in the silver production. After a brief period of activity, however, operations were rather abruptly discontinued and the district was idle until the year 1886, when operations were resumed, although upon a somewhat smaller scale. Work is now being conducted in a rather desultory manner. Mines that produced lead-silver ores are situated in and about the town of Galena. Most, if not all, of the ore bodies are in strata of Cambrian age. Some of the principal producing mines were the Richmond, Florence, Hester A, Coletta, Merritt No. 2, Cora, Carpenter, Alexander, Romeo, and El Refugio.

The ore is of a more basic character than that found in the more westerly ore deposits heretofore described. When unoxidized it consists chiefly of pyrite, which is either massive or disseminated more or less thickly through the body of the country rock. With the pyrite is associated argentiferous galena and, not infrequently, small quantities of sphalerite. In many cases the galena occurs as minute crystals lining the interior of druses, or in seams in the pyrite, and wherever they have not been oxidized these two minerals are found associated in this manner. The galena is, therefore, of later origin than the pyrite; occasionally the latter carries low values in gold, but these are unimportant. The values that render the mines workable are contained in the argentiferous galena. In most cases there is but little silica associated with the ores, but in the Florence and Richmond very considerable amounts of secondary silica are found in intimate association with the deposits.

Origin of the ores.—The refractory siliceous ores have been formed by a process which involved the gradual removal of the original rock substance and the simultaneous substitution of the ore minerals. This is commonly known as replacement or metasomatic alteration and has often proceeded with so little disturbance of the original rock material that both stratigraphic character and microscopic structure are preserved in the ore, although the original rock was carbonate and the ore is chiefly silica. The mineral which has been altered to form ore seems to have been exclusively dolomite, for where verticals pass through rocks of varying composition it is found that the dolomite alone has been appreciably affected. The ore minerals substituted are chiefly silica and pyrite, with which there are minute amounts of gold and silver. Smaller quantities of fluorite, barite, gypsum, and several other accessory minerals are also of frequent occurrence. To the dolomite, whether present as comparatively pure beds or as cementing material of sandy and shaly rocks, the ore minerals have been transported by circulating waters. Such waters have found in the fractures trunk channels, by means of which they have been enabled to penetrate the encompassing and comparatively insoluble rocks and reach the more readily replaced material. The mass of evidence seems to show that these waters have ascended.

ORES IN CARBONIFEROUS ROCKS.

In the heavy, gray limestones of the Carboniferous are found two distinct varieties of ore: (1) Gold and silver ores of a refractory siliceous type; (2) lead-silver ores. In general, the Carboniferous rocks have not figured largely in the mineral production of the region.

The refractory siliceous ores are in bodies of comparatively small size and are of less importance than those which occur in other formations. Two districts, the Ragged Top and the Carbonate, have been important producers.

The Ragged Top district comprises the country which lies to the northwest of the large mountain of phonolite, known as Ragged Top. There is here a series of seven nearly equally spaced vertical fissures or veins, which have been termed the Ragged Top "verticals." These fractures or crevices in the heavy, massive limestone show at the surface a maximum width of about 10 feet, and narrow, as they pass downward, to extremely minute crevices. In the lower portions where the surface alteration has not been extensive the ore can be observed to pass laterally into the limestone walls without disturbance of the structure of the latter rock. The ore is of a light, uniform, buff tint, which is so nearly the color of the surrounding limestone that it is difficult to distinguish it from the unmineralized rock. It differs in its superior hardness and slight yellow color. Much of the ore is composed of angular, brecciated fragments of what was once limestone but now is completely altered to silica. Traces of tellurium have been detected in these ores. At some points in the limestone area about Ragged Top Mountain flat, blanket-like beds of ore are found. These are either without distinct connection with the verticals or seem to have spread out from them. Some of the ore from these verticals was very rich, and in general it carried higher values than the siliceous ores found in the Cambrian rocks.

These Carboniferous siliceous ores have not at any time been very heavy producers, but have yielded small amounts of ore for some years. They have recently been successfully treated by the cyanide process.

Lead-silver ores.—Lead-silver ores were in the earlier days of mining in the Black Hills a very important factor in the production of precious metals. They were found in the vicinity of the town of Carbonate, which was in 1886 a flourishing camp, producing considerable silver and lead. The product was almost exclusively from the Iron Hill mine, but other mines in the neighborhood added a little to the total.

The country rock that carries the ore is the gray, Carboniferous limestone, in which sills, dikes, and irregular masses of porphyry have been intruded. The ore bodies are of two kinds—large, irregular bodies of lead carbonate, which pass in places into more or less unaltered galena, and generally lie in close contact with porphyry masses, and partially filled crevices which resemble in a general way the verticals of Ragged Top.

The first type of deposit is that which has formed the chief source of silver in the district, and this, as shown above, was largely obtained from the Iron Hill mine. In this mine the ore was a large mass of argentiferous lead carbonate extending down 300 feet on the east side of a thick dike of fine-grained, white porphyry. Much galena also was found together with the carbonates, and after the ore was worked out a seam or vertical was detected extending downward from the main mass. Other pockets of ore were also found at different points, and in one place a pocket of vanadinite containing 4 or 5 tons was encountered. Mr. Fowler[a] reports the occurrence of the following minerals: Galena, cerrusite, cerargyrite, matlockite, wolfenite, pyromorphite, plattnerite, atacamite, and vanadinite. This type of ore resembles in its general character and in its association with porphyry bodies the deposits of Leadville, Colo., described by Mr. S. F. Emmons.[b] From the workings now accessible too little can be determined regarding the details of the ore occurrence to afford any more definite idea of the manner in which it originated than the simple fact that it is probably a replacement of the limestone.

Of the second type of occurrence the most important case is that at the Seabury mine. This consisted of an irregular crevice striking S. 85° W. and running through the Seabury, Iron Hill, Segregated Iron Hill, and Adelphi mines, with a possible continuation in the Spanish R, a mine in which some ore was obtained, but at too great a distance for its relation to the others to be clearly made out. This crevice varies from 1 to 20 feet in width. The sides consist of a ferruginous jasperoid material which replaces the limestone, often for 2 or 3 feet from the crevice, and contains at times galena, lead carbonates, and horn silver in sufficient amount to be profitably worked. The latter mineral most frequently occurs as a thin film, covering druses of fine quartz crystals, which form linings to cavities.

The center of the crevice is loosely filled by a soft, ferruginous, gouge-like matter of a pinkish-red color and containing gold. A large quantity of this ore is reported to have been mined from the Seabury, and also from the west side of the porphyry dike in the Iron Hill.

Since 1891 there seems to have been but little work done in this district, no output being recorded for that period. Within the last year, however, a small, 35-ton cyanide plant has been erected to treat the tailings from the old smelter.

In concluding this brief review of the ore deposits of the northern Black Hills, it seems well to add a few words on the future prospects of the region.

Mining communities are, owing to the limited extent of the deposits on which their activity is based, generally short-lived. That this is true a glance at the history of many western mining camps will show. A few, like Leadville, have been productive for many years, and will probably continue so in the future, but there are few, if any, which, if dependent wholly upon mineral production, will not in time cease to thrive as their economic resources become exhausted.

[a] Oral communication.

[b] Emmons, S. F., Geology and mining industry of Leadville: Mon. U. S. Geol. Survey, vol. 12, p. 545 et seq.

If the production of mineral wealth be prolonged sufficiently for the activities of the community to be directed along other lines, what was once a mining camp may become a permanent settlement. In the Black Hills there are perhaps two features which may operate to give to the region a greater permanency than that which is generally seen in communities supported solely by mining interests. The first is the unusual size and the presumably long life of the mines of the Homestake belt. The second is the gradual decrease in the cost of treatment of other grades of ore, and the consequent opening of the market to material previously known but hitherto unworkable. The introduction of the cyanide process and the fact that large quantities of low-grade ore may be treated by its use have done much to extend the life of Black Hills mining. It is not improbable that these two factors working together may so prolong the mineral production of the region that the population may never be less than it now is. Other interests which grow side by side with the mining industry may in the future become so important and so little dependent on the mineral wealth of the country that their existence alone will be sufficient to support the cities which have grown up in this mining country.

PROGRESS REPORT ON THE PARK CITY MINING DISTRICT, UTAH.[a]

By J. M. Boutwell.

INTRODUCTION.

Field work.—In August, 1902, the detailed study of the economic geology of the Park City (Utah) district was undertaken by J. D. Irving and the writer. At the close of the season, late in December, the detailed geologic mapping of a considerable portion of the district on a scale of 3 inches to a mile, the larger part of the geologic mapping of the heart of the district on a scale of 1 inch to 1,000 feet, and a reconnaissance of the principal producing mines had been accomplished. The salient features of the geography, geology, and ore deposits which had then been studied have been briefly described in a progress report.[b]

Early in August, 1903, this detailed geologic mapping was again taken up, and after being completed late in the fall the detailed study of the underground geology and of the ore deposits was begun. This underground work is now in progress. In the work of this season the writer has been assisted by L. H. Woolsey, and toward the close of the year, for about seven weeks, by A. M. Rock.

Early in the season the Director of the United States Geological Survey visited the party en route to and from special field work in a neighboring range. Dr. C. W. Hayes, geologist in charge of geology, also spent a few days in the district investigating some of the problems under consideration, and Dr. T. W. Stanton, geologist in charge of paleontology, devoted ten days to field study of certain questions of stratigraphic and paleontologic correlation. Dr. G. H. Girty has examined the fossils collected during the season of 1902 and several additional lots of fossils collected for purposes of special cor-

[a] The complete report on the final results of the work in this district will be published as a professional paper.

[b] Boutwell, J. M., Progress report on the Park City mining district, Utah: Bull. U. S. Geol. Survey No. 213, 1903, pp. 31–40.

relation during the present season, and has rendered thereon a preliminary report.

The product of the field work during these two seasons consists of a somewhat detailed knowledge of the leading events in the geologic history of the central Wasatch Mountains and vicinity, a large body of precise geologic data regarding the immediate Park City district, and much valuable information about the ore deposits of the camp. Obviously, in the course of actual field work, which at date of writing is still in progress, there has been no suitable opportunity for thorough correlation of field data. Before final conclusions can be reached, such correlation and systematic office study of this material will be required. Certain results, however, which it is hardly expected will be materially altered by further study and which are of direct significance in current exploration and exploitation, may be tentatively stated for immediate utilization. It is to be clearly understood, however, that these preliminary statements in this rough, generalized field sketch are subject to such modifications as may be required by further studies.

In the first report of progress brief descriptions were given regarding the general geology and geography of the region, and the location and history of this district. For such particulars the reader is referred to that report. The present abstract will be confined to presenting in a brief, generalized form some of the additional information regarding this immediate district which has been procured during the last season.

This information falls naturally into two main divisions, namely, that relating to areal geology and that relating to economic geology. Under "Areal geology" the sedimentary rocks, metamorphic rocks, and structure will be described; under "Economic geology," the grade of ores, occurrence of ores, exploitation, recent industrial progress, and recent production will be considered.

AREAL GEOLOGY.

Sedimentary rocks.—The sedimentary rocks of the Park City district include quartzites, sandstones, shales, and limestones. They constitute, according to their lithologic character and paleontologic contents, five distinct geologic formations. These are, from older to younger, (1) a massive quartzite, approximately 1,500 to 2,000 feet in thickness; (2) a calcareous series made up of normal limestones, considerable sandstone, and some shale, varying several hundred feet in thickness, from 600 feet upward; (3) a red shale with intercalated thin, argillaceous limestone and varicolored shales, ranging in thickness from 1,000 to several hundred feet less; (4) a calcareous sandstone, normal sandstone, and varicolored shales, approximately 1,200 feet in thickness, and (5) red shale with intercalated thin, fossiliferous limestones and calcareous sandstones, capped by coarse, conglomeratic, quartzitic sandstone, approximately 1,000 feet in thickness. This group of five formations lies above a series of intercalated limestones, quartzites, and massive fossiliferous limestones of lower Carboniferous age several thousand feet in thickness and it lies below an immense thickness of red shale of Mesozoic (probably Triassic) age. Accordingly the geologic formations which outcrop within the Park City district are intermediate in age between lower Carboniferous and Triassic.

The geologic ages of individual formations in this Park City group are determined by means of distinctive faunas which characterize each of the two limestone formations. Thus the lower of these limestone formations, lying upon the massive quartzite and beneath the lower red shale, contains several members which carry faunas indicative of the upper Carboniferous. The underlying quartzite formation (known locally for many years as the "Ontario quartzite," after the famous silver mine in this formation) has thus far proved unfossiliferous. Its age may be closely limited however, as it underlies the upper Carboniferous limestone, and carries intercalated in its basal portion fossiliferous limestones of lower Carboniferous (Mississippian) age. The upper of the two limestone formations bears a limited but distinctive fauna, which is unlike any described typical fauna. Regarding this fauna, Dr. G. H. Girty has stated in a preliminary report (August 11, 1903) on fossils submitted by the writer for study with regard to special problems preparatory to the work of the second field season, "It now seems probable that the fauna will be correlated with the Permian of the Grand Canyon section * * *. For the present it seems * * * advisable to follow the usage instituted by the King survey, and to denominate these beds Permo-Carboniferous."

The lower red shale lying beneath this limestone formation and on the upper Carboniferous limestone has thus far yielded no remains of life and might be assigned to the age of either of the inclosing limestone formations. Inasmuch as its lithologic aspects are more characteristic of the overlying formations, however, it may reasonably be considered, for the present, to be "Permo-Carboniferous." The upper of these two red shale formations, although showing a dearth of organic life, presents a normal paleontologic and lithologic transition from the underlying "Permo-Carboniferous" (Paleozoic) limestone into the overlying Triassic (Mesozoic) sediments.

Igneous rocks.—Although the field work of the last season has disclosed significant information regarding the igneous rocks of this area, it has failed to yield conclusive evidence on the relations between the three recognized types previously described as a fine-grained dioritic type, a coarser porphyritic type, and a poorly defined, variable, andesitic type. Facts observed both underground and on the surface tend to suggest, however, that these are three closely related facies. In case further study should show that they were derived from the same magma and were contemporaneous or approximately so, it is not improbable that the fine-grained, granular facies (dioritic type) may represent the parent mass which, on breaking into the overlying sediments as restricted dikes, cooled in the porphyritic facies (porphyritic andesite), or breaking upward to the surface flowed out, blanketing the topography, and cooled as andesitic breccia (hornblende andesite). Final judgment in this case must be suspended until these rocks have been thoroughly studied microscopically and chemically. It now seems clear, however, that at least one, and probably two periods of intrusion preceded the above igneous activity. That an intimate relationship exists between these intrusions and the ore bodies which have been studied thus far seems indisputable. The determination of the nature of this relationship, however, is most difficult. Accordingly these problems assume immense practical significance, and their solution may reasonably be expected to throw light on the problems of the date, origin, and occurrence of the ore deposits.

Metamorphic rocks.—The entire sedimentary section, embracing all of the clastic formations represented in this area, has been traversed by an extensive mass of the dioritic rock and penetrated by dikes of andesitic porphyry. Adjacent to the main intrusive body, and to some of the minor intrusions, the sediments have been intensely metamorphosed. Numerous contact-metamorphic minerals, such as garnet, epidote, magnetite, specularite, serpentine, spinel, secondary mica, and others have been developed, and the lithologic character of the sediments has been thoroughly changed. The determination of the precise nature of the metamorphism by tracing strata continuously from their unaltered phases through transitions into their altered representatives is attended with much uncertainty, owing to the obliteration of fossil remains by metamorphism and to the presence of complex and extensive faulting in the transition zone between the altered and unaltered sediments. The equivalency of certain marbles, quartzites, and argillites to certain limestones, sandstones, and shales has been recognized. Furthermore, metamorphosed sediments have been noted in localities which, though relatively remote from visible intrusive masses, are in the neighborhood of strong dynamic movement.

Geologic structure.—The sedimentary formations of this region dip in general toward the northwest about 30° to 40°, and are traversed by many fissures, faults, and intrusions. Normally the oldest formation therefore outcrops in the southeastern portion of the area, while younger formations outcrop successively toward the northwest. This general structure, however, suffers several important and many minor modifications through folding and faulting. In the vicinity of Park City proper, the general northwesterly dip of the formations gradually changes to a northerly and northeasterly dip, until, in the northeastern portion of the district, the dip is toward the east. In short, the general northwesterly dip gives way locally to a broad arch along a NNE.

axis, which pitches northerly. The economic significance of this fact is that the two limestone formations which, in certain portions of this camp include valuable ore bodies, are thus preserved for some distance from burial beneath igneous intrusives to the north, and are brought into accessible positions immediately north and northeast of the city. This arch appears to have been faulted along a general NNE. zone of fracture at the east side of Deer Valley Meadow, with the net result that the eastern side has moved relatively a considerable distance to the south. To the south and within this general zone of deformation several hundred feet of sediments have been overridden and buried by strong overthrust faulting. McHenry Canyon, the scene of some of the earliest mining of this region, follows for a considerable portion of its extent a great fault along which the displacement was not less than 2 miles.

The principal mineralized fissure zone, passing in a northeast-southwest direction through the center of the district, has been the seat of much faulting. On one of the fissures in this zone the northern side has dropped several hundred feet, and on another the south side has dropped considerably.

Pronounced faulting of direct importance to mining has occurred in the western portion of the district. In Empire Canyon a fault truncates the "Permo-Carboniferous" limestones and throws their northern continuation westward for approximately a mile. A few hundred feet to the north of this fault in Empire Canyon a northwest-southeast fault displaces the contact between the upper Carboniferous limestones and the Ontario quartzite, so that the north side is offset westward for several hundred feet.

Evidence, mainly of paleontological character, tends to show that the strata which form the ridges inclosing Thaynes Canyon and White Pine Canyon all belong to the "Permo-Carboniferous," and that these ridges are duplications due to faulting along northeast-southwest planes. Other significant instances similar to those above described have been worked out, and many cases of folding and faulting have been observed.

In general there was fissuring in a northeast-southwest direction before the deposition of ore, and in northeast-southwest and northwest-southeast directions subsequent to both igneous intrusion and ore deposition.

Glacial features.—Evidences of local glaciation abound in the upper portions of the canyons which head on the higher divides and peaks. Although the exact succession of events during the period of ice invasion in this region can not be stated here, the occurrence of typical features may be cited. These include characteristically polished and striated bed-rock surfaces, rounded profiles of canyons, irregular kame-like deposits of mixed débris, erratics perched high on the sides of canyons, bowlder belts, lateral and terminal moraines, and other glacial features. Many of these are well developed in Lavigneur Canyon, at the northwest fork of Snake Creek, on Bonanza Flat, in Empire Canyon, Walker, Webster, and Woodside gulches, and Thaynes and White Pine canyons. About the head of Bonanza Flat certain rock knobs and walls exhibit excellent polishing and striation. A limit of advance of each stream of ice appears to be indicated on the valley bottoms by heavy deposits of mixed unsorted soil and rock débris, which terminate abruptly downstream. The numerous bowlder belts typically displayed on Bonanza Flat probably mark different positions occupied by the ice front. The Lady Morgan lakes, two small ponds just west of the Daly West shaft, are dammed back by a moraine. Collections of large, disordered masses of coarse rock débris simulating cirques at the extreme heads of valleys are best shown east of Clayton Peak and northeast of Scott Hill. Furthermore, glacial material composing the divide at the head of Woodside Gulch; the flat-topped lobe between Walker and Webster Gulch and Empire Canyon; the narrow, attenuated spur between Woodside Gulch and Empire Canyon, and the straight, narrow, level ridge east of lower Thaynes Canyon, indicate striking changes in topography and drainage produced by glaciation.

ECONOMIC GEOLOGY.

General statement.—With the appearance of snow in the fall of 1903 areal mapping and study of special surface features were necessarily abandoned, and the detailed mapping of underground geology and examination of ore deposits were undertaken. A large portion of this work has been finished, yet considerable remains to be done, and field work on this is now being carried on.

The number of properties in the district is relatively small, and the record of the camp rests upon the output from a few mines which have been developed very extensively, both laterally and in depth. The work of studying these exposures is greatly increased by the large amount of complex deformation, through faulting and intrusion. Although this work is at present incomplete and there has not been suitable opportunity thoroughly to correlate the results thus far attained, it appears that conclusions may be given in the final report which will not only aid present development, but should materially benefit future exploration.

The high rank of the mines of this district among the dividend-paying argentiferous lead mines of the world, the progressive methods employed, and the generally prosperous condition of the camp were briefly outlined in the progress report of last year. Additional information which may now be given comprises brief general descriptions of development, character of ores, occurrence of ores, exploitation, recent progress in the mining industry, and recent production.

Development.—The opinion is current among miners that the ore bodies of this district lie deep and do not crop. The means and determination to explore widely and at depth have resulted in very extensive development. Twenty-two shafts, now accessible, have reached a depth of at least 500 feet, 10 a depth of at least 1,000 feet, 6 a depth of 1,300 feet, and 1 a depth of 2,000 feet. Lateral development has been proportionately extensive. According in position with that of the great fissure zone, and of the ore-bearing limestone formations, the underground workings of the main properties lie in two parallel northeast-southwest belts. In addition to the shafts on individual properties the northern belt is entered by two long tunnels, the Hanauer and the Alliance; and the southern by three, the Ontario drain, the main Ontario-Daly-Daly West work, and the Daly-Judge drain tunnels. The adjoining mines in each belt have been connected, so that it is possible to pass continuously underground from one end of each belt to its opposite end. Thus in the southeast belt there is continuous underground connection in a northeast-southwest direction for a distance of over 5 miles. Furthermore, a crosscut only 450 feet in length would connect these two belts and afford continuous underground connection between all the great mines of the district.

Character of ores.—The ores mined in this district are essentially argentiferous lead ores with accessory gold and copper and a siliceous gangue. The values in the sulphide ore lie in galena (lead sulphide), tetrahedrite (gray copper), and pyrite (iron sulphide); and in the oxidized ore in cerussite (lead carbonate), angelsite (lead sulphate), azurite (blue copper carbonate), malachite (green copper carbonate), and complex oxidation products. Silver is obtained from the iron, lead, and zinc approximately as follows: 3 ounces to each per cent of iron, 1 ounce to each per cent of lead, and five-tenths of an ounce to each per cent of zinc.[a] Silver has also been found in its native state. Zinc is a common associate in fissure ore, and appears to increase in depth and toward the great intrusive mass at the southwest. Barite and fluorite occur sparingly. Oxidized ores are still mined to a limited extent, but the bulk of the shipments of both crude ore and concentrates is composed of sulphides.

Although values as a whole run rather high, a noticeable difference in value exists between ores from different parts of the district.

An average high-grade ore carries about 60 ounces silver, 40 per cent lead, 0.25 ounce gold, and 2.5 per cent copper. Ordinary crude ore carries 50 to 55 ounces silver, 20 per cent lead, 0.04 to 0.05 ounce gold, 1.5 per cent copper, and 10 to 18 per cent zinc. Just as the

[a] This statement is based upon results secured from a large number of precise tests by Mr. F. W. Sherman, superintendent of the Daly West and Daly-Judge mills.

values vary in different parts of the camp, so the degree of concentration required in milling ores varies. Some ores are concentrated four times, others five. It may be stated that in general the degree of concentration ranges from four to six into one. A good concentrate of sulphide ore carries approximately 55 ounces silver, 30 to 40 per cent lead, 0.05 ounce gold, and 15 per cent zinc. The above figures are based on published and reported average values of ores extracted at the present time. Bonanzas have been and are encountered, and excessively high assays of silver, lead, and gold are occasionally reported.

Occurrence of ores.—The principal ore bodies which have been opened in this district occur either (1) in lodes or fissures or (2) in limestone beds. Although in early days the high-grade silver ore was from fissure veins, at present the bulk of the shipments of crude ore is from bedded ore bodies in limestone. Fissures occur abundantly throughout the district. Those fissures which have been found to carry the largest and richest ore bodies lie in a northeast-southwest zone in the center of the camp and dip (with rare exceptions) steeply toward the northwest. They are branching systems, in which individual members may be single, narrow fissures, or broad, breccia zones. Thus ore is found in narrow pay streaks frozen to the walls and in groups of pay streaks included in lodes, which are 2 to 35 feet wide.

The ore bodies in limestone have replaced portions of certain members in both the upper Carboniferous and "Permo-Carboniferous" limestone formations, and they lie between siliceous members as walls. Those occurring in the upper Carboniferous formation which have been studied thus far have replaced a limestone bed that overlies a brown sandy or quartzitic member at a distance varying from 50 to 100 feet above the Ontario quartzite. Occasionally the calcareous bed underlying this sandy member is found replaced by ore, and the sandstone, normally the foot wall, is left barren between these two productive horizons. Ore in the Carboniferous limestones has been observed to have replaced certain metamorphosed calcareous members, and also to have been deposited in a quartzose breccia adjacent to a dike.

Both the lodes and the replacement bodies occur in frequent and intimate association with porphyry. Fissures occupied by ore bodies cut indiscriminately across porphyry and all other formations. Among the numerous cases observed in which ore-bearing limestone has suffered intrusion by porphyry, several have been noted in which the ore is in immediate contact with porphyry. The evidence now at hand tends to show that a period of igneous activity preceded the period of ore deposition.

Exploitation.—In underground exploration, in mining, in milling, and in shipping ore, the economies afforded by perfected mine and mill equipment are practiced. Air drills are used in development work, Stoping is done by the overhand process. Timbering is done on the square-set system when the size of chambers admits, in narrow fissures by props, and in low, flat stopes by props and cribs. Mine ventilation is good. Drainage, the lack of which has been for many years a serious obstacle in the development of the mines of the district, is now adequately effected through the long Ontario, Daly-Judge, and Alliance drain tunnels. Three properties, which apparently lie outside of the ground drained by these deep tunnels, are now encountering considerable water in sinking to explore virgin ground.

For the treatment of low-grade ores four large and four smaller concentrating mills have been erected by individual companies on their properties, and another large mill is expected to go into commission in the near future. These large mills effect an unusually high saving. Two of the large properties ship directly to the smelters in the Salt Lake Valley. The output of all the other mines passes to a local custom sampler en route to the valley smelters. One of the large mines transports its ore from the mine to the railroad by aerial tramway, the others by trams drawn by horsepower through long work tunnels. Labor is well paid, and employees may procure good board and lodging, if desired, from the companies at their mines.

Recent industrial progress.—During the last year the mining industry in Park City advanced to the highest stage ever reached. More men were employed and more work in surface improvements, in underground development, and in perfecting methods of mining and milling was accomplished than during any previous year in the history of the camp. In spite of two serious declines in the price of silver no properties were closed down. At date of writing, however, one of the most extensive properties has closed its mill, except to conduct experiments on treatment of its ores, and has reduced its activity to exploration of virgin ground. The large-paying mines have increased their plants and extended exploitation. Thus the Silver King Company has added to its mill; the Daly West Company is deepening its main shaft and erecting a tailings mill; the Ontario Company has sunk its main shaft to a depth of 2,000 feet, extensively explored its great lode at depth, and remodeled its amalgamation mill into a modern concentration mill; the Daly-Judge Company has entirely refitted its drain and work tunnel with heavier rails and equipment preparatory to utilizing it for regular shipping by power, has conducted extensive underground developments, and extensively expanded and remodeled its concentration mill; the Kearns-Keith Company has continued mining through the Hanauer and Alliance tunnels, erected a concentration mill, and begun regular shipments. In the other working properties the year has witnessed extensive underground operations. Following the unusual activity in the fall of 1902 in the incorporation of mining companies, resulting from the recent discovery of valuable ore bodies, exploration was undertaken which is still being vigorously prosecuted.

One of these new companies has sunk a shaft 600 feet, explored its ground on the 400-foot level, and is now drifting on the 600; another sunk 800 feet to catch a vein previously developed above; another is down 400 feet and has explored at the 200, 300, and 400 foot levels; another, after sinking 600 feet and extensively exploring the ground at that level, has put its shaft down to a total depth of 800 feet, and is now drifting on that level; another, guided by considerable previous development, has sunk 900 feet and drifted at the 700-foot level. Four of the older properties of intermediate size have carried on considerable prospecting and made some shipments.

As a net result of these operations some slightly mineralized ground has been opened, a small amount of ore has been discovered, and in the ground which was more wisely located the indications are good. So far as observed, however, no ore bodies of any considerable value have yet been uncovered. Although this exploratory work has been conducted with great vigor and persistence, if definite prospect of adequate returns is not soon disclosed it is inevitable that the work must be abandoned.

Recent production.—It might have been expected from the generally increased activity of last year that the output would also increase. On the contrary, the output fell from a total shipment, including crude ore and concentrates, in 1902 of 330,662,628 pounds to 292,598,365 pounds in 1903; a decrease in the shipments of last year amounting to 38,064,263 pounds. Notwithstanding this small decrease, the mines of Park City were the prime factors in making Utah the leading silver-producing State in the country in 1903. The decrease is not as unpropitious as might appear, for it is due to the fact that the Ontario Company, on deciding to erect a concentrating mill, greatly reduced its shipments. Neglecting the Ontario shipments during these two years, the total output from the camp increased in 1903 approximately 17,500,000 pounds. Each of the great mines contributed an individual increase to this total, but the larger portion of the increase was supplied by the Silver King mine. The two great producing mines alone paid dividends last year amounting to a total of $2,704,000. With regard to the future, the outcome of exploration and of experimentation on the treatment of zinciferous ores by one of the great properties, the results of development by the several young properties, and the proof of the capability of the mines and the new mills of two important properties are awaited with deep interest. On these factors and the continuance of good prices for lead and silver the future expansion of the camp depends. As to the immediate future, it is assured that, if the lead and silver market holds its present strength, the productive mines—even without continuing their current rate of increase—equal their shipments of last year, and the Ontario and Kearns-Keith mines ship regularly, the total output of the mines of the Park City district in 1904 will considerably exceed that of any previous year.

GEOLOGICAL SURVEY PUBLICATIONS ON GOLD AND SILVER.

The following list includes the more important publications by the United States Geological Survey on precious metals and mining districts. Certain mining camps, while principally copper producers, also produce smaller amounts of gold and silver. Publications on such districts will be found in the bibliography for copper on page 200. For a list of the geologic folios in which gold and silver deposits are mapped and described, reference should be made to the table on pages 13 to 16 of the present bulletin:

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QUICKSILVER, PLATINUM, TIN, TUNGSTEN, CHROMIUM, AND NICKEL.

Tin has been reported from several localities in the United States, but has never proved to be present in commercial quantities. A few years ago, however, stream tin was discovered by a Survey party in Alaska. This discovery attracted much attention. During the field season of 1903 a discovery of lode tin was made in Alaska. This is the subject of the paper presented below.

TIN DEPOSITS OF THE YORK REGION, ALASKA.[a]

By Arthur J. Collier.

INTRODUCTION.

The known occurrences of tin in Alaska are in what is called the York region of Seward Peninsula. This region derives its name from Cape York, an ill-defined promontory on Bering Sea about 90 miles northwest of Nome. It extends northwestward from this cape and includes Cape Prince of Wales, the most western point of the continent. The region has the general form of an isosceles triangle, with its apex at Cape Prince of Wales and its two sides formed by the shore lines of the Arctic Ocean and Bering Sea. (See map, fig. 6.)

The southern coast line is, in the main, inhospitable and unbroken by inlets or harbors. Back of narrow beaches the land usually presents to the sea an abrupt escarpment, giving it a forbidding aspect. On the north the land slopes more gently to the Arctic Ocean and the coast is characterized by barrier beaches which cut off broad lagoons from the open sea. Such a one is Lopp Lagoon, a large body of water, but unfortunately too shallow for any but light-draft boats. Port Clarence, 20 miles east of Cape York, is the only harbor worth mentioning in the region.

[a] Abstract of a report in preparation.

The York Mountains, comprising an area of rugged land forms, occupy the southeastern part of the triangle and culminate in Brooks Mountain, 2,900 feet in altitude, the highest point in this part of the peninsula. Northward and westward from this mountain group stretches the so-called York Plateau, a comparatively smooth upland which stands at 200 to 600 feet above sea level and comprises the greater part of the region under discussion. On the south this plateau presents an escarpment to Bering Sea, but on the north it slopes off gently to the coastal plain.

The chief settlement of the region is York, situated at the mouth of Anikovik River, about 12 miles southeast of Cape Prince of Wales and 8 miles northwest of Cape York. This town is on the open coast

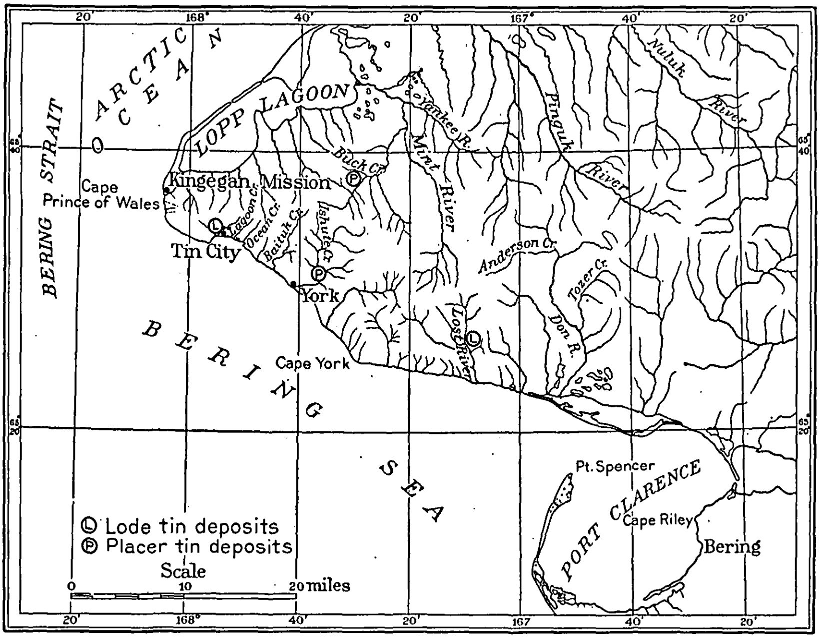

FIG. 6.—Map of the York tin region, Alaska.

of Bering Sea and landings are made through the surf, as at Nome. The nearest harbor for seagoing vessels is Port Clarence, 20 miles eastward.

After the discovery of gold at Nome, in 1898, prospectors rapidly extended their search to all parts of Seward Peninsula, and as early as the fall of 1899 placer gold had been found in Anikovik River. In 1900, Mr. Alfred H. Brooks, of the United States Geological Survey, visited the York region and found in the placers of Anikovik River and Buhner Creek, one of its tributaries, some specimens of stream tin. Early in 1901 an account of these discoveries was published by Mr. Brooks, and the general interest in the tin deposits of the York region dates from that publication. Since that time tin ore has been found both in lodes and in alluvial deposits at a number of widely separated localities.

In 1903 the writer, assisted by Mr. Frank L. Hess, was detailed to continue the investigation of the mineral resources of Seward Peninsula. In the course of the investigation the York region was again visited, hasty examinations were made of the three localities which give the most promise of the production of tin, and reports were obtained from many other localities which have been prospected to some extent. The three localities visited are known as Lost River, Buck Creek, and Cape Mountain, the two extreme points being 25 miles apart. The examination of the Lost River locality was made by Mr. Hess and the writer, jointly, while Buck Creek was visited by Mr. Hess and Cape Mountain by the writer.

GENERAL GEOLOGY OF THE YORK REGION.

The geology of the York region has been the subject of investigation during the years 1900, 1901, and 1903, but all of this work has been of a reconnaissance character. Four distinct rock types have been recognized in the region. These include slates and limestones, both probably of Paleozoic age, and some granular intrusives, chiefly of acid character. The slates and limestones, broadly speaking, form north-south belts of irregular outline, while the igneous rocks are found in intrusive stocks or dikes, the former outcropping in more or less circular areas. Besides these bed-rock formations, Pleistocene sands and gravels mantle the northern coastal plain, and are also found along the valleys of many of the streams.

The larger part of the area of the York Mountains is occupied by limestone of ash-gray color, which exhibits little evidence of metamorphism. This formation, called the Port Clarence limestone in previous reports, is of upper Silurian age. West of this large limestone area there is a broad belt of slates or phyllites, often so much altered as to be more properly called schists. They are of a graphitic arenaceous and sometimes calcareous character, are of a fine texture, and are much jointed, the lines of cleavage breaking them into rhomboidal blocks and pencil-shaped fragments. The bedding is often obscured and sometimes completely obliterated by the highly developed joint structures.

The age of these slates and their relation to the Port Clarence limestone have not been determined. There is some indication of faulting along the contact.

West of the slate area there is a belt of highly altered limestone more or less interbedded with micaceous schists. This belt, about 4 miles in width, lies between the slates on the east and the large mass of granite which forms the peak known as Cape Mountain on the west. Some obscure fossils collected last season indicate that these limestones are of either Devonian or Carboniferous age. The stratigraphic relation of this rock to the slates and limestones already described has not been determined.

Two distinct types of igneous rock are represented in the region. The first group comprises basic rocks in the form of dikes and probably sills, more or less altered, and sometimes sheared, which may be grouped together under the name of greenstones. The greenstones and greenstone-schists include a number of intrusive masses and find their greatest development in the slates near the contact with the limestones which form the York Mountains. These rocks are often called granite by the miners, but they can be readily distinguished from true granite by the absence of quartz and the generally greenish color. This distinction is of importance, since, so far as known, no tin deposits have been found in association with the greenstone.

The second group comprises the acid igneous rocks and includes a number of large masses of granite, as well as dikes of fine-grained porphyritic rock containing quartz phenocrysts.

These rocks find their greatest development in Cape Mountain, which is essentially a granite stock intruded in the limestones. The rock, a white, coarsely crystalline, somewhat porphyritic granite, is made up essentially of quartz, microcline, and biotite, but also contains as accessory minerals albite, muscovite, zircon, apatite, tourmaline, pyrite, and fluorite. Granitic rocks also occur in this district at Brooks Mountain and on Lost River, and similar rocks are found at Ears Mountain, Hot Springs, and Asses Ears, northeast of the York region, and in the Diomede Islands, west of Cape Prince of Wales. These granites are generally unaltered by dynamic influences such as would produce gneissoid and schistose phases, but in some places they have been considerably affected by processes which have produced various forms of granite called "greisen." The distribution of the granite is of the greatest economic importance, since it is in granite dikes and near their contacts that the lode tin deposits have most frequently been found. The prospectors of the region have not been backward in taking cognizance of this, and have made careful search for tin along these contacts.

The unconsolidated gravels and silts form a group of younger sediments. This formation covers the broad coastal plain along the Arctic coast and, extending southward in the river valleys, connects with the alluvium of the smaller streams. In the southern part of the York region these surficial deposits are confined to the creek beds and narrow strips along the coast. They are of economic interest because in them is found the stream tin.

ECONOMIC GEOLOGY.

The occurrence of tin-bearing lodes in the bed rock has been verified by the Geological Survey at points known as Lost River and Cape

Mountain. The occurrence of tin in placer deposits has been confirmed on Anikovik River, Buhner Creek, a tributary of the Anikovik, and on Buck Creek, a tributary of Grouse Creek which flows through Mint River into the Lopp Lagoon. Tin ore has also been reported from a great many other localities which have not been thoroughly examined by geologists. The tin deposits, as far as known, do not follow any definite system, and are confined to no particular belt or zone. The ore, either in lodes or in placer deposits, has been found in association with all the sedimentary formations above described. The known occurrences of tin ore will be described under the headings "Lost River," "Cape Mountain," "Buck Creek," "Buhner Creek," and "Anikovik River."

LOST RIVER.

Lode tin deposits have been found 4 or 5 miles from the coast on Lost River, which enters Bering Sea 10 miles west of Port Clarence. Lost River has a length of about 10 miles, and drains the central part of the York Mountains. Its two tributaries, Tin Creek and Cassiterite Creek, enter from the east about 3 miles and 4 miles, respectively, from its mouth, and tin ore has been found on both of these creeks. Cassiterite Creek, which is really the larger fork of Lost River, has a length of about 3 miles. Tin Creek, about 2 miles long, heads within about a mile of Cassiterite Creek, and, flowing parallel with it for about the same distance, turns westward and enters Lost River through a canyon cut in the limestones of the York Mountains. Lost River itself flows in a comparatively broad valley cut in these limestones. The bed of the river is not deeply gravel filled, and the valley floor is practically cut out of the limestones and not to any extent built on them. The mouth of Cassiterite Creek is about 100 feet above the sea. In the latter part of July, 1903, Lost River, just below this place, carried approximately 1,000 miner's inches of water.

The York Mountains, in the vicinity of Lost River, are composed almost wholly of ash-gray Silurian limestones showing little metamorphism and dipping at low angles. From the coast to Tin Creek the limestones generally dip to the north, and unless there be faulting, not detected in the hasty examination that was made, a thickness of over 4,000 feet must be exposed.

Dikes of igneous rocks were found cutting this limestone at several places, and are readily traceable by a growth of moss and other vegetation which forms over them, the limestone itself being utterly devoid of vegetation. Between Tin Creek aad Lost River there is a boss or stock of granite intruded into the limestone, which outcrops in a nearly circular area, probably half a mile in diameter. Around the margins of this area the limestone is considerably altered and contains small dikes of fine-grained pegmatitic rock, presumably offshoots from the granite, cutting the limestone apparently parallel with the contact of the limestone and granite. Many bowlders and pebbles containing minerals derived from this contact have been found along Tin Creek, which follows the contact for some distance. The more common of these are tourmaline, garnet, epidote, and fluorite. Large bowlders have been found which are wholly composed of minerals of this kind.

A white porphyritic dike cutting the limestone 4 or 5 miles from the coast forms the present focal point of interest to the tin miner. This dike, which is about 100 feet wide, has been traced from Tin Creek on the east to Cassiterite Creek on the west, a distance of about a mile. Tin ore has been found on the croppings of this dike and strewn over the surface along its course, but varies in general appearance and character. Some of the weathered ore from the croppings is highly siliceous and has the appearance of weathered iron-stained vein quartz, with small crystals of black cassiterite distributed through it, while other specimens show clearly their granitic origin, but contain comparatively little quartz. In the ore of the latter type the cassiterite occurs both as disseminated crystals, varying from the size of a pin head to a walnut, and as veinlets and irregular masses. Some of this granitic ore that was prepared and examined microscopically is found to be very much altered from its original character, now consisting essentially of calcite, fluorite, quartz, and large crystals of lithia mica; no feldspars remain, and the quartz is probably secondary. In addition to the cassiterite, tourmaline, pyrite, galena, and garnet occur as accessory minerals. The siliceous ore mentioned above, when examined with the hand lens, occasionally shows spangles of free gold. A small piece, but not a commercial sample, was assayed for gold and silver, and gave 0.36 of an ounce of gold per ton and a trace of silver. Assays reported to the writer show the presence of gold, though in less amounts than the above. The occurrence of so much gold associated with the cassiterite is unusual in tin deposits and merits further investigation. Pannings from the croppings of this ledge have yielded tin ore in angular unworn crystals. One specimen of placer tin of this kind, obtained near the croppings of the large dike described above, consists mainly of cassiterite, but contains also wolframite and garnet.

To summarize briefly the evidence in regard to this deposit, the tin ore is, in part at least, essentially an altered granite-porphyry, or "greisen," having crystals of cassiterite disseminated through it. This greisen forms a dike, which has been followed eastward from Cassiterite Creek to Tin Creek, a distance of about 6,000 feet, and has been examined at its eastern and western ends by United States geologists, who collected specimens of tin ore from it near Cassiterite Creek. At its eastern end, near Tin Creek, no specimens containing cassiterite were collected by members of the Geological Survey, but such specimens have been obtained by others.

When the dike was examined in the latter part of July, 1903, no excavations had been made on it, and it was therefore impossible to measure its exact width at any point, owing to the talus covering it, though considerable breadth was indicated by the fragments on the surface. Since that time crosscut trenches have been made near Cassiterite Creek, which are reported to reveal a width of approximately 100 feet. The excavations have not gone far enough to allow of systematic sampling, and the value of the lode must therefore be left an open question until further developments are made.

Tin ore has also been found in place on Tin Creek, about half a mile south of this main lode, at the northern contact of the large granite area which has been described. Specimens of mineralized granite were obtained that, on examination in the laboratory at Washington, are found to contain stannite, or tin pyrites, together with other metallic sulphides. Mineralized granite of this character apparently covers a considerable area, but the ore is probably of little value except as indicating a wider distribution of tin through the granites.

In 1898 and 1899 some prospecting for gold was done in the vicinity of Lost River, but nothing of importance was found, and the region was abandoned by prospectors for several years. In the winter of 1902 prospectors, searching for tin ore, again turned their attention to this region. Early in the summer of 1903 the interesting minerals above described were discovered in the bowlders in Tin Creek, and a thorough search for tin was made. When the Geological Survey party arrived at Teller, in July, 1903, they were enabled to examine a large collection of minerals from this vicinity. Metallic tin was readily obtained from one small specimen by the aid of a blowpipe, while the larger part of the collection was shown to contain minerals of no value. After examining these minerals, Mr. Hess and the writer proceeded to the Lost River country and made an examination of a part of the region in more detail than had been done in 1901, and were able to trace the tin ore which had been seen at Teller to the granite-porphyry dike above described, on Cassiterite Creek.

CAPE MOUNTAIN.

The Cape Mountain tin deposits occur in a high peak which marks the most western point of America. A settlement called Tin City has grown up within the last year on the southeastern side, while on the northwest side, facing toward Bering Strait, the old Eskimo village of Kingegan is located. East Cape and other points on the Siberian coast, only 60 miles distant, are plainly visible on a clear day from the summit of this mountain. On the west and south sides the mountain slopes down to bluffs which drop almost perpendicularly into the sea. On its southeast side, where Tin City is located, there is a small bight in the coast line that affords some protection from west winds, but for the prevailing south winds of summer the harbor is practically an open roadstead, and affords little if any better landing facilities than can be found at Nome or York. Tin City is 40 miles distant, and northwest of good anchorage on Port Clarence. East of Cape Mountain, the flat-topped upland called the York Plateau has an elevation of about 300 feet, and is made up of limestones and interbedded slates which have been already described. Cape Mountain itself is composed almost entirely of granite in the form of a boss or stock intruded in the limestone. The contact relations of the granite and limestone have not been studied in detail, but, from data gathered in the reconnaissance, it appears that the granite cuts across the stratification of the limestone.

The writer's visit to this locality was of necessity a very hasty one, and he was embarrassed by exceedingly rainy weather, so that his observations were limited in extent. However, specimens of tin ore were obtained, which undoubtedly came from the granite of the mountain, though the ore was not definitely traced to its position in the bed rock. It is reported that tin ore has been found at three distinct points on this mountain, and that it occurs in somewhat irregular deposits which have an east-west trend. Several tunnels were being driven into the mountain, but it was reported that ore bodies had not been found in any of them.

The ore obtained at Cape Mountain differs in general appearance from that seen on Lost River. Large pieces of nearly pure cassiterite, one of which weighed about 9 pounds, are said to have been found on the surface of the mountain. A specimen obtained by the writer weighs approximately 2 pounds, and is nearly pure cassiterite, showing little, if any, outward signs of crystallization, but has embedded in it and surrounding it much tourmaline in slender needles. While in this vicinity the writer was shown a number of large crystals of cassiterite which were nearly colorless and practically transparent. Much of the supposed tin ore contains a great many dark minerals that have been mistaken for cassiterite, but are simply tourmaline in slender black or brown needles.

Tin ore was discovered on Cape Mountain in July, 1902, and extensive developments were planned for the season of 1903. The plan of this work was as follows: A large dynamo driven by a gasoline engine was to be placed near the beach at the point now known as Tin City, and from this dynamo wires were to be run to several points on the mountain to supply power for electric drills. By the use of these drills it was expected that prospect tunnels could be rapidly extended into the heart of the mountain, in order to crosscut the ledges from which the float ore, above described, had been derived. After spending nearly the whole of the season of 1903 in getting the machinery in place, it was found that the engine for driving the dynamo was defective, and the plan for development work during the winter of

1903–4 was necessarily suspended. At the present writing, so far as is known, no work is in progress on Cape Mountain, and very little advance has been made in real knowledge of the nature of the ore deposits.

BUCK CREEK.[a]

Buck Creek is the scene of the first attempt at tin mining on a practical scale in Alaska, and is the present center of tin placer-mining activities. This settlement is on the Arctic slope of Seward Peninsula, about 20 miles northeast of York and 4 miles from tidewater on Lopp Lagoon, an inlet from the Arctic Ocean. It is reached by a wagon road from York, which follows the bed of Anikovik River for 10 miles, then crosses a low divide to Grouse Creek and follows down the bed of Grouse Creek to its junction with Buck Creek. This road is fairly good except for a mile and a half of deep, soft tundra in the divide between Anikovik River and Grouse Creek, where it is almost impassable for heavy wagons. A good roadbed could probably be easily built here by bringing gravels from Anikovik River. Lopp Lagoon is not navigable for deep sea-going vessels, and it is not probable that it will ever be used as a means of transportation of ore from the Buck Creek diggings.

The so-called York Plateau is well developed from the town of York northward to the Arctic Ocean. This plateau near York has an elevation of about 600 feet, and slopes northward to sea level along the Arctic coast. Buck Creek and other streams in its vicinity flow in comparatively new valleys cut in this plateau. Above the surface of the plateau there are several buttes of monadnack type, of which Cape Mountain and Potato Mountain are the most prominent. Potato Mountain, which is also known as Conical or Cone Hill, has an elevation of 1,370 feet. From its northern side a low range of hills extends northward for 3 or 4 miles toward Lopp Lagoon.

Buck Creek, which is a small stream about 5 miles in length, rises in this range of hills and flows southeastward to its junction with Grouse Creek, which in turn flows northward through Mint River and Lopp Lagoon to the Arctic Ocean. About a mile from its mouth Buck Creek receives a large tributary from the south, called Sutter Creek, and about 4 miles from its mouth it again forks, the two branches being known, respectively, as the Right and Left forks. Several smaller tributaries are received between Sutter Creek and the forks.

The bed rock out of which the York Plateau is cut and in which Buck Creek Valley is incised is a dark, slaty schist. Along Buck Creek this is characteristically jointed, as has been described. The mountains west of Buck Creek, including Potato Mountain, are composed of the same slates or schists. They apparently contain no beds of

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[a] This description is based on the field work of Mr. Frank L. Hess.

intrusive igneous rock, either of the greenstone or of the granite type. Some bowlders and pebbles of greenstone occurring in the gravels of Buck Creek near its mouth have not been traced to their source, but probably came from a group of greenstone hills on the south of Grouse Creek.

Small quartz veins were found in a number of places along Buck Creek, cutting both across the bedding of the slates and running parallel with it. Some of these quartz veins are 3 or 4 feet wide, and one or two of them can be traced for a quarter of a mile or farther. Most of the veins are mere stringers 1 or 2 inches thick and only a few feet long. At one place on the upper part of the creek a vein of nearly pure pyrite 6 or 8 feet wide was seen. Pebbles of pyrite 2 or 3 inches in diameter, oxidized on the outside to limonite, are found in the gravels below this vein.

Mr. Edgar Rickard, in the Engineering and Mining Journal for January 3, 1903,[a] reports that the source of the cassiterite can be readily found in the slate of the Potato Mountain range, where it undoubtedly occurs in countless small veins and vugs, sometimes associated with quartz scattered through the mass of slate. The action of the elements has worn away the slates, leaving the cassiterite on the hillsides, and the streams have concentrated it into appreciable deposits.

Though specimens obtained from the gravel justify this conclusion, no veins of this kind were seen by Mr. Hess nor by any of the considerable number of prospectors who were actually engaged in the search for veins containing tin.

The gravel deposits in the bed of Buck Creek are ordinarily from 100 to 150 feet wide, varying greatly in different parts of the creek. Excepting a few greenstone bowlders found below the mouth of Sutter Creek, they consist of slate and quartz, together with other minerals derived from the country rock, such as hematite, limonite, magnetite, ilmenite, pyrite, cassiterite, and a small amount of gold. Cassiterite in the form of stream tin is distributed from the mouth of the creek to within a mile of its head, above which point little more than traces have been found. The ore varies in size from fine sand to pebbles weighing 13 or 14 pounds. Several pieces from 5 to 8 pounds in weight were seen by Mr. Hess, though the average size is much smaller. A few of the pebbles are perfectly rounded, but most of them are subangular. The ore from the workings near the mouth of Buck Creek is generally well rounded, while that from near the head is sharp and angular. In general, the farther up the creek it is obtained the more angular is the ore. In color the ore varies from black to light resin or amber. All that has been seen makes a light-colored resinous powder, by which it is readily distinguished from hematite or other

[a] Rickard, Edgar, Tin deposits of the York region, Alaska: Eng. and Min. Jour., vol. 75, p. 30.

iron minerals that are frequently mistaken for it, since they give a distinct red, black, or brown powder.

A number of specimens were obtained that showed pieces of quartz and slate from the bed rock still attached to them, leaving no doubt as to the origin of the fragments. Some small pieces of cassiterite have been found inclosed between the fragments of slate, showing that they were broken out of small veins in the slate.

Near the head of Buck Creek Mr. Edgar Rickard, in 1902, tested the gravels and found them to contain about 8 pounds of 60 per cent ore to the cubic yard. Mr. Hess saw pannings made at a number of places along Buck Creek, but not enough to thoroughly test the richness of the ground. The best seen came from immediately above the mouth of Sutter Creek, where a drain ditch from 2 to 2½ feet deep was in construction. From these pannings Mr. Hess estimates that the gravels contained approximately 27 pounds of 60 per cent concentrates to the cubic yard of gravel. The gravel deposit here was about 5½ feet thick and approximately 100 feet wide. At this point there seemed to be no difference in the distribution of the tin ore through the gravels from the surface down, and the largest pieces were found on the surface.

From the evidence of prospectors it seems that this uniform distribution through the gravel prevails generally along the creek, though at one place it was found to be richer on the bed rock.

On Grouse Creek below the mouth of Buck the amount of tin ore is reported to be very small, and Mr. Hess found no evidence of prospecting in this section. The gravel deposits of Grouse Creek are more extensive than those on Buck, and seem to be worthy of attention. No large amounts of cassiterite have been reported from either Gold Creek, a tributary of Grouse above Buck, or from Sutter, a large southern tributary of Buck, nor has much gold been found there.

To briefly summarize the evidence regarding the Buck Creek region, tin ore has been found in the gravels of Buck Creek from its mouth to within a mile of its head. The pay streak is confined to the present stream-bed and flood-plain deposits, and probably varies from 10 or 12 feet to 150 feet in width. In the present creek bed the ore is found from the surface down. Outside the creek bed there is a covering of moss and muck above the gravels. No ore is known to have been found on the hillsides surrounding Buck Creek or on the plateau surface in which Buck Creek is incised, though such an occurrence is to be expected. The thickness of tin-bearing gravels varies from a few inches to 4 or 5 feet. Estimates of the amount of tin ore in the gravels vary from 8 to 27 pounds per cubic yard, but probably the former amount is more nearly the average of the creek.

Tin ore was discovered on Buck Creek in the fall of 1901, and some mining for stream tin was attempted in the summer of 1902. As a result of this work several tons of ore were shipped out to the States. During the summer of 1903 several companies were exploiting claims on the creek. The methods of mining and sluicing stream tin were all modifications of somewhat primitive methods of gold-placer mining. It is reported that considerable ore was obtained and hauled to York for shipment. Should the tin prove to be in sufficient quantity on this creek or in any of the creeks in its vicinity, more economical methods of mining must be adopted. In other parts of Seward Peninsula hydraulic mining has been practiced with marked success in the gold placers, and could probably be adapted to the tin placers as well. Water for this purpose can be obtained from the streams rising in the York Mountains, and can probably be brought in mining ditches to the tin placers of Buck Creek and vicinity, though this will be somewhat expensive.

ANIKOVIK RIVER AND BUHNER CREEK.

The first discoveries of tin ore in the York region were made on Anikovik River and Buhner Creek, a tributary of this river, by Mr. Alfred H. Brooks, by whom they were first described.[a]

Anikovik River enters Bering Sea at the town of York, and has a length of about 15 miles. It flows in a comparatively broad valley cut in the York Plateau. In the lower part of the Anikovik Valley there are rather extensive gravel deposits. The bed rock consists for the most part of slates, which break up into pencil-shaped fragments, as has been described.

Buhner Creek is a small tributary of Anikovik River, from the west, about 3 miles from the coast. This creek has a length of about a mile, and flows in a short V-shaped gulch cut in the slates. On this creek the stream tin was found concentrated on the bed rock with other heavy minerals. A sample of the concentrates from the sluice boxes yielded the following minerals: Cassiterite, magnetite, ilmenite, limonite, pyrite, fluorite, garnet, and gold. The determination by per cent of weight was as follows: 90 per cent of tin stone, 5 per cent magnetite, other minerals 5 per cent.

On Anikovik River, about one-half mile below the mouth of Buhner Creek, at the time of Mr. Brooks's visit to the region, sluicing for gold was in progress and specimens of cassiterite were obtained from the sluice boxes. One pebble of stream tin obtained from this locality was about 2 inches in diameter. Mr. Brooks was of the opinion that the source of the tin stone would be found in the quartz and calcite veins which carried the gold, though no cassiterite was found in any of this vein material.

Since 1901 these workings have been abandoned by miners, neither gold nor cassiterite having been found in paying quantities.

[a] Brooks, Alfred H., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900 (a special publication of the U. S. Geol. Survey), 1901, pp. 132-138.

On Anikovik River there are extensive gravel deposits, which it is possible might be made to yield fair returns, either in gold or in tin, if economically worked on an extensive scale by hydraulic methods. Sufficient water for this purpose can probably be obtained either from the head of Anikovik River or from Kanauguk River.

REPORTED OCCURRENCES OF STREAM TIN.

Prospectors who are familiar with the stream tin from Buck Creek report finding small amounts of the ore in a great many streams in the York region; among these are Baituk and Kigezruk creeks, flowing into Bering Sea; Banner Creek, a tributary of Anikovik River; several small creeks flowing into Lopp Lagoon; Clara Creek, a tributary of Mint River; and York Creek, a tributary of Pinguk River.

Stream tin has been reported from all parts of Seward Peninsula where gold mining is in progress, but except in respect to the York region, these reports have generally been found to be without foundation.

REPORTED OCCURRENCES OF LODE ORE.

Discoveries of tin-bearing lodes have been reported by prospectors from many other localities in Seward Peninsula, some of which deserve notice, since geologic conditions are known to be promising. These are the localities in which intrusive stocks of granite occur, but in no case has the presence of tin ore in appreciable amounts been confirmed by the Geological Survey, and they can be passed over with mere mention. These localities are Brooks Mountain, near the head of Lost River, and 4 miles north of the Lost River tin deposits; the hills east of Don River; Ears Mountain, about 50 miles north of Port Clarence; Hot Springs, about 70 miles northeast of Port Clarence; Asses Ears, about 20 miles south of Kotzebue Sound, and the Diomede Islands, in Bering Strait, about 30 miles west of Cape Prince of Wales.[a]

CONCLUSION.

The above facts show cassiterite to be rather irregularly distributed through an area of about 450 square miles, embracing the western end of Seward Peninsula.

At three localities—Anikovik River, Buhner Creek, and Buck Creek—its occurrence in placers has been verified by the Geological Survey, and lode tin has been found by the Survey at Lost River and

[a] Since this was written, four specimens obtained from Ears Mountain have been analyzed by Mr. Eugene C. Sullivan, chemist of the U. S. Geological Survey. In each case traces of tin amounting to a few hundredths of 1 per cent were found. The rocks assayed consist of a granite-porphyry in which the original constituents are largely replaced by calcite, tourmaline, and pyrrhotite. The occurrence of cassiterite in the Asses Ears region has been confirmed by Dr. Cabell Whitehead, of the Alaska Banking and Safe Deposit Company, who found it in fine grains in the placer gold from Old Glory Creek.

at Cape Mountain. There are a number of other places where prospectors report its occurrence in lode or placer form.

The tin ore is almost all cassiterite, though a little stannite has been found at one locality. Its original source is in deposits of at least two essentially different types. In the one it is in quartz veins, which cut phyllites or metamorphic slates; in the other the cassiterite is disseminated through more or less altered granitic rocks. This second type of lode deposit is the one which gives promise of commercial importance.

In estimating the value of tin ores in this northern region several facts should be borne in mind. The region is utterly without timber and is accessible by ocean steamers only from June to the end of October at the longest. Harbor facilities are poor, and all supplies and wages are high. On the other hand, the construction of railroads and wagon roads is not difficult, and will require comparatively small outlay. All of the occurrences described are within a few miles of tidewater. Freight rates to Puget Sound ports should be very low, as the large fleet of ocean steamers which run to Nome returns empty. Last summer upward of 98,000 tons of freight were brought to Alaska by vessels that called at Nome. It is fair to say that these tin deposits are well worth careful and systematic prospecting.

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——— Tungsten ore in eastern Nevada. In Bulletin No. 213, p. 103. 1903.

COPPER.

The papers here presented represent the results of the last year's field work by the Survey in various copper-mining districts. Other districts producing copper, but to a less value than the precious metals, will be found discussed under "Gold and silver," pages 28 to 153.

Practically all the important copper districts of the United States were discussed last year in Bulletin No. 213.

MINING AND MINERAL RESOURCES IN THE REDDING QUADRANGLE, CALIFORNIA, IN 1903.

By J. S. Diller.

RANK OF SHASTA COUNTY AND PRODUCTION IN 1902.

Shasta is the banner county of California in productive mineral wealth, and the chief sources lie within or very near the Redding quadrangle.

The total value of these products and the relative values of the various parts are stated in the following table, which gives the output for 1902. The returns for 1903 are not yet available, but from field observations it is evident that the output will exceed that of the previous year, especially in gold, silver, and copper. Although one of the smelters was closed temporarily in the early part of the year, the total product was less affected than by the strike of the previous year.

Mineral productions of Redding quadrangle for 1902.

	Quantity.	Value.
Gold:		
Placer ....ounces..	13,671.34	$605.15
Quartz veins ....do....		29,789.00
Associated with copper ....do....		252,214.10
Total	....	282,611.25
Silver, with copper ....ounces..	588,357	[a] 306,887.00
Copper ....pounds fine..	21,515,887	2,496,731.90

[a] Commercial value, average for 1902.

Mineral productions of Redding quadrangle for 1902—Continued.

	Quantity.	Value.
Lime ....barrels..	18,500	$12,500.00
Limestone ....tons..	3,500	3,600.00
Clay ....M brick..	2,450	12,250.00
Chromite ....tons..	315	4,725.00
Pyrite ....do....	3,202	7,005.00
Total........	....	3,135,060.15

GOLD.

GOLD OF PLACER MINES.

In the early fifties, millions of dollars' worth of gold were gathered from the placer mines about the northern end of the Sacramento Valley, especially in the vicinity of Horsetown, Shasta, and Buckeye, but as these shallow gravels became exhausted or hydraulic mining was restricted by laws concerning débris more attention was given to quartz mining, and lately to the development of copper ores containing gold and silver.

During the winter and spring, when water is plentiful, there is still much placer mining in a small way in the Redding quadrangle, but trustworthy returns are available from scarcely a dozen mines, showing a yield in 1902 of but little over $500. The greatest activity was on Dog Creek, west of Delta, where work was continued at several points during the summer upon the lower benches and stream bed. In the valley of Squaw Creek, near Copper City and Delamar, half a dozen placers were reported in 1902. Their values appear to have been derived largely from the leached copper ores, which leave most of the iron-stained gossan near the surface to find its way into the placers. The gold in the placers of Dog Creek, as well as about Shasta, Old Diggings, and Buckeye, is all derived from the quartz veins which occur in the igneous rocks of the region. In the early days the stream beds were rich with the accumulations of ages. Having been worked over they are now impoverished, but as erosion progresses, in the course of time they will doubtless be again enriched. The rate of enrichment, however, is so slow as to amount to comparatively little within a generation.

During the summers of 1902 and 1903 a suction dredger was operated irregularly at various places in Sacramento River, near the mouth of Middle Creek, 3 miles above Redding, and it is said that the work is to continue. A larger dredger, with a series of buckets on an endless chain, was installed on the flat by the side of Clear Creek, below Horsetown, near the southwest corner of the quadrangle. The gravels of the Horsetown region in the early days were very rich, and successful dredging, under good management, may well have been predicted for that region. Hard gravel was encountered, and early in the season the dredger burned. It is said that a stronger dredger, of greater capacity, is to be put in its place, and is, in fact, in October, 1903, reported well under way.

GOLD OF QUARTZ MINES.

The demand for silica to flux the copper ores creates a favorable opportunity for mining the comparatively low-grade quartz veins of the region, and during 1903 ore was sent to Keswick, or elsewhere, from a number of mines within the quadrangle, but the total shipment in part, at least, of carefully selected and graded ores did not amount to over 500 tons per month.

The country rock of the auriferous quartz veins throughout, with the exception of the Shasta region where granodiorite prevails, is essentially the same as that of the copper ore bodies and consists of an ancient series of igneous rocks, andesites, and rhyolites, so altered by pressure in many cases as to closely resemble slate. Most of the mines are shallow, but at Old Diggings, 6 miles northwest of Redding, the shafts have reached a depth of 500 feet, and indicate that the ore has a considerable degree of continuity.

Most of the mines about Old Diggings, especially the Central, Evening Star, Mammoth, and Spanish, were working to a greater or less extent in 1903. All are upon somewhat irregular but nearly parallel quartz veins which have a general course a few degrees east of north and a dip of about 85° SE. In thickness the veins range from a few inches to 18 feet, and carry small amounts of disseminated pyrite and chalcopyrite. The Central mine is at present the largest producer of the Old Diggings vicinity, and furnishes the bucket tramway over which the other mines of that place ship their ores across Sacramento River to the Southern Pacific Railroad.

The small group of mines near Quartz Hill, 4 miles northwest of Redding, were, at the time of my visit, less active than in 1902, but to the west, near the old Spanish mine, there was increased activity at the Bracket and Crown Deep. The quartz veins of the last two mines are less regular than those east of the Sacramento. They generally strike N. 12° to 40° W., and are crushed, containing vein material of various ages.

One of the oldest and once most active quartz mines of the Redding quadrangle is the Uncle Sam, on Squaw Creek, 6 miles west of Kennett. Its proximity to the large bodies of low-grade copper ore makes it of special interest, and the Trinity Copper Company, under bond, has recently made a thorough examination of the property. The main vein strikes about N. 70° W., and dips 53° NE. Years ago, when the stamp mill and the chlorination plant were running, the ore was removed through a 1,200-foot tunnel, from which drifts extended on the vein for 1,500 feet at a level of 500 feet below the croppings. From the tunnel level an incline was sunk on the vein to a depth of 1,050 feet below the outcrop. The greater values were found toward the eastern end of the mine near the surface, in the neighborhood of a dike of andesite-porphyry, which cuts the siliceous rocks of the region and is intersected by the vein. The Riley-Bliss, Clipper, Beien, and other quartz prospects in the vicinity of Uncle Sam, are doing little now, the greater activity being confined to the adjacent deposits of copper ore. On Dog Creek, however, 4 miles west of Delta, just beyond the western border of the quadrangle, the Inca mine is shipping assorted ore in bags.

GOLD AND SILVER OF COPPER MINES.

By far the greater part of the gold, and particularly all of the silver of the Redding quadrangle, as shown in the table, comes from the copper mines. The oxidation of the pyritiferous copper ores near the surface formed the gossan which characterizes such bodies. Leaching removed the copper but left most of the iron in the form of limonite and with it the bulk of the gold and silver, so that in the early days the mines were opened and worked for gold and silver before the copper values at greater depths were discovered.

COPPER.

The brief account of the copper deposits of the Redding region published in United States Geological Survey Bulletin No. 213, pages 123–132, will here be supplemented by additional general observations on some of the lodes and prospects and the progress in mining during the year. The term lode is used to include all the ore bodies in essentially the same shear zone. In the copper region they are rarely as much as 100 feet in width and a mile in length, and several may occur in each ore-bearing tract within a district.

Within a decade California has come into prominence as a copper producer, and is now the fourth in the rank of States. The greater part of this mineral wealth comes from the Redding quadrangle or close to its borders. During 1903 the mines and many prospects in all districts of the copper region have been active, and the time is approaching when the output will be greatly increased.

IRON MOUNTAIN DISTRICT.

The largest and most active district of the copper region is that of Iron Mountain. As yet the only producing part of this district includes the mine of the Mountain Copper Company just outside of the Redding quadrangle, but prospecting is rapidly advancing within the quadrangle.

Spread Eagle lode.—The King Copper, Loraine, and Spread Eagle prospects are in the general course of the Iron Mountain lode. The open cuts and tunnels of the first two were not greatly extended during the year, but the Spread Eagle had a considerable force at work tunneling beneath the large outcrop of gossan, which appears to strike N. 74°-80° W., approximately parallel with one of the ore bodies of the King Copper, and at a high angle to the general course of the Iron Mountain lode. The ore is traversed in several cases by fractures along which there is evidence of shearing both in the ore body and country rock. The fractures extend about N. 80° E., dip steeply to the southeast, and were formed later than the ore body. Beneath the gossan the ore, almost wholly pyrite, is generally wet from surface waters and soft, so as to be easily crushed to a granular mass. In places it is cemented by small quantities of quartz gangue. At greater depths, as shown in the lowest tunnel, small masses of chalcopyrite appear, but at this level in July, 1903, no large bodies of ore had yet been reached.

Balaklala lode.—The Balaklala lode is one of the largest of the Iron Mountain district. Development was actively pushed by Superintendent Grant Snyder. A considerable force of men was employed and electrical light and power introduced. The lode is well marked in places by a heavy gossan and has been traced more or less continuously for over half a mile. It lies in the slope of the South Fork of Squaw Creek nearly parallel to the surface and strikes about N. 70° E. with dip to the northwest somewhat steeper than the slope on which it occurs. The principal ore body known in this lode, the Windy Camp, has been followed along the strike for nearly 1,000 feet, and on the dip for over 500 feet. It has an irregular thickness ranging from a few feet to over twenty and appears to pitch to the northeast. At the northeastern end of the lode, where great masses of gossan occur, comparatively little is known of the ore bodies. The ore is chiefly pyrite with more or less chalcopyrite, but generally, like other bodies in this portion of the district, is of comparatively low grade. Quartz is the only gangue mineral. Although disseminated in small quantities yet it forms a larger percentage of the ore than at Iron Mountain.

In the Shasta King development work continues with a smaller force than last year, although the same company, the Trinity Copper Company, A. H. Brown, general manager, has exploited under bond a number of other properties in the immediate neighborhood. One of the most interesting discoveries was barite locally as a gangue mineral in the sulphide ores. In the Bully Hill region greater values generally accompany barite, and its occurrence in the western district is a matter of promise. The Shasta King ore body lies upon the west slope of the South Fork of Squaw Creek nearly opposite and at a lower level than Windy Camp. As the general dip of the Windy Camp body is toward the Shasta King they have been regarded as belonging to the same shear zone. This view is strengthened by the occurrence of smaller ore bodies on the steep slope between them which suggests that a former connection has been severed by the erosion of Squaw Creek. The relations are not yet clearly understood and can not be fully worked out until the deeper parts of the Windy Camp body are disclosed in detail.

The Shasta King ore body is somewhat irregularly basin shaped, is some hundreds of feet in width, and has a longer nearly north-south axis rising to the north and limited for the most part by fissures along which there has been decided shearing. An exception is found in places on the upper surface of the ore body where it is solidly "frozen" to the country rock. The region is one of much disturbance and the bodies of copper ore appear to have suffered greater deformation than the adjacent quartz veins.

Mammoth lode.—Exploration has continued upon the Mammoth lode under the superintendence of Mr. Fred. Grotefend. Its general course appears to be about N. 80° E. It has been traced over 300 feet in length to a depth of at least 200 feet from the upper gossan cropping. On the principal level it dips 30° NW. and crosscut tunnels show an extensive development in that direction which may be accounted for, in part at least, by change to gentler dip. The ore, like that of all the ore bodies, is composed chiefly of pyrite but is locally rich in chalcopyrite and considerable sphalerite. Quartz is the gangue mineral, but in much of the ore there is scarcely a trace of it.

Beyond Squaw Creek the Friday and Lowden prospect has not been worked to any considerable extent during the year. The Golinsky was bonded and thoroughly examined by the Trinity Copper Company. The most northern openings of the Iron Mountain district are near the head of Little Backbone Creek, where the Summit mine tunnels completed this year show much impregnated metarhyolite with included slate and small indistinctly banded veins in which chalcopyrite is most prominent, with smaller amounts of quartz and pyrite.

BULLY HILL DISTRICT.

The Bully Hill district yields more than any other district wholly within the Redding quadrangle. It has two ore-bearing tracts, one in Bully Hill and the other near Copper City, besides a number of prospects to the west on the slopes of Horse Mountain. All these have been worked more or less continuously during the year. As is now generally known the ores of the Bully Hill district differ from those of the district west of the Sacramento in containing the richer sulphides, such as bornite and chalcocite, and also in the presence of barite as a gangue mineral associated with the greater values.

In Bully Hill there are two lodes which for convenience may be designated the Delamar and Anchor. The first is worked in the Bully Hill mine and the last in the Rising Star. Both are under the general management of H. A. Cohen and are operated by the same company. These ores are sent to the smelter at Delamar, which has been considerably enlarged during the year.

Delamar lode.—The Delamar lode has thus far yielded the greater part of the Bully Hill values, and within the last year has been developed chiefly in depth to about 800 feet beneath the surface or to 1,180 feet above the sea. It is interesting to note that bornite continues to form an important part of the ore, with barite as gangue, at the greatest depths yet reached, and according to Mr. Keating chalcocite has lately been found at the same level. The silver values, too, are reported to be of importance. It is evident that the bottom of the zone of enrichment has not yet been attained and gives promise of continued values at greater depths.

Anchor lode.—The Anchor lode, although worked years ago, was opened up afresh at a new locality in 1902 and has become an important producer. It lies over 200 yards west and in the strike of the Delamar lode. It strikes about N. 10° E., is approximately vertical, and is wholly within the old metarhyolite, the so-called Bully Hill quartzite. The ores are generally like those of the Delamar lode, but in an old shaft near the summit of Bully Hill just beneath the gossan the pyritic ore is wet and friable like that already noted at the Spread Eagle. In both cases partial solution and disintegration take place before oxidation. Secondary chalcocite and carbonates are perhaps more abundant locally in the Anchor than in the Delamar lode, but bornite at the greatest depth (200 feet from the surface, July, 1903) is of less importance.

On the west slope of Bully Hill some ore was removed from the North Star and Ydalpom, and works extended during the early part of the year, but later they were closed. The Recorder on the north slope of the hill and a mine farther west were prospected for a time by the Mount Shasta Gold Mines Corporation.

The Mount Shasta May Blossom, a mile northeast of Bully Hill, has been active in a prospect near the contact between the igneous rocks and the shales. An air compressor is reported to have been installed in October.

Copper City lode.—This lode was worked by the Bully Hill Company in 1902, but was closed the following year, and the mining activity in the Copper City tract was confined chiefly to the Arps and Tamarack prospects. The interesting occurrence of native copper in igneous rocks near the summit of Horse Mountain was prospected to some extent. On the southwest slope of the same mountain toward Potter Creek numerous prospects showed a large amount of copper staining, but when examined no definite bodies of copper ore had been disclosed. The Mineral Wealth of northern California recently reports that the Bully Hill Company has bonded some of these claims.

AFTERTHOUGHT DISTRICT.

Copper Hill lode.—This locality was worked years ago and lately revived, but is not yet producing. It consists, so far as known, of two short, nearly vertical ore bodies—the Copper Hill and the Afterthought lodes—which strike about N. 55° W. parallel to the Copper City arch. The two bodies are nearly parallel and are approximately 350 feet apart en echelon, and one of them has been prospected to a depth of over 100 feet. They lie close to the contact in metarhyolite that incloses fragments of slate, and the ores, like some of those found elsewhere, are composed largely of pyrite, sphalerite with chalcopyrite and galena, and local traces of bornite. The gangue, less than 5 per cent of the ore, is barite with a trace of calcite.

In the Black Diamond district and the Roseman group of prospects there has been scarcely any development work during the year, but farther south along the western edge of the McCloud limestone the Memorial prospects have been extended with no important discoveries at the time of examination.

LIMESTONE.

The limestone of the Redding quadrangle was briefly noted last year in Bulletin 213, page 315. The McCloud limestone, near the United States fishery at Baird, was formerly used for flux at Bully Hill, but in 1903 the material for that purpose was obtained from the Hosselkus limestone of Brocks Mountain, about 6 miles northeast of Delamar. Mr. J. B. Keating, the general superintendent at Bully Hill, has kindly furnished the following partial analyses of these limestones:

Partial analyses of McCloud and Hosselkus limestones.

	McCloud.	Hosselkus.
	Per cent.	*Per cent.*
CaO	52.5	51.0
Fe_2O_3 } Al_2O_3 }	1.5	1.5
Insoluble	2.0	4.0

The McCloud limestone contains nearly 94 per cent of carbonate of lime, while the Hosselkus contains less than 92 per cent, but both are said to be good for the purpose for which they are used.

The limestone near Kennett is the only one extensively quarried, and has furnished the material from which 18,500 barrels of lime were burned in 1902 at Kennett, besides 3,500 tons of rock shipped chiefly to the Keswick smelter. As the demand increases with development the output was probably greater in 1903.

The general scarcity in northern California of hydraulic limestone or cement rock, suitable for the manufacture of hydraulic cement, creates a demand for the small quantities of such rock that exists and of other material which may be used for the purpose. The only beds of promise in the Redding quadrangle are in the lower half of the Hosselkus limestone of Brock Mountain and elsewhere, which is much thinner bedded than the upper portion, and in places is somewhat darker gray, with an earthy odor as if containing somewhat more clay than the general mass.

It is well known that hydraulic cement of good quality may be made by mixing ordinary lime with some siliceous substance in such proportions that the interaction of the two forms silicate of lime and sets or hardens the cement. In Italy, tuffaceous volcanic material, there known as "pozzuolana," is extensively used for the purpose, and in parts of Germany a volcanic tuff called trass is largely employed in the same way. The Tuscan tuff, bordering the northern end of the Sacramento Valley, is very like the trass of the Rhine Valley. This is especially true of that on Stillwater, near the Copper City road, or east of Millville, and at a number of points on the western side of the Sacramento Valley. The limestone and the tuff are at several places within a few miles of each other, and there is reason to believe that a good quantity of hydraulic cement may be made from them within convenient reach of the railroad. This matter is of importance in the construction of large dams for irrigation or water power in the Redding region.

CHROMITE.

Chromite is mined on Shot Gun Creek, but the serpentine in which it occurs reaches as far south as Slate Creek, and it is not improbable, from the trend of the chromite bodies, that some may yet be discovered within the northwest portion of the Redding quadrangle. At the forks of Shot Gun Creek, about a mile from the Southern Pacific Railroad, a series of lenticular chromite bodies occur in a somewhat indefinite shear zone, which is vertical, and courses S. 40° W. through the serpentine. Five bodies, ranging from 200 to 1,500 tons each, connected by more or less distinct vein-like leaders, have been mined within a distance of 250 yards. The ore masses have nothing in them resembling vein structure, except some of the connecting leaders. Generally, the ore separates easily from the serpentine, but in other cases it is "frozen" firmly to it. Other parallel zones, but as yet less productive, have been found in the same region. A partial analysis by Dr. E. T. Allen of an average sample of the chromite selected in the mine gave the following results:

Partial analysis of chromite from Shot Gun Creek.

	Per cent.
Cr_2O_3	43.87
FeO (total iron reckoned as FeO)	15.86
Platinum, gold, and silver	None.

The ore is used for furnace linings, and 315 tons were shipped in 1902.

IRON ORE.

The iron-ore deposits of the Redding quadrangle were noted in Bulletin 213, page 219, but since then other observations have been made and one of the localities prospected, although no ore has been removed except that formerly used for flux at Bully Hill. It occurs at two points in quantities worth noting. The first is 1¼ miles southeast of Baird, and the second on the northeast slope of Hirz Mountain, near the McCloud. The ore in both cases is chiefly magnetite, changed to limonite at the surface, and occurring on the contact between the McCloud limestone and a dioritic, often diabasic, rock which cuts it. At the first locality the occasional presence of small bands of garnet and traces of other related minerals locally in the magnetite indicate that it is a contact phenomenon similar to that in the Black Diamond region. The ore body has been opened to a width of 40 feet without exposing its limits. It appears to be nearly vertical, and its occurrence on the north slope of the hill suggests an ore body of considerable size. As to its composition, Mr. Keating informs me that it contains about 70 per cent of iron, 1 or 2 per cent of insoluble material, and only a trace of sulphur.

On the northeast slope of Hirz Mountain the iron ore has a somewhat wider distribution, but this may be due to the gentle dip to the east parallel to the slope of the limestone. It has been prospected by a number of open cuts, and, as in the other case, is generally a contact deposit on the borders of the limestone and diorite, but in places appears to penetrate the diorite.

In both cases the bodies of magnetic iron ore are large, but the contacts are very irregular. Each contains an element of promise of other ore bodies below, for at the Black Diamond mine both chalcopyrite and pyrrhotite are common with the magnetite.

CLAY.

Clays of two sorts, occurring under entirely unlike conditions, have been used in the Redding quadrangle. In the copper region clay selvage to the ore bodies is never very abundant, but in some of the upper workings of the Bully Hill mine there is enough for local use to line the converters in the smelter.

Bricks were made several years ago of the sandy alluvial clay in the flood plain of Sacramento River, several miles south of Redding, where there is a large deposit, but a few miles farther down the valley beyond Clear Creek and near Anderson there is a brickyard that made about 2,500,000 of brick in 1903 and supplied much of the trade of the Sacramento Valley.

BUILDING STONES.

A variety of stones have been used locally for structural purposes, but scarcely any were shipped from the quadrangle. The Chico sandstone from Sand Flat and from Clear Creek, near Texas Springs, was formerly used for some of the railroad culverts and furnished trimmings for several buildings in Redding. It is soft, grayish red or bluish, and easily worked, but occasionally marred by mud spots.

A granodiorite of bright-gray color forms a hill at the southwest corner of the quadrangle and is locally used to a limited extent for tombstones, also for street curbing in Redding, and for doorsteps. This granitic rock weathers gray with slight discoloration from the decomposition of the ferromagnesian minerals. It is only 6 miles from the railroad, with easy grade, and deserves consideration for any large structure in the northern part of the Sacramento Valley.

The Tuscan tuff stands fire well, and, being soft, is easily hewn to any shape. It is commonly used for chimneys and fireplaces, and in the vicinity of Millville a small church and several smokehouses are made of it. The Tuscan tuff is similar to the trass of the Rhine Valley, which is so extensively used in the manufacture of cement, and there appears to be no good reason why it might not be used in the Redding region for the same purpose. This is especially true since the necessary lime for admixture is abundant.

COPPER DEPOSITS IN GEORGIA.

By Walter Harvey Weed.

A large number of localities are known in Georgia at which copper minerals have been found in greater or less quantity. About thirty years ago several deposits of pyrrhotite carrying chalcopyrite were worked in the southern extension of the Ducktown, Tenn., copper belt. Upon the exhaustion of the rich black sulphide and oxide ores these properties were abandoned, and nothing has been done in recent years. The records show that the ore bodies are somewhat smaller than those farther north, but the grade and mineral character of the ore is the same, so that there is a possibility of these deposits proving of economic value.

In the Dahlonega district the gold veins have long been known to contain occasional bunches of copper ore, but so far as known none of these veins offer any prospect of becoming copper producers. On the other hand, a well-marked vein occurring about 6 miles east of Dahlonega contains a large mass of pyrite carrying an average of 3 per cent of copper. This property is being actively developed and promises to become an important producer of pyrite, which will be used in the manufacture, not only of sulphuric acid but of copper, which will be extracted from the sinter left after roasting the ore. This deposit was described by Mr. Eckel in Bull. 213, but its features are so unusual that it is worthy of further notice. Like the Dahlonega gold veins this deposit occurs at the contact between the micaceous schists and a mass of altered igneous rock. An examination of the locality by Mr. Eckel showed that there was no ground for the current and long-prevailing belief that the rocks of this district are of pre-Cambrian or Cambrian age.

Another deposit of copper ore occurs at Villa Rica, Carroll County, Ga., where pyrite containing copper is mined. In estimating the usefulness of such pyrite deposits as producers of copper it must be remembered that experience the world over has shown that the copper contents gradually decrease with depth, though the pyrite remains unaltered in quantity and quality.

For the last three years development work has been in progress upon an old gold property in Lincoln County. This property, formerly known as the Magruder gold mine and now designated as the Seminole copper mine, has already yielded high-grade mattes carrying gold and silver values, and the development work is sufficient to give assurance of the permanence of the ore. For this reason a careful petrographic examination of the rocks was ordered, because the writer desired to follow it up by a careful study of the ore deposit itself. Prof. Thomas L. Watson was therefore sent to the property and has furnished the notes contained in the following paper.

THE SEMINOLE COPPER DEPOSIT OF GEORGIA.

By Thomas L. Watson.

Location.—The mines of the Seminole Mining Company are in the extreme western part of Lincoln County, 12 miles northeast of Washington, the county seat of Wilkes County, and 2½ miles east of Metasville, the nearest post-office. The property lies partly in Lincoln and partly in Wilkes counties. The mines are in the former county.

History.—The Seminole property was worked for gold from 1852 to 1861, under the name of the Magruder gold mine. It then remained practically inactive until 1880, when mining for gold was resumed and continued until 1884. During the latter period some lead and copper are reported to have been shipped. In 1900 mining was again resumed on the property by the Seminole Mining Company, principally for copper, and is now being actively carried on.

GEOLOGY.

Physiography.—The area is in the Piedmont Plateau region, a short distance north of the fall line, which marks the passage of the plateau crystallines southeastward beneath the Coastal Plain formations. Its surface is more or less hilly and forms a part of the broadly undulating plain so characteristic of the inner margin of the plateau region. A number of low ridges or unreduced residual areas of harder rock, locally called mountains, rise above the general level of the plateau surface over parts of Lincoln County. None of these occur in the immediate vicinity of the mines. A few are not far distant.

Rocks.—In the immediate vicinity of the mines the country rock is composed of variable schists greatly crushed and jointed and penetrated by a network of closely intersecting basic dikes, which in most cases are completely altered. The schists are of the mica type, varying from biotitic to sericitic, and in places highly quartzitic. Feldspar is only sparingly developed in the schists and in places it is absent. Its very slight occurrence is a noteworthy feature. In a large number of thin sections hastily examined not a piece of striated feldspar was observed. Variation in color of the rocks is from dark to white in accordance with the amount and mineralogical form of the bisilicate present.

In general the strike of the schistosity is northeast-southwest, with considerable local variation observed from place to place. The dip is northwest. The schists are intersected by two major sets of joints which strike about east-west and north-south, with minor jointing developed at various angles to the major jointing. Slickensides usually characterize the joint-plane surfaces, indicating subsequent movement in the rocks.

Dike rocks.—Dikes, mostly of altered basic igneous rocks, intersect the schists in large numbers. They vary from a few feet to several hundred feet in width. Where exposed in the underground workings they are completely schistose and broken at close intervals by joints. They are very dark and are composed chiefly of altered feldspar, some biotite, hornblende, and much quartz, which in most cases at least is probably secondary. Furthermore, they are in general abundantly impregnated with large and small crystals of pyrite.

In the stream bed, about 700 feet west of the shaft, is exposed an igneous rock, which is entirely distinct in mineral type from the dikes exposed in the underground workings. The rock is moderately dark and fine to medium textured, and contains innumerable conspicuously developed rounded quartzes of opalescent appearance. Under the microscope large phenocrysts of both potash and plagioclase feldspars are recognized. Fresh exposures of the rock in the stream bed indicate a degree of mineralization with pyrite equal to the schistose-hornblende dikes in the mine openings. On the opposite side of the stream from the mine the rock is deeply decayed, but can be readily traced by means of the rounded quartzes which litter the surface.

Both underground and on the surface the dikes strike in two general directions, namely, about N. 75° W. and N. 20° E. So far as could be determined from the underground working the dikes striking N. 20° E. are the oldest, since they are cut across by those striking N. 75° W. The rocks are so completely altered that no contact phenomena could be definitely made out, though the contacts between the dikes and inclosing rocks are at all times entirely sharp. Neither was there apparent evidence for regarding the dikes striking N. 20° E. as apophyses from those striking N. 75° W. The dikes vary but little from the vertical, though the dikes striking N. 75° W. show local variations in the dip of as much as 15° N. in some places, while those striking N. 20° E. indicate a tendency in dip toward the west.

At the time the mine was examined the shaft had penetrated to a depth of approximately 200 feet, with ore worked on the 90-, 125-, 145-, and 185-foot levels. Where the levels had been opened for a long enough distance from the shaft the same dikes could be readily traced penetrating the rocks in each of the levels.

VEINS AND ORES.

Veins.—Three fairly well-defined veins have been opened, named the Wardlow, the Finley, and the Magruder, which are approximately parallel, having a general direction of N. 25° to 40° E. They vary in width, and represent the more completely silicified portions of the sheared and crushed schists. They are composed of fine, granular, saccharoidal quartz, interlaced with stringers of broken, massive quartz. Like the country rock proper, they are throughout thinly laminated or schistose in structure. The ore is distributed through the veins in the form of stringers, irregular bunches, or nests, and as large and small disseminated grains and particles. The ore occurrence as disseminated grains or particles closely resembles that of the inclosing rock, except that in the veins the mineral particles are in a more localized and concentrated form. The ore distributed through the surrounding rock, particularly the pyrite, is invariably in the form of large and small cubical crystals. The central portions of the veins are characteristic and are sharply differentiated from the inclosing rock, while the outer portions next to the wall appear less easy of differentiation from the schists in many places. Lenses of varying sizes, composed of schists similarly silicified and mineralized as the true veins, occur between the veins and in some instances afford equally as good ore. These lenses may be spaced at wide intervals or they may occur close together.

Ores.—The ores consist chiefly of chalcopyrite, galena, sphalerite, and pyrite. A little native copper occurs in the Wardlow and Finley veins; and in places traces of tenorite (black oxide of copper) are observed. The veins are remarkably free from carbonates; only traces of malachite (green carbonate) occur, and this has probably formed in large part at least since the opening of the veins.

More complete silicification is invariably accompanied by increase of chalcopyrite and gold. Galena when present is always associated with chalcopyrite and both are argentiferous. The galena is invariably concentrated in the form of stringers and bunches, but has not been observed disseminated through the veinstuff in grains and crystals like the other sulphides. Pyrite is found in all types of the rocks; it occurs as stringers in the veins, and as disseminated large and small crystals and grains in the schists and dikes. As a rule the wall is more heavily impregnated with pyrite than the rock at some distance from the vein, and it may be present in larger or smaller quantity in the veins than in the wall rock. When galena is present pyrite almost entirely disappears or is reduced to a minimum.

In general sphalerite follows the hornblende-schist dikes. It is found in largest quantity in the Magruder vein, with only traces noted in the Wardlow vein and none in the Finley. Very little galena occurs in the Magruder vein, but it is abundantly concentrated in the form of ore shoots in the Wardlow and in the Finley.

At the 185-foot level and below the veins are perfectly tight and dry, but a free percolation of surface waters downward takes place through the crushed and fractured country rock.

STRUCTURAL FEATURES.

The veins occur in an area in which the rocks are profoundly altered and, accordingly, covered to some depth by the products of residual decay, hence outcrops of the fresh or moderately fresh rocks are rare. Alteration extends to the entire depth of working, about 200 feet. The rocks are further extensively crushed and fractured, and are traversed by a multiplicity of joints and intruded dikes of altered basic igneous rocks—probably diorite or diabase, or both. As a result of the action of intense dynamic forces the rocks are, moreover, rendered completely and thinly schistose, the planes of schistosity showing a general northeast-southwest strike, with wide local variation in places. Both the dikes and country rock are, in general, strongly mineralized.

So far as it was possible to interpret the conditions, the veins are developed along and in a shear zone, which approximates a northeast-southwest direction, possibly a few degrees north of east of the strike of the schistosity. Clearly the conditions were entirely favorable to the free circulation of mineralizing solutions, which were more concentrated along certain definite lines within the shear zone, determining the position of the present veins. While the thin sections of the rocks have not yet been studied sufficiently to warrant definite statement, the general character of the veins in the underground workings afford some suggestion of metasomatic action or replacement.

The veins are cut across by some of the dikes of basic rocks, but enrichment, so far as could be determined, seems not more characteristic near or at the contacts with the dikes than at some distance away. Moreover, it is impossible to state whether secondary enrichment has taken place or not. The veins do not conform entirely with the direction of schistosity, but they cut it at very slight angles; and the schistosity is likewise cut across by the shear zone at angles varying from 7° to 15°, a circumstance which results at times in a step-like arrangement in the veins. In a general way, however, the veins follow more or less closely both the shearing and the schistosity.

From the available field evidence the order of events, so far as it has been possible to interpret them, are, in general, as follows: An early period of intense dynamic disturbance caused extensive crushing and fracturing of the country rocks, resulting in secondary structure. This was followed by silicification and mineralization concentrated along fairly well-defined, roughly parallel lines marking the present veins. A second period of disturbance resulted in the intrusion of the rocks by basic igneous dikes. Finally there was a third period of dynamic action, which rendered the massive dikes schistose in structure and caused further mineralogic alteration of the dikes into forms unlike the original eruptives. Necessarily the second and the last periods of disturbance increased the metamorphism of the country rocks and aided in the mineralization.

THE GRIGGSTOWN, N. J., COPPER DEPOSIT.

By Walter Harvey Weed.

Throughout the Atlantic States the red sandstones of Triassic age, grouped as the Newark formation, contain intruded masses of trap (diabase) which form the eminences rising above the relatively flat country into which the soft sandstones have been eroded. Copper ores occur at various localities throughout this entire region, and always near the trap rocks. Attempts to work these deposits have been made in various States, and in the early part of the last century, when the price of copper was high, a considerable amount was obtained from the deposits of this type in New Jersey. The deposits in that State are typical of those of the class, and as they have been exposed by extensive underground workings they are best fitted for careful investigation. In Bulletin 213 a summary was given of the results of a study of the deposits found beneath the great trap sheet of Watchung or Orange Mountain, New Jersey, particularly of the deposit near Somerville. The field evidence shows conclusively that this great trap mass was a lava flow practically contemporaneous with the red sandstones that lie above and below it. There is, therefore, no thermal metamorphism of the rocks, and no possible derivation of the copper from direct igneous emanations from this trap rock.

In November, 1903, a brief trip was paid to another New Jersey property, formerly worked for copper, in which the ores do not occur in immediate contact with trap rock, but in the sedimentary rocks lying above an *intrusive* sheet of trap whose heat has baked and altered the soft, red shales to a hard, compact hornstone. This property is alluded to in all geological reports as the Griggstown copper mine, and this name is therefore retained. The following notes are presented in advance of the detailed study to be included as part of a general report on the copper deposits of the Appalachian States.

Location.—The property is located in the hilly tract north of Princeton, N. J., and about 8 miles from that town. It is nearer the town of Rocky Hill, the terminus of a branch line of the Pennsylvania Railroad, running north from Monmouth Junction. The high trap ridges, locally known as Tenmile Mountain and Rocky Hill, are cut through by Millstone River, the principal tributary of the Raritan, and excellent exposures are seen near the village of Rocky Hill. The copper property is about 3 miles north of this town, on the open, smooth, cultivated fields on the east side of the river, at an elevation of about 200 feet above the sea.

Geology.—But two rock types are found in the vicinity, trap (or diabase) and red shales of the Newark formation. The trap is a coarse-grained, bluish-gray rock of very uniform character. It forms a thick, gently inclined sheet lying conformable with the red-shale beds into which it was intruded. These shales are always more or less highly altered near the igneous rock, sometimes for a distance of 100 feet vertically above the sheet. This alteration is particularly marked at the copper mine.

The copper property.—The copper mine is located about 4 miles from Rocky Hill Station, on the east side of Millstone River and 150 feet or so above its bed. A wooded area with an outcrop of trap forms the summit of the hill, the mine being located on the smooth, rounded slopes below, that extend downward to the Raritan Canal.

The property was worked early in the last century, and was cleaned out and reopened some years ago by the present owners, but no copper has been produced lately. The workings consist of several vertical shafts, now caved in, a drain tunnel 1,200 feet long, and a new incline shaft, together with stoped-out chambers. The main vertical shaft is said to be 150 feet deep, but is filled with water to the level of the old drain tunnel, and the workings at present accessible are all above this point.

The deposit consists of an ore seam varying from an inch to a foot or more thick, occurring in and conformable to altered shales. These rocks are shales altered by contact metamorphism, resulting from the intrusive sheet of trap. They are hard, dense, and have lost their fissile character, and are more properly called hornstones. A noticeable feature is a peculiar spotting due to the presence of dark-colored spherical segregations, which are scattered singly or in groups through the dark-purple rock. These vary from minute pellets up to globes an inch across, but are commonly about one-fourth inch in diameter. They consist of green hornblende in part altered to chlorite, and are commonly surrounded by a rim 1 millimeter wide of bleached rock. This is the rock which carries the ore, but when mineralized the groundmass is rotted and altered to a pale flesh-colored or white, kaolin-like mass, in which the dark-green spherules resemble plums in a pudding.

The ores.—The ores consist of native copper, red oxide of copper (cuprite), black, glassy-looking tenorite (black oxide of copper), malachite, chrysocolla, copper glance, and rarely bornite. The ore seam also carries considerable micaceous hematite. These ore minerals occur in the leached and white altered hornstone.

The ore seam appears to be a bedding plane of the old shales, along which slipping has occurred during the tilting of the beds. It is, so far as observed, entirely conformable to the shales, and dips west at 10°. The trap sheet exposed on the summit of the ridge passes underneath the coppper bed, and the exact thickness of rock between the ore and trap was not determined. The ore seam does not show in outcrop, and the mine dumps are in a cultivated field, no rock appearing in place. However, the inclined shaft exposes an excellent section of the altered shales overlying the ore, and the ravine scoring the slope, from which the long drain tunnel was driven nearly a century ago, also shows good exposures of the shales.

The ore seam consists largely of altered, leached, and whitened rock, with patches of ore, and of a soft, blackish material which proves to be chlorite. Cracks run down and connect with chlorite bunches in the rock below the ore seam proper, but no copper ore was found except in the thin seam mentioned. Samples of the soft chlorite, which at times forms a layer several inches thick, showed no visible copper minerals, and upon assay yielded 0.69 per cent of copper. The ore follows fractures crossing the ore seam proper and is not uniformly distributed. The ore body worked consists of bunches of glance and oxidized ores, which cover irregularly elliptical areas of possibly a couple of hundred feet across. In mining so thin a seam the underlying waste has also been broken down. There is said to be a vertical vein of copper ore exposed in this shaft, with a lower layer, a sheet of ore on the 150-foot level, but no evidence of this could be obtained on account of the water. Several nearly vertical fractures intersect the ore seam near the incline. These fissures are filled by crushed and altered rock and carbonates, and are said to be gold bearing, but assays made in the Survey laboratory failed to show even a trace of gold.

The scientific interest of this deposit is very great, on account of the evident reducing action of the hornblende and chlorite upon copper-bearing solutions, but the discussion of the origin of the ore involves a consideration of the various cycles of uplift and erosion to which the region has been subjected since Triassic time and the accompanying movements of percolating waters, which are supposed to have derived the copper from the alteration of the trap from a fresh basaltic lava or diabase sheet to its present somewhat altered condition.

Such discussion, together with an account of the impregnation of the white sandstones overlying similar intrusive sheets of trap rock at Arlington, New Brunswick, and many other localities in New Jersey, is reserved for a future paper.

NOTES ON THE COPPER MINES OF VERMONT.

By Walter Harvey Weed.

Copper mining in Vermont, though now almost at a standstill, was for a long period one of the chief industries of the State, and its chief mine, the Ely, was, prior to the opening of the Michigan deposits, the largest copper producer of the country. The deposits belong to a type that is well known in many parts of the world and includes some of its most famous producers. They have not as yet been studied in detail, but a brief reconnaissance was made in September, 1903, to determine their character. The salient features of the deposits visited in this preliminary trip are presented herewith.

The deposits contain vast amounts of low-grade copper ore which await the development of some cheap method of treatment to become great producers. The ores present considerable variation in their amount of silica, but are of fairly constant mineralogic character and very uniform in their percentage of copper. In fact, they are practically identical in mineral and chemical composition with the Ducktown, Tenn., ores. While it is true that for many years relatively high-grade ores were treated and shipped from the mines, the average content of copper is only about 3 per cent, and as the metal occurs as copper pyrite intimately mixed with pyrrhotite (mundic or magnetic iron pyrite) the ore is not in demand as a source of sulphur. The successful utilization of the sulphur content of the Ducktown ore proves, however, that the sulphur of these ores can be recovered.

These deposits occur in the hilly region forming the eastern part of the Green Mountains, the three principal localities being in a north-south line from 7 to 10 miles west of Connecticut River. The prevailing rocks are crystalline schists, the "calciferous schists" of the earlier geologists, flanked on the east along the Connecticut, and on the west near Montpelier by "Huronian" slates. A few miles due north of the copper deposits lies the Barre granite quarries, and numerous smaller intrusions of granite occur scattered over Orange County, while dikes of granite and of dark and heavy basic igneous rocks are known but are not mapped. The most recent report[a] upon the areal geology of the district also locates numerous areas of horn-

[a] Rept. State Geologist Vermont for 1900-1901, p. 46.

blende, presumably meaning amphibolite. Their course and that of the granite intrusions suggests a deep-seated batholitic mass. In this report the schist is separated into two formations—the Washington marble and the Bradford schist. The copper deposits occur only in the micaceous rocks grouped under the latter name. These rocks are concealed over large areas by the bowlders and gravels of the glacial moraines, so that while good exposures occur near the mines the rocks can not be continuously traced from one locality to another. The published structure sections indicate folding, but the distribution of the rocks appears to suggest extensive faulting as well.

The schistose rocks of the region, which underlie the glacial drift and frequently project through it, are prevailingly slate colored or gray, varying from coarse to fine in texture and foliation, the differences in color being due to varying proportions of biotite and silica. At the Elizabeth mine the foliation is very regular and the bands can be traced for long distances, although the exposures are not always satisfactory. At Copperfield the general foliation is north and south, with a dip of 25° to 30° E., but the structure is in general that of a broad anticlinal fold, the detailed structure showing close folding and puckering of the softer, more schistose beds, so that no single band can be followed for a long distance. The rocks when so folded contain many intercalated masses of quartz, occupying the crests of the little anticlines and filling irregular lenticular spaces along the flanks of the folds. The origin of this quartz is believed to be associated with the alteration of the original rocks to their present sericitic condition. As shown elsewhere, the change of ordinary silicates to the fine talc-like form of muscovite-mica, known as sericite, is accompanied by the liberation of free silica, which is carried to the nearest cavity and accumulates as quartz. Examinations of thin sections of these rocks under the microscope shows them to consist of quartz, biotite, calcite, and magnetite. They thus appear to represent metamorphosed sedimentary rocks, probably impure sandstones, and siliceous shales.

A detailed study of all the granite intrusions of this part of the State has never been made, but a recent examination and study of the Barre granite mass, which is extensively quarried, has been made by Mr. G. I. Finlay, under the direction of Professor Kemp, of Columbia University.[a]

This Barre mass lies due north of the copper belt, but many outlying bosses of it extend southward in a line west of the copper belt. The rock at Barre is of fairly uniform composition as a whole, but shows various border facies, a feature also found in a minor degree in the smaller masses to the south. The rock is a normal quartz-biotite-granite, containing accessory muscovite and apatite. The intrusion occurs associated with dikes of pegmatitic granite, which, according

[a] Finlay, G. I., The granite area of Barre, Vermont: Rept. State Geologist Vermont for 1901-2, p. 46.

to Finlay, grade into quartz veins, and are accompanied by dikes of black trap rocks (camptonites).

General character of the deposits.—The deposits of the Vermont copper belt occur as lenticular masses in foliated micaceous schists. They therefore simulate the type known as bedded deposits, being apparently entirely conformable to the schistosity of the inclosing rocks. The outcrops are generally concealed, however, except where the bed is exposed by mining operations. The ore forms lenses of varying horizontal extent and thickness, and these lenses overlap, so that in going down a lens wedges out, but the tapering bottom of one lens overlies the upper end of another. This feature was observed at the Copperfield mine and at the Union mine in Corinth.

The ore bodies sometimes show a clearly defined foot wall, but more commonly show transitions into the adjacent rock. As a rule the foot wall is more regular than the hanging wall, the latter showing frequent undulations.

The horizontal extent of the ore lenses varies considerably at the different mines, and indeed in the different lenses of the same mine. The ore body at the Elizabeth mine has been extracted for 700 feet horizontally, and in the Ely mine a lens over 100 feet across has been mined. Along its strike the ore mass may either end in a blunt wedge, sometimes showing a mere film continuing along the horizon, or the ore may fork into rapidly thinning wedges, or simply grade into country rock by an increasing amount of "slaty" material. The horizon of this Elizabeth ore body is traceable for nearly a mile, and another ore body (Reynolds) is found on its continuation 1½ miles northward.

The thickness varies at different localities. At the Elizabeth mine the ore was as much as 100 feet wide in the open-cut workings, and on the 225-foot level is 35 feet between walls. The ore has a maximum width of 12 feet at the Union and adjacent properties in Corinth Township, and of 20 feet at the Copperfield property.

The depth to which these deposits extend is not known. At the Ely mine the inclined shaft is 3,400 feet long. As already noted, the ore body consists of several lenses, so that one lens may pinch out; but in the Union and Ely mines the ore continues in overlapping lenses to the greatest depth attained.

The ore bodies are remarkably free from water. At a depth of 3,400 feet on the dip or 1,500 feet vertical the Ely ore body is very dry, the water of the mine being confined to a few hundred feet of upper workings. The ore and incasing rock are very solid in all the mines and practically no timbering is used.

Character of ore.—The ore consists of pyrrhotite (magnetic pyrite of iron, locally mundic) with scattered grains and irregular masses of chalcopyrite, and small amounts of pyrite and of zinc blende. The gangue minerals consist of quartz, actinolite, garnet, and other metamorphic minerals. In the main part of the ore body it consists of very massive pyrrhotite, with small amounts of quartz, etc.

The copper appears to be confined to the chalcopyrite, and though it is asserted by some observers that the pyrrhotite of the Elizabeth mine contains some copper, an examination of thin sections indicates that the copper is held in minute grains of chalcopyrite.

The chemical composition of the ores is shown by the following average of a large number of chemical analyses made of ore from the Elizabeth mine. It should, however, be understood that this ore contains less silica than the ores of other localities.

Average composition of copper ore from the Elizabeth mine, South Strafford, Vt.

	Per cent.
Copper	3.25
(Or between 1 and 4 per cent.)	
Iron	35.60
Silica	27.00
Lime	1.55
Sulphur	19.18
Magnesia	0.82
Alumina	7.76
Zinc	1.07
	96.23
Gold	Trace to 0.02 oz. per ton.
Silver	0.20 oz. per ton.

The ore when cobbed to 5 per cent gave: Iron 30 per cent, silica 21.4 per cent. The Ely ore carries about 15 per cent more silica, and the Corinth mines are of intermediate character. The relative amounts of silver and copper in the ore are about 0.10 ounce of silver to each per cent of copper. Gold is commonly present in mere traces, but, though the values sometimes run up to $1.20 per ton of ore, they are spotty and seem to bear no relation to the percentage of copper. The blister copper produced at the Ely smelter in 1899 gave 13 ounces silver and $2 in gold per ton, which is lower in silver than the above.

Unlike the Elizabeth ores the product of the Copperfield mine shows a very uneven distribution of the silver values as shown by the following assays of selected ores:

Assays of copper ores from the Copperfield or Ely mine, West Fairlee, Vt.

Sample No.	Silver.	Copper.
	Ounces.	*Ounces.*
1	1.28	23.15
2	.44	13.25
3	.62	19.75
Eureka 4	.76	19.65

The normal ores carry an average of 0.5 ounce of silver per ton.

THE COPPERFIELD OR ELY MINE (VERSHIRE MINE).

The Copperfield or Ely mine, near the village of West Fairlee, is the best known, as it is the deepest mine in the State. It was for many years known as the Vermont copper mine, and though other copper deposits have been worked, the Ely has been the one great mine of the State.

History.—It was discovered in 1821, the burnt appearance of the outcrop leading to digging by the neighboring farmers. The discoverers organized the Farmers' Company and opened up a body of good ore and smelted it in a rude furnace. This was continued with more or less success and interruption until in 1853 the Vermont Copper Mining Company acquired the property, completed an adit (tunnel), and opened up an ore body 8 to 16 feet in thickness that averaged over 9 per cent copper, as shipped, some shipments yielding as much as 17 per cent. The property was worked successfully, paying large returns, until a variety of causes led to the closing down in 1892–93. It was acquired by Mr. Westinghouse in 1899.

Production.—No records are at hand to show the production prior to 1854. The production since that year is, so far as known, given in the following table:

Production of Copperfield mine.

Copper ore shipped:		
1854–1860	tons	3,270
1861	do	1,812
1863	do	1,430
1865	do	1,430
Metallic copper produced, 1870	pounds	943,461
Average amount pig copper produced annually, 1872–1882 (sold to Ansonia Brass and Copper Co.)	pounds	2,500,000
Copper produced:		
1876	do	1,646,850
1880	do	3,186,175
1890	do	7,500,000

The property yielded large profits from 1870 to 1880, but in consequence of bad management and litigation it changed hands. It was then successfully and profitably worked for seven years, clearing over $4,000 a month in 1888. The following year further litigation led to a change of ownership.

Development.—The deposit has been gradually developed, at first by long crosscut adits (tunnels), which, however, opened up comparatively small amounts of ore. An incline shaft was then begun and gradually extended downward, the ore being stoped out on each side as the work progressed. When the ore pinched out downward, which has happened four or five times in the history of the mine, winzes were sunk in the foot wall and the upper end of the new lens opened. In 1861 this incline was 315 feet long, the depth was 1,800 feet in 1886, and 3,386 feet in 1903.

Reduction works.—This property was equipped with smelting works early in its history, and was for many years regarded as a model in this respect. In 1885 there were 24 brick furnaces, of a type originating here, and called the Vershire type. Rapid advances in metallurgical treatment soon made the plant antiquated, and it was remodeled by Cazin in 1888–89 and a 100-ton concentrator built at an expense of $53,000. The plant erected at that time is estimated to have cost $700,000.

After the purchase of the property by the present owners various changes were made and a year's work done. The result was not satisfactory, for although equipped with modern water-jacket blast furnaces, reverberatories, and a Bessemer plant, the treatment of raw sulphides resulted in low-grade mattes (14 per cent) and the re-treatment of material so increased the cost as to render the work unprofitable. The ore was found to be somewhat lower grade than had been expected and very siliceous, so that barren fluxes had to be obtained.

The ore deposit.—The ore deposit is composed of lenticular masses, averaging 100 feet in horizontal extent, 10 feet in thickness, and 100 to 300 feet along the dip. The ore bodies appear to be conformable to the foliation of the inclosing schists, and therefore simulate bedded deposits. The strike is north-south; the dip 24° E. The ore consists of magnetic pyrite and chalcopyrite, with some pyrite and sphalerite, with intergrowths of quartz and actinolite; in the leaner ores are biotite, calcite, garnet, and other characteristic metamorphic minerals. The chalcopyrite is partly of the same age as the pyrrhotite, but the larger masses of this mineral fill fractures in the pyrrhotite and represent the filling of later fractures.

A study of the thin sections of the ore made for me by T. L. Watson shows conclusively that the sulphides are of later formation than the silicates. The lean ore consists of quartz, with a mesh of hornblende needles, all more or less altered. Actinolite is present in small amount. Zoisite, so common in the analogous ores of Tennessee, is entirely absent. Brown biotite mica is very common in the ore-forming tufts and groups of elongated shreds. In some samples much of the biotite is altered to brownish red rutile. An examination of the ore on the dump shows that while hornblende and biotite occur at times together, that there is a general tendency toward a segregation of either one or the other mineral.

The ores carry an average of 3 per cent copper as mined. They contain the usual small amounts of gold and silver, with a little zinc, and are free from arsenic and antimony. The Bessemer copper contains about 13 ounces of silver and $2 in gold per ton.

The average composition of the ore (from information furnished by the owners) is:

Average composition of ore of Copperfield mine.

	Per cent.
Copper	3.31
Iron	30-39
Sulphur	14.71
Insoluble	36.67

An interesting feature of the ore and one that has an important bearing on its treatment, is the brittleness of the quartz, so that when the ore is subjected to coarse crushing it yields about 40 per cent of fines, which carry more silica than the lump ore. The following analyses, kindly furnished by the owner, show the results of actual tests on large samples of No. 1 ore:

Analyses of coarse and fine ore.

	Coarse.	Fine.
	Per cent.	*Per cent.*
Copper	4.45	1.70
Iron	33.5	25.3
Sulphur	20.5	13.6
Silica and insoluble	31.1	45.4

ELIZABETH MINE.

History.—The Elizabeth mine, at Copperas Hill, near the town of South Strafford, and about 6 miles due south of Copperfield (Ely mine), is the oldest copper mine of the State. It was opened in 1793, the magnetic pyrite being used for the manufacture of copperas (sulphate of iron). The manufacture of copperas was continued for many years, until the discovery of increasing amounts of copper led to the working of the property for that metal and the building of a smelting plant.

Production.—The production was 2,804 tons in 1883, and 3,299 tons from 1881 to 1884.

Equipment.—The mine is equipped with a power plant, 4-drill air compressor, with ore bins, crusher, picking belt, and a small smelter plant.

Development.—The early working of the property consisted of open-cut work with a 60-foot drift. In 1886 a vertical shaft 160 feet deep was sunk in the hanging wall, cutting the ore at 100 feet in depth and continuing in it to the bottom. From this shaft a level was driven southward at 50 feet below the surface, connecting with the open-cut work 200 feet south of shaft. A level was also driven 300 feet to the north. Another level at 110 feet in depth was driven 100 feet to the south and 225 feet to the north, while a third level at 160 feet in depth afforded the main stoping ground. A wing 60 feet deep connects this level with 225-foot adit workings. In 1898 a crosscut tunnel 1,340 feet long was finished, opening up the ore body 225 feet below the outcrop. There is 578 feet of drifting on this level.

The ore body.—The ore body is interlaminated with micaceous schists, forming a lens whose axis pitches gently to the north. The foot-wall rock is harder and more quartzose than the hanging-wall material. The foot wall is smooth, regular, and in the open-cut workings is seen to form a well-defined plane with a dip of 70° E. The ore body has a northeast-southwest course. The ore lens is said to pinch out along the outcrop at a point about 700 feet south of the shaft. It varies from 25 to 100 feet in thickness along this open cut. On the 225-foot level the ore is 35 feet between walls, but only a thickness of 24 feet has been extracted. As seen in the open cut the ore body is a compound one, with a slab of schist 2 to 5 feet thick separating the main mass from a hanging-wall layer.

The ore is similar in mineralogic character to that of the other deposits of the belt. The average composition has already been given. The best ore occurs in the central 6 to 8 feet of the ore body, and becomes lower grade as the walls are approached, the ore passing gradually into country rock. This feature is particularly well shown in the foot wall at the north end of the 225-foot level. Samples from each section of the vein were assayed, and yielded as follows:

Copper in ore from Elizabeth mine.

	Per cent.
Hanging-wall portion	2.30
Central portion of vein	4.64
Foot-wall portion of vein	4.28

Each sample represents a width of 8 feet. As already noted this ore is low in silica, compared with other properties in the State. The total amount of ore developed is estimated by private parties at 275,000 tons of 3 per cent material. In working this mine in 1899 and 1900 the ore was broken, sorted into two grades, and the richer portion, called No. 1 ore and carrying about 4 per cent copper, and amounting to 30 to 35 per cent of the total tonnage, was hauled to the railroad and shipped. The second-class ore, averaging but 2 per cent copper, was placed on roast heaps for local treatment. Only 5 per cent of waste was produced in sorting the ore.

CORINTH MINES.

The mines of Corinth Township are located about 11 miles north of Copperfield, and 7 miles west of the Boston and Maine Railroad. The ore bodies lie in gneissoid rocks somewhat harder than the micaceous schists seen southward. There are two adjoining mines—the Union and the Eureka.

The Union mine was first opened in 1866. The production from that year up to 1881, inclusive, amounted to 31,504 tons of ore, carrying 8.5 per cent to 10 per cent copper. In 1879 and 1880 a total of 5,712,604 pounds of fines, carrying 2.7 per cent to 4.5 per cent copper, was sent to the Copperfield smelter.

The property is developed by an inclined shaft about 900 feet long, or 766 feet below the adit level. Down to a depth of 300 feet four overlapping lenses of ore were worked. The shaft leaves the ore at a depth of 500 feet on the incline below the adit level, and continues downward in the hanging-wall schists. The lower ore bodies are developed by winzes sunk in the foot wall. Assay of a sample of selected ore from the dump showed 8.15 per cent copper, 25 per cent silica, with traces of gold and 0.3 ounces silver per ton. The vein has a north-south course, dips 30° E., and has an average thickness of 8 feet.

The Eureka mine lies south of the Union. It has been opened by an inclined shaft said to be 500 feet deep, with two adit levels, the uppermost cutting the vein at a depth of 200 feet below the outcrop. The vein is said to average 8 feet in thickness, and about 100 feet in horizontal extent. Selected samples of the rich ore contained 19.65 per cent copper, 19.52 per cent silica, and 0.76 ounces of silver per ton of ore.

COMPARISON WITH OTHER REGIONS.

The similarity of these deposits to those of Ducktown, Tenn., has already been remarked. They are also very similar in form and mineral contents to the deposits found in the province of Quebec, Canada, which lie almost due north of the Vermont belt. Almost all previous writers have remarked upon this fact, and have attempted to correlate the deposits as a geologic unit, basing their conclusions on the fact that the rocks are similar and occur along the strike of the schists. The danger of such hasty correlation is shown by the recent study of the Quebec deposits by Dresser. His work proves the talcose, micaceous, or chloritic schists to be disguised volcanics of early geologic age and variable composition, but largely diabasic in character. The so-called sandstones of the Ascot belt, in which the Capelton, Suffield, and Sherbrooke mines occur, is really a quartz-porphyry, while the westerly belt, embracing the copper mines of Acton, Upton, Roxton, Wickham, and St. Flavien are in limestones, with associated, black, graphitic shales intruded by igneous rocks, the copper ores being near and sometimes in igneous masses.

SUMMARY.

The Vermont copper belt contains three districts, Corinth, Copperfield, and South Strafford. The deposits occur along a due north-south line, which corresponds to the general direction of schistosity of the rocks. The rocks are micaceous schists and gneisses, formed from sandstones and shales by regional metamorphism. The original bedding, though obscure, is occasionally detectable, and does not correspond to the foliation. Igneous intrusions of granite are common in the region, but not in the immediate vicinity of the ore deposits.

The ore bodies are lenticular masses which simulate bedded deposits, since they appear to conform to the banding of the inclosing schists. At each locality but one workable lens has been found outcropping, and in the deep mines the lens wedges out in depth, but is found to overlap the upper tapered end of another lens in the foot-wall rock. The deposits have no gossan cap, the sulphides appearing at the surface. The ores consist of massive pyrrhotite, chalcopyrite, pyrite, and a little sphalerite mixed with varying amounts of quartz, actinolite, and in the leaner ores of garnet and biotite. The deposits correspond in character and copper contents to the Ducktown, Tenn., ores, and can probably be as cheaply mined and treated as those of that locality.

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LEAD AND ZINC.

In addition to the two papers presented below, other references to lead will be found in several papers in the section on gold and silver, as all reports on districts in which silver-lead ores are prominent have been included under the precious metals.

An extensive investigation of the Mississippi Valley lead and zinc deposits is now being carried on by the Survey.

LEAD AND ZINC DEPOSITS OF ILLINOIS.

By H. Foster Bain.

Location.—Lead and zinc are found and have been mined in Illinois in two widely separated districts. One of these occurs in the extreme southern portion of the State and includes portions of Hardin, Pope, and Saline counties; for convenience it may be referred to as the southern Illinois district. The other includes a portion of Jo Daviess County, in the extreme northwest corner of the State. It may conveniently be called the northwestern Illinois district.

SOUTHERN DISTRICT.

The southern Illinois district has not as yet yielded zinc in commercial quantity. The lead which is found there, and which has been mined more or less steadily since 1842, is produced at present in connection with the mining of fluorspar. As the district is separately discussed in this volume in connection with a description of the fluorspar mines, no attention will be devoted to it here, except to note that it has never been a producer of zinc, and for many years has yielded only a very few tons of lead. Probably its maximum production was in 1866-67, when there was a yield of 176,387 pounds of lead from the Fairview mine. Within the present year prospecting near Jonesboro, in Union County, west of the fluorspar district, has developed the presence of galena; whether in paying quantities or not, it is too early to say.

NORTHWESTERN DISTRICT.

The northwestern Illinois area forms a portion of the upper Mississippi Valley district, in which mining has been carried on since 1788 and which up to the middle of the nineteenth century was the principal source of American lead. With the opening of the silver-lead mines of the Western States attention was diverted from the district, and at about the same time the mines reached a depth at which pumping became a serious burden and at which the lead ores gave place commonly to zinc ore. There was at that time no considerable market for such ore. Indeed, up to the period of high prices in 1899 no serious effort was made to develop the sulphide ores, the carbonates of zinc alone being salable. The principal production now is of zinc sulphide, though some galena and zinc carbonate still find their way to the market. The producers of zinc blende in this district are at a disadvantage in competition with those of the Joplin district, since the Wisconsin-Illinois ores carry a higher percentage of iron. Up to recent years there has been no convenient method of separating the iron from the zinc, and the northern ores have accordingly lacked a market.

The Mineral Point Zinc Company, the principal buyer of the ores of the district, has equipped its plant for the manufacture of sulphuric acid, and hence is now able to economically handle the sulphide ores. The development of the method of roasting and magnetic separation has made it possible to build plants in small units adapted to the wants of individual mines, and the ore when cleaned by this process has a wide market. Experiments with static electricity operating on unroasted ores are now being made, with most encouraging results, and it seems probable that the district as a whole will gradually become an important producer of zinc ores.

Topography of the district.—The lead and zinc deposits of the upper Mississippi district lie within the driftless area. The region is one in which the topography seems exceedingly rugged in contrast with the smooth drift plains surrounding it. The principal topographic feature of the region is an elevated peneplain, well seen from the top of the bluffs of the Mississippi River. Above it rise certain detached hills, spoken of locally as mounds. Below it the streams of the region have cut their channels, in the case of the Mississippi to a depth of more than 200 feet.

Stratigraphy of northwestern Illinois.—The stratigraphy of the area within which the mines are located is simple. There are no igneous rocks within the area or in its vicinity, and the strata have suffered very little deformation. There is a rather uniform dip to the southwest of about 10 feet to the mile. The outcropping formations include the Niagara limestone, the Maquoketa shale, the Galena limestone, and the Trenton limestone. The St. Peter sandstone occurs a short distance below the surface and outcrops only a few miles north of the State line. The Niagara limestone is a massive dolomite with certain cherty layers. It forms the tops of the mounds and of the escarpment which encircles the whole district on the south and west. It is not ore bearing. The Maquoketa shale is a soft, blue to drab, argillaceous shale, about 175 feet thick. It underlies the gentler lower slopes of the mounds and the escarpment, and spreads out in thin disconnected patches over the higher portions of the flat upland. It, like the Niagara, is not ore-bearing.

The Galena limestone is a very massive dolomite, weathering with a rough, carious surface, and with heavy chert beds occupying the middle of the section, non-cherty members occurring above and below. It is the main ore-bearing horizon and is about 240 feet thick in Jo Daviess County. Beneath it is what has been called the Trenton limestone, which, in contrast with the Galena, is not a dolomite, though usually not entirely free from magnesia. Near the top of the Trenton are certain thin shale beds, the most important being locally known as the "oil rock." The Trenton in this area is about 40 feet thick. To the north a greater thickness has been assigned to it, but this is due, not to a thickening of the strata, but to the reference of a portion of the overlying beds to this formation. The Trenton does not outcrop in northwestern Illinois except in a small area near Millbrig.

Below the Trenton is the St. Peter sandstone, which is a common source of artesian water to the south and west. Below it are sandstones and dolomites representing Ordovician and Cambrian sediments, none of which outcrops within this particular area.

Ore bodies.—The ores now being mined in northwestern Illinois are found in the Galena limestone. In Wisconsin the Trenton also yields ore, but the mines in the vicinity of Galena have not as yet been worked at these lower horizons. The Illinois mines resemble more closely those at Dubuque, Iowa,[a] than those near Platteville and the other Wisconsin shipping points.[b] Indeed, almost every feature of the Dubuque mines can be duplicated in Illinois, and vice versa, though the Black Jack, or Peru mine, not now open, has been worked to a horizon below that of any of the mines opened at Dubuque. A somewhat generalized section of the Galena limestone is given below.

Generalized section of the Galena limestone.

	Feet.
4. Dolomite, earthy, thin bedded	30
3. Dolomite, coarsely crystalline, massive to thick bedded	60
2. Dolomite, thick to thin bedded, coarsely crystalline, cherty	90
1. Dolomite, thick bedded, coarsely crystalline	60

[a] Geology of Dubuque County: Iowa Geol. Surv., vol. 10, 1900, pp. 385-657.

[b] Grant, U. S., Preliminary report on the lead and zinc deposits of southwestern Wisconsin: Wisconsin Geol. Nat. Hist. Surv., bull. 9, 1903, 103 pp.

The thickness of these divisions varies slightly, the difference being due to variations in the levels at which chert begins to appear and to disappear. There are certain horizons characterized by fossils which maintain constant relations to the top and bottom of the formation and which make it possible to recognize stratigraphic horizons. Notable among these are two horizons marked by *Receptaculites oweni*, known locally as the "sunflower fossil" and found constantly 70 feet below the top and 40 feet above the bottom of the formation.

The mines now open are working in the flint beds and the dolomite above. In these beds the characteristic mode of occurrence of the ore is in crevices or open fissures which are at certain horizons locally constant. These horizons are marked by greater weathering of the rock and the consequent production of openings—a local term for either actual open spaces or horizontal bands of soft decayed rock occurring along a crevice. It is characteristic of the area that crevices which are tight or are marked by cracks of the thickness of a knife edge open out into caves from 2 to 12 feet wide at these definite horizons. By the action of solutions and the dropping of unsupported rock from above, the openings are extended upward irregularly, even to the extent of connecting one horizontal opening with another through chimneys. Both the openings and the chimneys are often loosely filled with tumbled rock and with dolomite sands residual from the breaking down of the wall rock. The ore occurs in part as crystals and clusters of crystals attached to the sides of these open caves, and as broken masses scattered with the tumbled rock through the loose sand. To a limited extent there is a tendency for the ore to penetrate the wall rock and to metasomatically replace it. There are some crevices, usually very small ones, which are entirely filled from wall to wall with ore. The two last-named modes of occurrence are not common in the beds so far worked in Illinois. They are, on the other hand, characteristic of the occurrence of ore in the lower beds worked in Wisconsin. In these lower beds the simple vertical crevice with horizontal openings gives way to flats and pitches. The flats are horizontal sheets of ore in openings along bedding planes or partially replacing the beds. The pitches are similar bodies occurring in crevices parallel to the main crevice but cutting across the beds and pitching away from the crevice proper. The pitches connect the flats with one another and with the vertical crevice.

Flats and pitches are found in the rock from the top of the flint beds downward, but reach their greatest development in the lower portion of the Galena, ending in most cases with a rather extensive flat at the horizon of the oil rock, a shale and shaly limestone bed found within a few feet of the top of the Trenton. They afford the largest and richest bodies of ore, and accordingly the maximum development of the mines now working in and around Galena, Ill., is to be expected when they reach somewhat deeper horizons than those now penetrated.

Vertical distribution of the ores.—The characteristic ore of the upper openings is galena. This occurs in well-developed crystals, and is frequently embedded in red, residual clay. It was this ore which was first mined and which led to the development of the region. Below it is the zinc carbonate which next attracted attention and which for two decades has formed the main output of the region. At still lower horizons is zinc sulphide with minor amounts of lead and iron sulphide. It is the sulphide ore which is now attracting attention. The lines between the three classes of ore are not perfectly sharp, and to some extent the ores mingle, but in any general survey the three classes become quite distinct. In general the galena and the zinc-carbonate ores are most abundant in the crevices and openings, while the zinc-sulphide ores characterize the pitches and flats.

Origin of the ores.—The order of superposition of the ores is readily explained as a result of secondary concentration by descending waters. By their action the zinc and iron sulphides originally present with the galena in the upper levels have been oxidized and carried below to be reprecipitated. The galena, being less readily soluble, is left behind. The belt of carbonates marks the zone in which this leaching is yet in process. The great pitches and flats filled with mixed sulphides, of which blende is dominant, mark the zone of secondary enrichment. Whether this second concentration marks a reversal in direction of flow of the local ground water or merely the final stages of a general downward movement is yet in question, and is, in this instance, mainly of academic interest. The ore bodies of the region are confined to the Galena-Trenton rocks, and neither hypothesis offers encouragement for the prospecting of lower-lying beds. The second concentration is the dominant one and accounts for the fact that the richest ores occur in the lower portion of the section and good bodies of zinc ore are below the old lead workings.

Present development.—In northwestern Illinois there is at present no important producing mine. A considerable amount of development is under way and an increasing production may confidently be expected. There are thirteen properties upon which work is now being done with a view to zinc production. A few of these are hoisting ore, but none are as yet down to the horizons at which large bodies may be expected. The Oldenburg mine was for many years a producer of lead ore, and later of zinc carbonate. The bottom of the old workings, as reported, is at least 100 feet above the oil rock. The mine has lately resumed operation. The Black Jack, or Peru mine, south of Galena, has produced an important amount of zinc ore. The workings extend well down toward the bottom of the Galena, and drill holes have been carried down to the St. Peter. This mine, since it is located well toward the southern boundary of the district, has proved that mineralization, even of the lower beds, is not confined to the north, and this fact offers large hope for prospecting throughout a wide area. In the main the mines now being operated are clustered around Galena and Elizabeth.

Probably 150 square miles, occupying the northwestern portion of Jo Daviess County, may fairly be considered to be within the proved ore-bearing district. With a less degree of probability, the whole of the county may be included. So far the largest production has come from the areas from which the Maquoketa shale has been removed by erosion, and no ore has, so far as known, been mined under the Niagara. Within a year, however, an important find has been made in the Sand Prairie mine, at the very edge of the Niagara escarpment and where the whole thickness of shale is present. At Dubuque an amount of ore, in the aggregate very large, has been taken from under an important thickness of the shale. For the present, therefore, the only known areal limitation to be regarded in prospecting is the boundary line of Niagara bluffs. In depth the St. Peter sandstone marks the horizon below which there is no reason to expect ore, and very little ore has heretofore been found beneath the well-known oil rock.

Grade of the ore.—The grade of the crude ore so far mined has probably been notably above that of the Joplin district, though it is difficult to get reliable figures. It is to be remembered, however, that the concentrates, since they carry a high percentage of iron, must either be sold at low price or be subjected to a secondary treatment which increases the cost of production. It is also true here as elsewhere that the grade of the ore mined depends on cost of production and on the state of the market. There are considerable quantities of rock containing a percentage of the sulphides sufficient to make the rock an ore whenever mining costs become as low as in the Joplin district.

In conclusion, it may be stated that the upper Mississippi district may be expected in the future to produce large quantities of zinc ore, and that the portions lying in Illinois give every promise of developing with the rest of the district.

RECENT ZINC MINING IN EAST TENNESSEE.

By Arthur Keith.

The zinc deposits of East Tennessee have been known and worked for many years. Some of them were described in the Morristown and Maynardville geologic folios of the United States Geological Survey. Considerable developments were being made when those folios were in course of publication, and it seems desirable to make public the additional knowledge since obtained.

Location.—Deposits of zinc ore are found at numerous places in East Tennessee. Those in which recent developments have been made lie between Knoxville and Morristown, in Knox and Jefferson counties. They are thus nearly in the center of the East Tennessee Valley. The area in which the zinc is found is less than 40 miles long, hardly over a mile in width, and has a general northeast-southwest direction. In all cases thus far developed the zinc is within a mile or two of the main line of the Southern Railway. From southwest to northeast the zinc localities are as follows: On Loves Creek, 5 miles northeast of Knoxville; close to McMillan station, 9 miles northeast of Knoxville; 2 miles, 1 mile, and one-half mile west of Mascot station; one-half mile east of Newmarket; 1½ miles southeast of Newmarket, and at Jefferson City.

Topography.—The surface of this portion of the valley consists of lines of rounded hills and intervening valleys. These follow straight or irregular courses, according as the underlying rocks change their trend and dip. Near Knoxville, for instance, they run in regular lines, while around Newmarket there is considerable variety. The crests of the hills are all from 1,000 to 1,100 feet above sea, and form a plateau below which the streams have worn their channels. Holston River drains the entire zinc belt, and is from 200 to 300 feet below the general level of the plateau. Its larger tributaries have cut their channels to about the same depth, while the smaller ones descend to the river with numerous rapids. The slopes adjoining the streams are usually much steeper than the rest of the plateau slopes, and contain many rock ledges and cliffs. The supply of water in the streams is good, and the larger ones are unfailing. Most of the water of the smaller streams is derived from springs, whose flow is only stopped by severe droughts. In the areas underlain by limestone much of the drainage is underground, and the water reappears from place to place in bold springs.

Rock formations.—The rocks of this portion of the valley are all calcareous, and include limestone, dolomite, and shale. The zinc deposits are found in the Knox dolomite, the principal formation of the region, which consists of massive limestones and dolomites, more or less cherty. These have various colors, ranging from blue, gray, and dove colored to nearly white. Above this formation are the blue and gray Chickamauga limestones. These in turn are succeeded by the Holston marble, consisting of variegated marbles of a general red or gray color. The zinc deposits are found in the upper part of the Knox dolomite and not far below the Chickamauga limestone. The lower portion of the Knox dolomite is of Cambrian age, but all the strata near the zinc deposits are Ordovician.

Structure.—The rocks of the East Tennessee Valley are seldom found in a horizontal position, but are bent into folds of various angles and broken by faults. These structures have a general northeast-southwest trend, and cause the belts of rock to outcrop in similar courses. One of the principal synclinal folds of the region passes a few miles south of the zinc deposits, so that the rocks inclosing the zinc ores have a general dip to the south toward its axis. The amount of dip varies considerably—from 40° to 45° near Knoxville to 10° or 20°, or even less, in the vicinity of Newmarket and Jefferson City. Minor rolls, or flat arches, form exceptions to the general southerly dip, but do not appear to have any close relation to the zinc deposits. At Newmarket and Jefferson City the zinc-bearing rocks are near the plane of a great overthrust fault. That they are possibly all of the same origin would seem to be borne out by the nature of the deposits themselves, which are in all cases formed in broken or brecciated strata. In general, however, only the most limited brecciation is to be observed along the faults of this region. Toward the southwest end of the belt, moreover, there is no such association of the faults with the deposits, so that a common origin is not likely.

Developments.—As already stated, the existence of the zinc ore in this region has been known for many years. The ores have the same features in all cases; carbonate and silicate of zinc near the surface are succeeded by the sulphide 10 or 20 feet downward. About twenty years ago many openings were made and considerable rock was blasted out on Spout Run, about 2 miles west of Mascot station, on the Southern Railway, and also 1½ miles west of Mascot, where the Roseberry Zinc Company is now operating. Work in these places was practically limited to the more easily treated carbonate ores. A great many test pits were sunk within a few miles to develop the extent of the ore.

At Jefferson City, formerly Mossy Creek, is located the most extensive mine of the region, which was opened about 1860. The carbonate and silicate were manufactured into zinc oxide. This was soon closed down, but operations have been resumed at several different times in taking out the blende below the surface ores. No work has been done for several years. In this mine the ore has been taken out from a series of large open cuts. These cover an area about 600 by 75 feet and are from 20 to 40 feet deep. The rock was blasted out and sorted by hand. The best material was crushed and the blende was concentrated by washing. Water for the purpose was abundant in Mossy Creek, which flowed past the mine. The ore was not reduced at the mine, but was all shipped away for smelting.

In 1898 interest was revived in the zinc deposits, and mining operations were begun 1½ miles southeast of Newmarket, 5 miles northeast of Knoxville, and at McMillan. The operations at Newmarket were discontinued after the rock and ore had been removed from an open cut about 80 feet in diameter and 30 feet deep. A mill was erected and the ore crushed and washed at the mine. A great drawback to successful work was the scarcity of water. The mine was situated on a hillside in low, rolling country, and the only neighboring stream was below the mine and practically dried up during droughts. Operations 5 miles northeast of Knoxville consisted of the sinking of a shaft and several test pits. No great amount of ore was handled, and work was soon discontinued. Loves Creek flows past the mine and furnishes sufficient water. At McMillan an open cut was made in a good body of ore.

In 1900 work was begun on the blende by the Roseberry Zinc Company on the site of old workings 1½ miles west of Mascot. In 1903 the Holston Zinc Company began operations in both blende and carbonate ore one-half mile west of Mascot. Both of these mines are being worked at present through open cuts, though short tunnels have been driven at the Roseberry mine to verify the extent of the ore. At the Roseberry mine the open cuts are 200 by 50 feet; at the Holston mine they are 100 by 25 feet. A mill has been erected at each mine to crush the rock and wash out the blende, but none of the ore is reduced at the mines. Each mine is situated on a creek which supplies water for concentrating.

Nature of the deposits.—The ores of zinc consist of the sulphide, blende, of the carbonate, smithsonite, and of the hydrous silicate, calamine. The carbonate and silicate are not found deeper than 20 feet, and were formed from the blende by various weathering processes, primarily oxidation. Much calcite was dissolved in this operation, leaving open spaces and veins lined with crusts of the silicate and carbonate. The process of transformation from the blende to these minerals is readily apparent in all its stages. In their formation the silicic and carbonic acids were derived from the atmospheric waters, and the sulphur combined with the blende passed away in other forms. Associated with the blende is a large amount of secondary calcite, which probably represents redeposition of the original limestone material.

The ore is found, as has been already stated, in masses of brecciated limestone and dolomite. This is the case in all deposits which have been exploited, and is probably true for the remainder of the region, where there are only surface indications of the ore. The breccias are extremely angular, and the fragments vary from minute grains up to blocks a foot or two in size, most of them being but a few inches. Only here and there does there appear to have been much change of the large fragments by solution. Their edges are sharp and clear in most cases, and the calcite and blende are practically limited to the angular spaces between them. All parts of the formation are brecciated, including dolomite, limestone, chert, and a few thin slaty partings. The limestone appears to have been more subject to the brecciating action than the other beds. In a number of cases a single bed of limestone appears to be more brecciated than the overlying and underlying beds.

The ore body consists of the entire mass of brecciated rock. The portions of this which are richest in blende are selected by hand for crushing and washing. Thus considerable material is handled which is too lean to be profitably worked. Small pockets and bodies of ore are very rich, and contain as much as 50 per cent of their volume in blende; the other extreme consists of large blocks of limestone with scattered streaks and crystals of blende. Taking the ore bodies as a whole, there seems to be no regularity or system in the distribution of the richer pockets. Such defined shape as they have is roughly lenticular, and they do not partake of the character of fissure veins. According to analyses by the Roseberry Zinc Company, 90 per cent of the concentrates is zinc sulphide, the impurities being nearly all calcium and magnesium carbonate.

The mixture of blende and calcite which occupies the spaces between the limestone blocks has various forms. Usually the two minerals are intergrown at random. In many cases there is a separation of the two minerals into bands on opposite sides of the fissure or space between two limestone blocks. In this respect, and for small distances, the deposits have the appearance of fissure veins. These do not run at any regular or single angle or group of angles, however, but follow irregular cracks and breaks between the limestone fragments. By far the larger part of the ore is the irregular mixture which practically honeycombs the rock, and its chief variations are in the proportions of blende, calcite, and limestone. In the deposits west of Mascot and at Jefferson City are here and there to be seen bright-yellow stains of some salt of cadmium. These are weathered from blende which carries a small percentage of cadmium.

The extent of the deposits.—The ores of zinc are known to extend, as already stated, over a distance of about 40 miles. They are not continuous throughout that distance, of course, but are found in large quantity at many places and have been traced by the float at small intervals over much of the intervening space. The largest body of ore exposed is in the old mine at Jefferson City, where open cuts have developed it along a north-and-south line for about 600 feet, with an average width of 75 feet and depth of 20 to 40 feet. This is by no means the total extent of the deposit at that place, and its continuation toward the northeast is assured by the presence of the float ore. The silicates, in particular, are a ready means of tracing the zinc deposits, for they persist in the residual clays long after the disintegration of other materials. The slopes of the limestone hills are gentle, and the float would not be likely to travel far from its source. Thus its wide distribution is a guarantee of an equally wide extent of the ore. It is, accordingly, probable that the developments have shown up only a very small fraction of the ore available.

Source of the material.—The origin of the blende is a subject on which there is little evidence. The inclosing rocks, so far as known, contain no trace of zinc, nor is it known in any of the other formations which come to the surface in the Great Valley. The secondary blende and calcite appear to replace the finer fragments of the original limestone, the blende being substituted for a certain amount of the limestone, and the limestone recrystallizing as calcite. The ore and gangue were clearly deposited from aqueous solutions. From the entire absence of metamorphism in the interior of the limestone fragments, it can be inferred that the solutions were either only slightly heated or cold. In regions where metamorphism is due to heat, its results are found uniformly in all portions of the rock mass affected. Nor are there any bodies of igneous rock cutting the limestones at the surface in this region, from which the heat might have been derived. It is, of course, possible that such may exist beneath the surface, but that would be a pure assumption.

Heated waters are found emerging from the limestones in a few places in the Appalachian uplift at the present day, so that it is possible that they may have issued in this region at some previous time. The present heated waters, however, do not contain zinc. Moreover, the ability of cold waters to break up and replace calcite and blende is amply shown by the alterations of these minerals into carbonates and silicates in all of their weathered outcrops. The surface waters which effect this change are probably slightly charged with carbonic acid from vegetable matter.

The only source for the blende which appears possible is some portion of the earth's crust which lies below the sedimentary rocks. As nearly as can be inferred, the igneous rocks which occupy this position are about 15,000 feet below the surface. To support the conclusion that this is the actual source of the zinc, there is only the negative evidence before mentioned; nor is there any known reason why the zinc should be deposited along this line rather than along others in similar situations.

In this zinc belt the zinc was deposited only in the upper portions of the Knox dolomite. However, this is not the only part of the formation which contains zinc, but it is found in the bottom of the Knox dolomite at a number of localities about 30 miles north of Knoxville. Nor is the zinc limited in any of these general localities precisely to one horizon, but it varies more or less. This would be expected from waters which circulate through masses of broken rock. Judging from similar phenomena elsewhere, the zones of crushing and breaking dip beneath the surface at considerable angles and extend to great depths. It is therefore probable that here the zinc-bearing waters rose from below through the mass of broken limestone, dissolving here and depositing there, as local conditions permitted.

PUBLICATIONS ON LEAD AND ZINC.

Many papers relating to silver-lead deposits will be found included in the list on pages 151 and 153 of this bulletin. The principal other papers on lead and zinc, published by the United States Geological Survey, or by members of its staff, are the following:

ADAMS, G. I. Zinc and lead deposits of northern Arkansas. In Bulletin U. S. Geol. Survey No. 213, pp. 187–196. 1903.

BAIN, H. F., VAN HISE, C. R., and ADAMS, G. I. Preliminary report on the lead and zinc deposits of the Ozark region [Mo., Ark.]. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 23–228. 1902.

CLERC, F. L. The mining and metallurgy of lead and zinc in the United States. In Mineral Resources U. S. for 1882, pp. 358–386. 1883.

HOFMANN, H. O. Recent improvements in desilverizing lead in the United States. In Mineral Resources U. S. for 1883–84, pp. 462–473. 1885.

ILES, M. W. Lead slags. In Mineral Resources U. S. for 1883–84, pp. 440–462. 1885.

SMITH, W. S. T. Lead and zinc deposits of the Joplin district, Missouri-Kansas. In Bulletin U. S. Geol. Survey No. 213, pp. 197–204. 1903.

ULRICH, E. O., and SMITH, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. In Bulletin U. S. Geol. Survey No. 213, pp. 205–213. 1093.

VAN HISE, C. R. Some principles controlling deposition of ores. The association of lead, zinc, and iron compounds. Trans. Am. Inst. Min. Eng., vol. 30, pp. 102–109, 141–150.

VAN HISE, C. R., and BAIN, H. F. Lead and zinc deposits of the Mississippi Valley, U. S. A. Trans Inst. Min. Eng. (England), vol. 23, pp. 376–434.

WINSLOW, A. The disseminated lead ores of southeastern Missouri. Bulletin U. S. Geol. Survey No. 132. 31 pp. 1896.

WOLFF, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin U. S. Geol. Survey No. 213, pp. 214–217. 1903.

IRON AND MANGANESE.

THE LAKE SUPERIOR IRON REGION DURING 1903.

By C. K. Leith.

VERMILION DISTRICT.

The Vermilion district of Minnesota is described in Monograph XLV, by J. Morgan Clements. It is accompanied by both general and detail maps of the range between Tower and Gunflint Lake. The field work for this report was done by Messrs. Clements, Van Hise, Bayley, Merriam, and Leith. The features of the monograph were summarized in Bulletin No. 213.

MENOMINEE DISTRICT.

The Menominee district is described by W. S. Bayley in Monograph XLVI. This is a volume of 501 pages, accompanied by a general map of the Menominee range, and several detail maps. The discussion of the geologic features does not differ essentially from that in a preliminary report on the district published in 1900 as the Menominee Special geologic folio (No. 62), but in the present discussion much of interest has been added, including a complete description of the ores, their geologic occurrence, structure, physical characteristics, chemical composition, mineralogical composition, etc.

The ores are confined to the Vulcan formation of the so-called Upper Huronian series. The Vulcan formation is subdivided into three members, from the base up, the iron-bearing Traders member, the Brier slate, and the iron-bearing Curry member. The ores are further confined to the Traders and Curry members, and, other things being equal, are more likely to occur at lower and higher horizons than at the middle horizon.

The richer ores are found in situations where the attitudes of the rocks are such as to furnish converging channels for percolating waters, and the largest deposits are in the main channels toward which the drainage converges. Consequently, the deposits of large size rest upon relatively impervious foundations, which are in such positions as to constitute pitching troughs. A pitching trough may be made (a) by the dolomite formation underlying the Traders member of the Vulcan formation, (b) by a slate constituting the lower part of the Traders member, and (c) by the Brier slate between the Traders and Curry members. The dolomite formation is especially likely to furnish an impervious basement where its upper horizon has been transformed into a talc-shist, as a consequence of folding and shearing between the formations. Smaller ore deposits occur at contacts between the different members and at places within the iron-bearing members where severe brecciation has occurred.[a]

The ores are largely of Bessemer grade. "The rich ores are usually bluish-black, porous, fine-grained aggregates of crystallized hematite." Some are highly siliceous, resulting from the enrichment of jaspilites and differing very little in appearance from them. "The brecciated ores may consist of jasper fragments in a mass of hematite, or of hematite fragments in a mass of dolomite, or they may be composed of fragments of ore, jasper, and slate in a mass consisting largely of slate débris that has been strongly ferruginized." The ores, when exposed to the action of the atmosphere, become coated with a white efflorescence, consisting of a mixture of the sulphates of sodium, magnesium, and calcium, in which the first-named is greatly in excess.

The forms of the ore bodies vary with their positions. They conform in a general way to the shape of the foundation on which they rest. The deposits in troughs have in general a U-shaped cross section, very thick at the bottom. Where much compressed, the arms of the U may unite at the center and produce a lens-shaped deposit. Contact deposits are usually broad and sheet-like, with irregular projections extending from their upper surfaces.

The shape and structure of the ore deposits, their locations along lines of major water circulation confined below by impervious basements, and association with minerals of aqueous origin, point to the concentration of much of the ore through the agency of downward-percolating waters. But the iron-bearing formation of the Menominee district, and especially the Traders member, differs from that of other districts in the Lake Superior region in having a comparatively large quantity of original detrital ore. Principally from the close similarity of the nondetrital ores of the Menominee district to the nondetrital ores of the Marquette and Gogebic districts it is believed that the nondetrital ores of the Menominee district are largely a result of the secondary alteration of an original cherty iron carbonate, although the alteration has been so thorough that little or none of this material now remains in the iron formation. In the slate overlying the iron formation there still remains iron carbonate showing characteristic alterations, on a small scale, to chert, jasper, and iron ore, thus affording corroborative evidence that iron carbonate originally existed in the iron formation itself. In both the Curry and Traders members pseudomorphs of concretions of iron carbonate are found. The

[a] Bayley, W. S., The Menominee iron-bearing district of Michigan: Mon. U. S. Geol. Survey, vol. 46, 1904, p. 392.

essential chemical change through which the ores have been developed from the cherty iron carbonate is oxidation of the ferrous iron and carrying away of silica and carbon dioxide, as so often described for other parts of the Lake Superior region.

The total thickness of the Vulcan formation is about 650 feet, of which over half is a fragmental, noniron-bearing rock. This thickness is small as compared with iron formations of other districts of the Lake Superior region.

The Hanbury slate, overlying the Vulcan formation, contains iron-formation material, but no considerable deposit of ore has thus far been discovered.

MARQUETTE DISTRICT.

A small amount of field work in the Marquette district was done in 1903 by C. K. Leith and W. N. Smith, with a view to determining the extent and nature of an unconformity at the base of the Ajibik quartzite in the Lower Huronian series, discovered by Prof. E. A. Seaman, of the Michigan School of Mines. It was found to be of considerable importance and to represent a time interval long enough to allow of truncation by erosion of the underlying series to a very considerable extent, as held by Professor Seaman. Evidence of the unconformity was found at a number of places along the north, east, and south sides of the Marquette syncline. As a result of this work there are now discriminated three distinct unconformable series in the so-called Huronian of this district. The important bearing of this on the general correlation of formations in the Lake Superior and Lake Huron regions is obvious.

The Mesnard quartzite of the Lower Huronian series was carried in the mapping some distance farther west than on the previously published maps of the Marquette district. Toward the west the quartzite becomes altered to a sericite-schist and is discolored, making its recognition difficult except where actually followed through the stages of its alterations. The western portion of the formation had been included in previous mapping with the Kitchi schist member of the Archean.

The Carp River fault was mapped in detail and found to have a somewhat different attitude and larger extent than previously shown on the Marquette maps.

Important changes have been made in the mapping of the Palmer district, principally by mining companies in connection with their explorations for iron ore in this area. Two companies have prepared large-scale detail sheets showing not only all the surface features but many underground records. One of the most conspicuous changes is the introduction of one and perhaps two faults to explain the distribution.

MESABI DISTRICT.

During the year exploration has been vigorous, though with less success than in preceding years. Some of the results of the work have been to show the iron formation in the vicinity of Biwabik to be much wider than indicated on the recent Survey map of this range. The slate layers there found, which have been previously taken as the northern margin of the overlying black slate (Virginia slate), are now shown to be but interstratifications within the iron formation. Exploration has also seemed to confirm conclusions as to the essential barrenness of the extreme eastern and western portions of the Mesabi district.

BARABOO DISTRICT.

During the present year the Wisconsin geological and natural history survey made an investigation of the newly found occurrence of iron ore in the Baraboo ranges in southern Wisconsin. This investigation was carried out by S. Weidman, and his report is in the form of a bulletin of the Wisconsin survey (Bull. 13), containing a general map of the district on a scale of 1 inch to the mile.

A pre-Cambrian quartzite formation, having an estimated thickness of 3,000 to 5,000 feet, forms an east-west synclinorium about 20 miles long and ranging in width from 2 miles on the east to 10 or 12 miles on the west, resting on a basement of igneous rock. The upturned north and south edges of the quartzite forms respectively the north and south ranges of the Baraboo Bluffs, standing 700 to 800 feet above the surrounding country and above the intervening valley. This valley is occupied by formations younger than and conformable with the quartzite. Mr. Weidman has named these formations the Seeley slate and Freedom formation. The Seeley slate has an estimated thickness of 500 to 800 feet, and above this is the Freedom formation, mainly dolomite, which has a thickness estimated to be at least 800 feet, and which bears the iron-ore deposits in its lower horizon.

Flat-lying Paleozoic sediments, unconformably overlying the pre-Cambrian rocks, occupy the surrounding area and partly fill the valley. The Paleozoic rocks range from upper Cambrian (Potsdam) in the valley bottom to Ordovician (Trenton) on the upper portions of the quartzite ranges. The Potsdam sandstone has a thickness ranging from a few feet to a maximum of about 570 feet in the valley. Glacial drift is abundant over the quartzite ranges and in the valleys in the eastern half of the district, but occurs only in the valleys in the western half.

The iron ore occurs in the lower horizons of the Freedom formation and is mainly a Bessemer hematite with soft and earthy, hard and black, and banded siliceous phases. A very small amount of hydrated hematite or limonite is also present. The rocks immediately associated with the ore and into which the ore grades are dolomite, cherty ferruginous dolomite, ferruginous chert, ferruginous slate, and ferruginous dolomitic slate—in fact, all possible gradations and mixtures of the minerals dolomite, hematite, quartz, and such argillaceous minerals as kaolin and chlorite. In the ferruginous rocks associated with the iron ore the iron occurs as hematite and also in the form of carbonate, isomorphous with carbonate of calcium, magnesium, and manganese, in the form of ferro-dolomite and manganic-ferro-dolomite and as silicates combined with various proportions of alumina, lime, magnesia, and manganese, as chlorite and mica, and also very probably to a small extent as iron phosphate.

The ore deposits thus far found are all in the valley between the quartzite ranges, and because of the structure of the pre-Cambrian series it is hardly possible that ore deposits will be found elsewhere than in this valley.

The iron ore is a stratified formation and is conformable with the associated stratified rocks, both below and above. The ore bodies therefore have the dip and strike of the associated rocks, and are found dipping at various angles from nearly horizontal to nearly vertical.

At the Illinois mine, 3 miles southwest of North Freedom, and on the south limb of the syncline, the ore deposit has a thickness of 30 to 35 feet, and bears an average of 54 to 58 per cent metallic iron. The dip of the ore body and adjacent formation is about 50° N. Between the ore and underlying Seeley slate are 100 feet of alternating beds and thin seams of iron ore with a considerable thickness of dolomite and ferruginous dolomite, ferruginous chert, and ferruginous slate. Between the ore deposit and the overlying dolomite are alternating strata of similar character grading up into the nearly pure dolomite. North of the Illinois mine a thickness of 600 feet of dolomite is known to occur.

Underground exploration seems to show that the conditions and character of the rock existing at the Illinois mine prevail generally, as should be expected, throughout the valley wherever the iron formation and overlying rocks have not been eroded by the subsequent pre-Potsdam erosion. In general, there appears to be a highly ferruginous horizon near the base of the dolomitic formation, having a variable thickness, probably ranging from 400 to 500 feet. This ferruginous horizon bears one or more deposits of iron ore separated by intervening strata of associated ferruginous rock. In one of the drill holes in the west end of the district nearly 200 feet of iron ore and paint rock were penetrated immediately beneath the unconformable Potsdam sandstone, the average content of iron for this distance being about 45 per cent.

The iron ore is believed by Weidman to be mainly a product of metamorphism of what was originally a deposit of nearly pure ferric hydrate, deposited in shallow lagoons and protected bays and formed in a manner similar to bog and lake ore at the present day, through chemical and organic processes acting upon and within shallow waters unusually rich in iron. The evidence of shallow water, and not deep sea, in which the iron was originally deposited, is furnished by the numerous sun cracks in the ferruginous carbonaceous slate immediately associated with the ore strata and the presence of carbonaceous matter in the iron ore and associated rocks. The process of metamorphism, it is believed, has been mainly that of dehydration of the original ferric hydrate analogous to the partial dehydration of the originally hydrated silicates, chlorite, and kaolin of the underlying Seeley slate.

CANADIAN PORTION OF THE LAKE SUPERIOR REGION.

Ore has been found by drilling in the Animikee series (the eastward continuation of the Mesabi series) near Loon Lake, east of Port Arthur. The iron formation is similar to that of the Mesabi range, although it is thin and intruded by Keweenawan sills. If the ore deposit is here found to be of commercial size and grade, it will be the first of its kind discovered in the Animikee series between the eastern portion of the Mesabi range and the north shore of Lake Superior, a distance of 160 miles.

Exploration has been active in the Attikokan and Mattewan districts, although apparently without decisive results.

Exploration has been active in many other localities from the Attikokan district, on the west, to Georgian Bay, on the east, and has resulted in a considerable extension of the areas of known iron formation. The increased activity in exploration on the Canadian side of the boundary is largely due to the entrance of American companies, and signifies to a considerable extent diminution in the discoveries and of the area available for exploration in the parts of the Lake Superior region within the United States.

IRON ORES IN THE UINTA MOUNTAINS, UTAH.

By J. M. Boutwell.

INTRODUCTION.

The examination of the economic geology of the Park City district, which involved the first detailed geologic mapping in the Wasatch Range, necessitated an investigation of broad geologic problems in neighboring regions to the east and west. Accordingly, in the latter part of September, the general geology of the region to the east was studied en reconnaissance by the writer, with the assistance of Ellsworth Huntington. This region, which has been mapped topographically by this survey on a scale of 2 miles to the inch, is included in the Coalville quadrangle, which extends from Echo to Heber in a north-south direction, and from Park City nearly to the headwaters of Weber and Provo rivers in an east-west direction. It embraces an area of approximately 240 square miles. In the course of this reconnaissance deposits of rich, red iron ore (hematite) were visited, and significant geologic data were obtained. The purpose of this sketch is to present the essential facts learned about these iron deposits. In order that these facts and the problems which might arise in connection with them may be more clearly understood, the broad geographic and geologic features will be described and new data on the unsettled age of the geologic formations in the interior of the range will be presented.

GEOGRAPHY.

Location.—The Uinta Range is situated in greater part in the northeastern part of Utah, and in lesser part in the extreme northwestern part of Colorado, immediately south of Wyoming. In about the latitude of Salt Lake City and the southern shores of Great Salt Lake, it extends from the Wasatch Range eastward approximately 150 miles, with an average width of about 35 miles. The region in which the principal known deposits of iron ore occur is near the central part and on the southwestern slope of the mountains.

Topography.—The general form of the range is an elongated, broad, flat-topped arch. As the main east-west divide lies north of the center of the range, a north-south profile shows unsymmetrical slopes. The northern slopes fall off steeply to a great, undulating basin, while the southern slopes descend very gently to an extensive plateau region. The elevation of the range varies from 6,500 feet in its western foothills, where it dips under Kamas Prairie, to 12,400 on Mount Agassiz, 12,500 on Hayden Peak, 13,200 on Mount Tokewana, 13,250 on Mount Lovenia, and 13,486 (corrected) on Emmons Peak.

An oval central area is encircled by a series of generally continuous, unsymmetrical ridges, with steep inward-facing scarps and more gentle outfacing slopes. Dissection has reduced the inclosed interior plateau to a region of strong relief characterized by an exceedingly narrow, steep-sided main east-west divide, which rises into isolated peaks and falls off steeply to the north and south to heads of great canyons. These canyons, especially those draining to the south, are characterized by broad, flaring, high-lying, upper levels, deeply trenched by very narrow, steep-sided gorges. In the western part of the range some of these headward portions, on emerging from the interior area, continue north or south along radial courses through the encircling ridges and down their gentle outfacing slopes. Others on reaching these ridges turn abruptly and escape by longitudinal valleys, whose alluvial bottoms are terraced and trenched. A third class of streams, which are characteristically short and not graded, head near the crests of these encircling ridges and flow down infacing scarps toward the interior of the area (opposite to the direction of prevailing dip), thence out by the longitudinal valleys. In the eastern part of the range the drainage departs from these simple types. Thus, in different parts of its course, Green River exhibits characteristics of several different types of drainage. In the extreme western portion of the range Provo and Weber rivers, the master streams of the region, pursue longitudinal courses for a large portion of their extent. They are fed not only by headwaters of transverse radial streams, but also by streams flowing toward the interior against the dip.

In brief, the range is an elongated dome composed of a deeply dissected, central plateau and encircling cuestas. The dissection of the central area is characterized by a postmature master divide, surmounting broad glacial amphitheaters, which, in turn, are incised by deep, narrow canyons. Intermediate between the eastern and western portions of the range the drainage is largely consequent; at the eastern end it is complex, Green River probably being superimposed, locally at least; and in the western portion the master streams follow partially graded, subsequent courses, and obsequent drainage is well developed.

Local physiography.—The iron deposits which are the subject of this paper lie near the inner margin of the belt of encircling cuestas, and thus immediately outside of the interior plateau region. The narrow divide in which they occur overlooks eastward the broad glacial amphitheater of the upper Duchesne and its canyon, and westward the corresponding amphitheater of Soapstone Basin. From Soapstone Basin the fall to the main canyon of Provo River is abrupt, but from near its head to its outlet from the range the Provo flows in a terraced, graded, alluvial bottom, which merges on the west with Kamas Prairie.

GEOLOGIC FEATURES.

Stratigraphy and structure.—The stratigraphy and structure of the Uinta uplift have been described by S. F. Emmons as follows:

The geological structure of the Uinta Range, like its physical structure, is in its main outlines remarkably simple and regular. Its main mass was formed by the uplifting of an immense thickness of practically conformable strata at the close of the Cretaceous period in a broad, anticlinal fold, having the form of a flat arch or inverted U. The movement which produced this fold was accompanied by comparatively little fracturing and dislocation of strata and by no intrusion of igneous rocks. * * *

The conformable series of beds involved in the Uinta fold extend in geological horizon, as far as their age has been satisfactorily determined, from the Carboniferous up to the top of the Cretaceous. The Carboniferous formation, whose beds form the main mass of the range, is represented by the groups of the Weber Quartzite, Upper Coal-Measures, and Permo-Carboniferous. The beds of the first of these form the crest throughout the greater part of its extent, lying nearly horizontal or inclined at very low angles. They consist of a lower series of white and reddish compact quartzites, a middle series of purple, coarse quartzites, and an upper of red and striped sandstones, in all of which no unconformity was observed; they are in general barren of all fossil remains, only two species of *Spirifer* obtained from quartzite débris having been found by us; but as they are quite conformable with the limestones of the Upper Coal-Measure group, which abound in well-defined fossil remains, they have been referred to the Weber quartzite group.

Their thickness, as observed in different parts of the range, is from 10,000 to 12,000 feet, while, as their base is never reached, the actual thickness of the formation may be indefinitely greater. This fact might seem to throw some doubt on the correctness of the assumption that they all belong to the Carboniferous formation, since the Weber quartzite in the Wasatch Range, at a comparatively short distance to the west, attains a development of only 5,000 to 7,000 feet, and the general tendency of all the formations is to thin out to the eastward. Lithologically, also, the lower beds of this group resemble, perhaps, the Cambrian rather than the Weber quartzite of the Wasatch, and it might be supposed that the upper portion of this group had been deposited over a shallow, rounding uplift of Cambrian rocks in such a manner as to show no appreciable unconformity of angle.

* * * * * * *

Since the above was written, there has been published in the report of Prof. J. W. Powell on the Geology of the Eastern Uinta Mountains, sections made in the canyons of the Green River, showing an unconformity of deposition in these beds, which, if correct, would seem to prove the latter supposition to be more correct. [Footnote by S. F. Emmons.]

While throughout the greater portion of the range the folding * * * has been mainly produced by forces * * * at right angles to its longer axis, there has also been some, though considerably less, longitudinal compression * * * producing minor, transverse corrugations * * *.

In the eastern portion of the range the longitudinal compression has been proportionately greater * * *. The crest of the main fold is much widened, and bent somewhat to the southward * * *. To the south of the main fold the region of the Yampa Plateau was uplifted bodily, developing a double anticlinal at its western extremity, which merges into a single fold at the east end, while the sharp, rectangular folds on either flank were accompanied by a certain amount of dislocation * * *.

To the north of the Archean body of Red Creek was also some disturbance * * * in the vicinity of Bitter Creek, and on the western edge of the basin a series of narrow, wave-like ridges were formed, having a direction resultant of that of the shores of the Uinta and Wasatch mountains, whose influences in the folding are seen in the two independent directions of strike found in these ridges.[a]

The above quotations, from the general descriptions of features observed by the geologists of the fortieth parallel, present the broad facts of structure and sedimentation. They show also that one of the great problems, which, in the absence of conclusive evidence, was left an open question, was the age of the rocks constituting the great central area of the range. It appears that the discovery of an unconformity by Powell in the eastern Uintas was considered by Emmons as explanatory of the otherwise inexplicable thickness of siliceous beds, and that accordingly these rocks of the interior were tentatively supposed to be Cambrian.

In the middle eighties White encountered the same problem. He states:

Much difference of opinion has prevailed as to the true geological age of the Uinta sandstone. King, who gave it the name of Weber quartzite, states that it is of Carboniferous age, in which view Hague and Emmons concur. Powell referred it provisionally to the Devonian; Marsh was disposed to regard it as belonging to the Silurian, at least in part; and Hayden was of the opinion that it ought to be referred to the Lower Silurian.

Whatever may be the geological age of the Uinta sandstone, it is certain that the undoubted Carboniferous rocks of this district rest directly upon it, and, according to Powell, there is in many places distinct unconformity between them. It is also true that within this district no other rocks than the Archean have been found beneath the Uinta sandstone.[b]

Although in the course of such rapid traversing as is required on reconnaissance work, it is obviously impossible to work out minor structures and to detect all great faults, the general relations may be observed. During the writer's visit to the Ferry iron property definite paleontologic data were obtained which tend to bring the problem nearer solution.

The general course of Provo River lies along the division between the sandstone and quartzite formations whose geologic age is in doubt and the overlying limestone formation. This great sandstone formation, which is exposed in the canyon cut by the North Fork of the Provo, and in the canyon of the main Provo River, north from its junction with Soapstone Gulch, appears to underlie a gray, fossiliferous limestone. From croppings of this limestone on the Provo-Duchesne divide between the heads of Soapstone and Iron Mine

[a] Emmons, S. F., U. S. Geol. Explor. 40th Par., vol. 2, pp. 198-199, 201, 202.

[b] White, C. A., Ninth Ann. Rept. U. S. Geol. Survey, 1889, pp. 687-688.

gulches three lots of indicative fossils were collected. These have been determined by Dr. G. H. Girty to belong to the lower Carboniferous (Mississippian). Accordingly it would appear that the great sandstone series is earlier than lower Carboniferous.

It was not practicable to remain in this region long enough to work out the detailed structure, nor to examine the character of the contact between the lower Carboniferous and the underlying siliceous series. In general, it was noted that the members which immediately underlie the fossiliferous limestone include varicolored and cross-bedded sandstones and quartzite, black fucoid shales, and occasional waterworn quartz pebbles. Special investigation of these problems was undertaken by a Survey party last summer, and the result of that work will throw much additional light on this important geologic problem.

ECONOMIC FEATURES.

The traditional absence of deposits of metallic ores in the Uinta Range and the prospective development of this region in the near future gave added interest to the detection of such deposits during the reconnaissance. Reports were obtained regarding a number of apparently unimportant occurrences within the limits of the quadrangle. Copper is stated to have been found in a narrow seam near Rockport, in the river bed just east of the north line of the town. In 1874 small seams of argentiferous lead ore were discovered in the southwest portion of the range, on Beaver Creek, 2 to 3 miles southeast of Kamas, and iron associated with some lead was reported in the fall of 1902 in Hoyles Canyon, in the extreme western end of the Uinta Range.

East of the Coalville quadrangle iron deposits are known to occur in at least two localities in the Uinta Mountains. One of these was recently visited by Mr. James A. Hogle, a mining engineer, of Salt Lake City, Utah, from whom the following information was obtained: The deposit is located in the northeast shoulder of Utah, in Uinta County, 20 miles north of Vernal, and 8 to 9 miles east of the point at which Green River enters Utah in Spring Creek Valley, on the boundary between Utah and Wyoming. It is a brown, manganese-iron ore of limonitic character. It outcrops prominently as a bed 3 to 8 feet in thickness at the crest of a hogback, and is traceable along its strike for several hundred feet. The age of the sandstone country was not determined, but it occupies an area which has been previously mapped as Jurassic and Cretaceous.[a]

This deposit has been visited by prospectors and representatives of mining exploration companies, who report traces of gold in the iron and a siliceous gangue. It is their opinion that, although this ore is of

[a] White, C. A., Geology and geography of a portion of northwest Colorado and adjacent parts of Utah and Wyoming: Ninth Ann. Rept. U. S. Geol. Survey, 1889, pl. lxxxviii.

good quality, at present it is too far from a railroad to admit of profitable exploitation, and that it is most suitable for use as a flux.

The iron deposits of Rhodes Plateau, which are the main subject of this sketch, appear to be in the principal metallic deposits thus far opened in the Uinta Mountains. The more important facts regarding these deposits, including their situation, history and development, character and occurrence, follow.

Situation of ore deposits.—These iron deposits are situated in Wasatch County, Utah, in the southwestern portion of the Uinta Range, about 10 miles south of its main divide, on the main divide between Provo and Duchesne drainages, at the head of Soapstone Basin, at an elevation of between 9,600 and 9,700 feet above sea level. The locality is easily accessible from the west by way of Provo River and Soapstone Creek. It is reported that the continuation of the same route leading by other deposits to the south may also be taken from the Duchesne on the east.

History and development of iron deposits.—The iron was probably discovered and first used by the Indians, and a reliable authority informs the writer that the red ore of these iron deposits was used by them for paint.

About twenty-five years ago the most promising deposits were located by a party from Heber led by a man named Cummings. It is believed that they did the first actual development work on the property and hauled a few loads of ore to the smelters in Salt Lake Valley. Two years later, when Mr. Potts first visited the locality, he noted "two small cuts about 200 feet apart" which "looked as though 10 or 12 tons of ore might have been taken out.[a]" In 1879, upon the completion of a smelter at Park City, he mined 200 tons of this iron ore and delivered it at the smelter for flux. The following year he delivered 300 tons, and further shipments were then stopped by the closing of the smelter. It is thus known that shipments were made amounting to 500 tons. It is believed that the total is a little higher. In 1882 or 1883 the ground was surveyed for patent, and seven claims, each 600 by 1,500 feet, were eventually patented to E. P. Ferry. Some further prospecting has since been done in the vicinity, and as a result a few more claims may have been staked. In the fall of 1902 other croppings were prospected, additional claims were laid out, and some assessment work was done.

Character of ore.—The ore is a red hematite of two varieties, the red ocherous and the gray massive semispecular. It varies in purity from samples of higher grade, which are solid, pure iron, to samples

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[a] The principal historical facts here given are based upon information supplied by W. V. Rice, of Salt Lake City, who visited this locality in the early eighties, while associated with the owners of the property from which ore was shipped, and by Thos. W. Potts, of Woodland, who assisted in the survey of that ground for patent, and took the contract to transport the ore to Park City.

which are breccias made up of angular fragments of ore, to others which include barren siliceous gangue, and finally to those in which the barren country rock predominating incloses patches of lean ore. The following analysis is of a selected sample of the high-grade, massive, semispecular variety.

Analysis of red iron ore (hematite).

[Analyst, E. T. Allen.]

	Per cent.
Fe_2O_3	79.34
Al_2O_3	.15
TiO_2	None.
CaO	None.
MgO	Trace.
SiO_2	18.55
S	None.
P_2O_5	Trace.
Au	None.

The above analysis reveals not only a high content of iron and a suitable amount of silica, but also a most desirable absence of the deleterious elements, titanium and sulphur, and only a trace of phosphorus. In short, it indicates a high grade, workable iron ore. The records of assays of the lots shipped to the Park City smelter in the early eighties were entirely destroyed in the great fire of 1898. It is reported from memory, however, by T. W. Stringer, custom assayer at Park City, Utah, that the shipments averaged about 50 per cent iron and 5 to 20 per cent silica.

Occurrence of ore.—The features shown by the few comparatively restricted croppings, together with those revealed in the two small open cuts, did not afford complete evidence as to the true nature of the occurrence of the iron. The country rock is a gray limestone. In the saddle in which the ore has been worked the general southerly dip of the strata (S. 50° W. 10°) passes into a gentle northerly dip, thus forming a shallow trough. Further, certain disagreements of dips and zones of breccia suggest that the deformation at this point includes not only local folding, but also fracturing and perhaps faulting. The age of the limestone member in which the ore is found is proved by its fossil contents to be lower Carboniferous.

The croppings of the iron ore, and thus the pits which have been opened in them, appear to lie in certain fairly distinct easterly-westerly lines or zones. This fact, in connection with the presence of breccia in the upper pit, and the exposure of a marked breccia zone in the lower pit, suggests that the ore occurs along lines and zones of fracture. Further, the fact that the limestones, both in the breccias and in the country traversed by the breccias, has given place to iron ore, and the apparent but indistinct retention of bedded structure by the ore, leads to the belief that the iron ore is a replacement of limestone in and adjacent to east-west fracture and breccia zones.

Commercial aspects.—The above analysis indicates that this ore is of excellent quality. So little development work has been done that there is meager basis for estimating its quantity. The upper cropping, from which the sample for analysis was taken, has been opened by a pit 20 feet in diameter, and the lower by a pit covering a right triangular area 30 to 40 feet on the legs and to a depth of 15 feet. These were the best two croppings. Others in the immediate vicinity had been only slightly prospected. A surveyor who ran a line for a railroad through this region in the early days reports an extensive body of iron, apparently on this same divide, several miles to the north, and others state that promising outcrops occur to the south along this divide at intervals of several miles. A good wagon road, now out of repair, was built in the early eighties from the main road along the Provo River, up Soapstone Creek, past a sawmill, to the ore pits at the crest of the divide. At present the nearest railroad point is Park City, about 35 miles west. Standing timber is plentiful, and a small creek flows across the property. If on thorough investigation of these deposits, and the others reported to occur in its vicinity, it should appear that the amount of ore warranted operation of the property, the chief problem would be transportation.

CONCLUSIONS.

From the general observations made during the reconnaissances which have been described above, the following leading conclusions may be drawn: (1) The determination that limestone at the head of Soapstone Gulch is of lower Carboniferous age, and apparently overlies the great red sandstone series, and thus the rocks which compose the large central area of this range, tends strongly to indicate that the age of the core of the Uinta Range is earlier than lower Carboniferous; (2) on the divide between Duchesne and Provo rivers, at the head of Soapstone Gulch, high-grade workable red iron ore (hematite) occurs in limestone, probably as replacement deposits along easterly-westerly fracture zones, in considerable but unproved quantities.

IRON ORES IN SOUTHERN UTAH.[a]

By C. K. Leith.

Iron-ore deposits of considerable promise have long been known in the Iron Mountain district of Iron and Washington counties, Utah. They were described by E. E. Howell in 1875 in Volume III of the Final Reports of the Wheeler Survey, which volume contains also two analyses by C. E. Dutton. In 1880 in the Tenth Census report they were described and mapped by Putnam, who referred to them as "probably the largest masses of iron ore in the whole West." In 1880 also Prof. J. S. Newberry described these ores in the Columbia School of Mines Quarterly as "constituting perhaps the most remarkable deposit of iron ore yet discovered on this continent." Since that time occasional references to southern Utah iron ores have appeared. But because of the remoteness of the deposits from railways, and from principal coking, manufacturing, and consuming centers, little general attention was given them until the latter part of the last decade, when developments in the iron and steel industry made it necessary to look outside of the well-known iron-producing districts for further supplies.

The enormous consumption of iron ores in recent years and the necessity, enforced by new conditions, for steel companies to provide their own reserves of iron ore, lest they be at the mercy of competitors controlling raw materials, have emphasized the fact that the known supply of high-grade iron ore in the United States is not unlimited; that, in fact, the known supply guarantees but a short life to the industries based on the production of high-grade iron ore. The Lake Superior region is at present producing three-fourths of the iron ore used in the United States, and has also much the largest reserves of high-grade ores known, but even these reserves are likely to be exhausted in fifty years or less. The low-grade ores of the Lake Superior region and other parts of the United States will necessarily be available much longer, since the production in the United States is

[a] The writer thanks Mr. Fred Lerch, of Biwabik, Minn., and Colonel Milner, of Salt Lake City, for analyses of the iron ores, for maps showing mining locations, and for facilities in seeing the district to good advantage.

at present coming so largely from high-grade ores and is likely to come predominantly from such ores while they last. With this state of affairs it is not surprising that efforts of iron and steel companies to secure the iron ore necessary for their future existence should have been strenuous in recent years, and that deposits previously considered to be too remote or of too low grade to be of value should be carefully investigated for future availability and remote areas explored for the discovery of new deposits. Among the remote deposits long known the southern Utah deposits are receiving much attention.

The following discussion is based on a brief examination of the southern Utah deposits by the writer in the fall of 1903. The writer was accompanied by Mr. Oscar Rohn, a mining engineer from the Lake Superior region, and many of the points here discussed were noted jointly with him. No detailed examination or mapping was attempted.

Distribution and geologic relation of the ores.—The deposits are located along the slopes of a spur of the Wasatch Mountains bordering the west side of the High Plateaus of Utah, where the mountains break off to the Escalante Desert to the west. The area is represented on a topographic map of the Powell survey, published in Dutton's "High Plateau" Atlas, by a map by Putnam in the Tenth Census report, based on the Powell Survey, and by the St. George topographic sheet of the United States Geological Survey, also based on the Powell Survey. The district is reached by taking the Salt Lake, San Pedro and Los Angeles Railway to Lund, and thence by stage about 22 miles across the Escalante Desert to Iron Springs and Iron City, adjacent to which the ores are located.

Sediments not markedly inclined from the horizontal, described as Lower Silurian by Newberry, are intruded by andesite. The andesite now forms cores of the foothills lying between the elevated areas of flat-lying sediments of the Wasatch to the east and the desert to the west. The intermediate valleys are underlain by limestone and sandstone, but the rock in immediate contact with the andesite on the flanks of the hills is for the most part a pure, dense, gray limestone.

The andesite has porphyritic plagioclase feldspars and augite in a fine-grained but holocrystalline groundmass of which feldspar, much kaolinized, is the conspicuous constituent. The rock is much weathered to a reddish color, and its débris covers the slopes, for the most part effectively hiding the more easily eroded limestone.

Along and adjacent to the contact of the andesite and limestone are the exposures of the iron ores. These are in several isolated groups in a general southwest-northeast-trending area about 18 miles long and ranging from a few feet to 2½ miles in width. The ores appear in conspicuous narrow ridges and crags, following roughly the contours of the hills, and sometimes rising as much as 100 feet above the base of the outcrop. Fragments of the ore have fallen down the slopes, giving an impression that the ore occupies a larger area than it really does. In width the outcrops vary from a few inches to 600 or more feet, and have the shape of lenticular veins. In general the masses of ore, in following the contact of the andesite and limestone, dip toward and under the limestone, though markedly so in but few places, as in certain parts of the Pinto group and the Desert Mound, where the ores are found to extend well under the limestone. At Desert Mound ore apparently occurs not only at the contact of the andesite and limestone but within the limestone itself, although further exploration may afford some other explanation of the occurrence in this locality. Also ore may be observed to be entirely within the andesite, as in the vicinity of the Great Western mine to the north of Iron Springs and above the Duluth group in the southern part of the district, and in the Mountain Lion group of the central part of the district. At the former locality several roughly parallel lenticular veins of ore, varying in thickness from a fraction of an inch to 20 feet or more, appear in the andesite.

The contact of the ore and limestone may be observed at a number of localities, and especially well in pits in the Pinto group and on Desert Mound. While the contact is well defined, in detail it is irregular; small stringers and projections, and also apparently isolated masses of ore, appear in the limestone. The limestone is much altered to clayey material and is stained with iron oxide at the contact. At one locality, the Homestead mine, the limestone is largely replaced by iron, although the rock still has the aspect of a limestone. An analysis by George Steiger is as follows:

Analysis of ore from Homestead mine, Utah.

	Per cent.
Fe	57.32
MgO	3.09
CaO	3.09
P_2O_5	.29

At the contact of the ore with the andesite, the andesite commonly is much altered and consists, for many feet from the contact, of a clayey mass retaining andesite textures, but iron stained and somewhat brecciated.

Nature of the ore.—The ore appearing in the jagged exposures is a hard black crystallized hematite and magnetite, these minerals being present in varying proportions. The hematite tends to occur in botryoidal or mammillary forms and the magnetite in coarse octahedra, often with modified dodecahedral faces. Associated with the hematite and magnetite is chalcedonic and crystalline quartz, which has been deposited as vein material in numerous minute cavities, sometimes completely filling them, but more often not. The chalcedonic quartz is in characteristic dense, opaque, white, gray, bluish, or purplish masses, which in cavities present mammillary surfaces. Not infrequently the crystalline quartz has a purple color for a fraction of an inch immediately adjacent to the iron oxide. Well-developed quartz crystals project into the cavities. Crystals of apatite occasionally penetrate the ore, and in the veins at the Great Western mine above mentioned cross partially filled cavities.

Much of the ore that has been reached by test pits and shafts, and especially that beneath and in immediate contact with the limestone, is a somewhat soft, earthy, red hematite containing much magnetite. This may be well seen in one of the shafts of the Pinto group and in numerous test pits on Desert Mound.

Analyses of the ore published in Volume III of Lieutenant Wheeler's report on Explorations and Surveys West of the One-hundredth Meridian and in Putnam's report in the Tenth Census indicate a content of metallic iron ranging from 39 to 68 per cent, and phosphorus commonly above the Bessemer limit. Commercial analyses made in recent years from samples carefully selected for the purpose of determining the composition of the ore in the large quantities in which it would have to be mined give for the most part results intermediate between the extremes above noted. Twenty-one analyses by Harry L. Brinker, each of them representing a considerable area, show a range in composition as follows:

Range in composition of ore of southern Utah, as shown by 21 analyses.

	Range.	Average.
	Per cent.	*Per cent.*
Iron, metallic	46.78 to 67.98	58.54
Silica	2.57 to 19.74	8.29
Sulphur	.029 to .224	.082
Phosphorus	.029 to 1.134	.185
Manganese	.02 to .58	.118
Lime	.779 to 6.33	2.71
Magnesia	.47 to 3.76	1.77
Copper	.002 to .151	.027

Ninety-five analyses by Lerch Brothers from average samples from 37 claims, in all parts of the district, but especially in the southern portion, show the following range and average:

Average analyses of ore from 37 claims.

	Range.	Average.
	Per cent.	*Per cent.*
Iron, metallic	48.32 to 69.50	58.96
Phosphorus	.009 to .478	.141
Sulphur	.018 to .024	.020

A fuller analysis by Lerch Brothers of all samples from the shafts on the Pinto, Blackhawk, and Mountain Lion groups, with the exception of the top 30 feet from the Pinto shaft, respresenting a total depth of 291 feet, is as follows:

Average analysis of ore from Pinto, Blackhawk, and Mountain Lion groups, Utah.

	Per cent.
Iron, metallic	56.48
Phosphorus	.136
Sulphur	.039
Manganese	.27
Silica	9.67
Alumina	1.08
Lime	1.81
Magnesia	1.12
Loss by ignition	3.02
Moisture	4.00

An analysis by Lerch Brothers of a sample from the magnetic ore outcrops of 17 claims is as follows:

Average analysis of magnetic ore from 17 claims.

	Per cent.
Iron	64.71
Phosphorus	.174
Manganese	.23
Silica	5.65
Alumina	.88
Lime	1.02
Magnesia	.80
Sulphur	.020

It is apparent that a considerable proportion of ore is of good grade, though for the most part non-Bessemer, but it remains to be determined by further underground work just what the proportion is. The quartz so abundantly present in cavities in the ore rapidly lowers the grade.

Quantity of ore.—While there is a large amount of iron ore appearing in the exposed ledges and uncovered in pits, it is difficult to make quantitative estimates of the tonnage of ore of present commercial grade because of the variable composition of the ore above noted, and further because insufficient underground exploration has been done to show the depth of the ore and the extent to which it occurs in covered areas and especially beneath the limestone. The underground work has been done largely to meet assessment requirements, and up to the present time there has been no systematic underground exploration of the deposits on a large scale. A shaft has been sunk to a depth of 130 feet in ore in the Pinto group, and many pits and drifts in this area have penetrated a short distance into the ore. On Desert Mound also a large number of pits have uncovered red earthy hematite, but have not penetrated far into it. It might be suggested that where the ore seems to follow the contact of andesite and limestone the depth of the limestone may measure the depth of the ore.

Mining.—It seems, then, that there is a considerable quantity of high-grade iron ore present in this district which can be mined under favorable circumstances and undoubtedly must be mined in the future, but it remains to be seen whether or not the conditions are such that profit may be derived from mining these ores at the present time. The nearest railway, the San Pedro, Los Angeles and Salt Lake Railway, running south from Salt Lake, passes about 22 miles west of the iron range. Parties interested in the ores are now discussing the feasibility of erecting blast furnaces and steel plant at Utah Lake or on Green River. Recent coking experiments are said to have shown the existence of coal suitable for coking within a reasonable distance of these points. If this be true, the principal difficulty to be overcome is the securing of a market for the iron and steel products—a problem in which transportation is an important element.

Origin of the ores.—Until the ore deposits are further exploited and studied in detail, any discussion of their origin must be tentative and perhaps ought not be attempted. Yet certain features of the Utah deposits seem to be significant of the manner of origin, and a discussion of these features in their relations to origin may afford a better understanding of the nature of the deposits.

The contrast between the Utah and the Lake Superior ores in relation to origin is striking. The Lake Superior ores are secondary enrichments in limited areas within extensive bedded, sedimentary iron formations. That the Utah ore in its present form is not an original sediment nor the alteration product of an original sedimentary rock is taken to appear from the following facts:

(a) No traces of an original sedimentary formation are to be observed. In the much more metamorphosed iron districts of the Lake Superior region, where the ores have resulted from the alteration of an original sedimentary iron formation, traces of the original bedded iron formation are always to be found in protected areas. The contact of the ore with the overlying limestone shows no rock other than ore and limestone, as it would probably show were a sedimentary iron formation originally present, judging from analogy with the Lake Superior region.

(b) There are no clastic grains or sedimentary structures, such as bedding, which ought to appear in the ore if it is sedimentary or secondary to a sedimentary formation, as they invariably do in the Lake Superior ranges. None of the characteristic banding of ferruginous cherts or jaspers, and none of the interstratified fragmental ferruginous slates or paint rock, are to be observed in the deposits under discussion.

(c) The long, high, steep-sided masses in which the ore occurs are not characteristic of sedimentary deposits, and there is no evidence that folding, either in the rocks themselves or in the rocks of the adjacent areas, has brought about the present configuration of the deposits from an original flat-lying sediment.

(d) Ore is occasionally in veins in the foot-wall rock. This vein ore has identically the same character and association with quartz and apatite as the ore in the large ridges elsewhere in the area, and there is no reason to believe that the vein ore in the andesite differs in origin from that along the contact of the andesite and the limestone. Further, the little projections and stringers of iron oxide running a few feet into the limestone, as well as the apparently isolated masses of ore a few feet from the contact, are not characteristic of an original sedimentary contact.

(e) The ores follow the contact of the limestone and andesite. There is no evidence that this contact follows any one horizon in the limestone; indeed, it is probable from the manner of the andesite intrusion that the contact cuts diagonally across the layers of the limestone. If the ore represents an original sedimentary formation, its inclination to the bedding of the limestone would mean an erosion unconformity between the limestone and the ore. Of this there is no evidence.

(f) The ore masses alternately widen and pinch out along the strike. If they represent an original iron formation at a definite horizon and conformable with the limestone, the horizon ought to appear in more continuous and uniform belts. The narrowing and widening and the discontinuity along the strike of a sedimentary formation could be explained by an erosion unconformity at the base of the limestone, but, as above noted, there is no evidence of this.

It is believed that the ore is a secondary replacement and vein deposit, through the agency of percolating water, mainly along the contact of the andesite and limestone, but with veins extending into the footwall andesite, and perhaps also into the overlying limestone, for the following reasons:

(a) The ore occurs for the most part along the contact of intrusive andesite and limestone, a favorable zone for the action of replacing solutions.

(b) The contact apparently to some extent cuts diagonally the bedding of the limestone, and there is no evidence of an erosion unconformity.

(c) There is a generally sharp surface of demarcation between the ore and the wall rocks, and especially between the ore and the andesite. This, together with the absence of minerals of igneous origin, shuts out suggestion of magmatic segregation.

(d) The lenticular shape of the ridges of ore. The sides are usually monoclinal and steeply inclined. In other words, the shape is characteristic of contact and vein deposits. At the narrow ends the vein aspect is especially noticeable. There is no evidence that folding or other secondary deformation has had anything to do in developing the present configuration of the deposits.

The existence of veins of ore within the andesite, the comb structure to be observed where the ore is associated with apatite in such veins, the prevalence of mammillary forms, and the intimate association with chalcedonic and vein quartz, might point to original deposition of the iron ore in this form from percolating solutions or to recrystallization and alteration of a previously deposited iron compound. From analogy with other western contact and vein deposits it may be suggested that the original deposit may have been an iron sulphide. No evidence of the preexistence of iron sulphide has yet appeared, although it may develop at considerable depth. It may be further suggested, from analogy with other districts, that if sulphides should appear with depth the sulphides of metals other than iron may in time give the property its chief value.

The ores here described have points of similarity to iron ores at Fierro, N. Mex., at Iron Mountain, Mo., in various parts of Mexico, and in southeastern Cuba. It is interesting to note that explanations similar in certain respects to those above given have been presented by R. T. Hill[a] for the Mexican deposits and by J. P. Kimball[b] for the Cuban deposits.

The above discussion offers no explanation of the ultimate source of the iron. One first thinks of the surrounding limestone and andesite, and of the masses of these and other rocks which have been removed from above by erosion, and then of rocks far beneath the surface. Neither the limestone nor andesite contain a large percentage of iron to contribute to percolating waters, although it is difficult to say how small a percentage of iron in rocks might, during a long geologic period, furnish sufficient iron to account for the observed deposits. Partial analyses of the limestone are given below. Analyses 1 and 2 are by George Steiger and analysis 3 by Lerch Bros.

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[a] Hill, R. T., The occurrence of hematite and martite iron ores in Mexico: Am. Jour. Sci., 3d series, vol. 45, 1893, p. 111.

[b] Kimball, J. P., Geological relations and genesis of the specular iron ores of Santiago de Cuba: Am. Jour. Sci., 3d series, vol. 28, 1884, p. 416; also, The iron ore range of the Santiago district of Cuba: Trans. Am. Inst. Min. Eng., vol. 13, p. 613; Eng. Min. Jour., Dec. 20, 1884, p. 409.

Analyses of limestone from southern Utah.

	1.	2.	3.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	....	....	3.78
Al_2O_3	....	....	1.14
Fe	0.46	0.28	0.62
P	....	....	.042
P_2O_5	.03	.03	....
CaO	49.46	50.77	50.19
MgO	2.67	1.78	.68

A partial analysis of the andesite by George Steiger gives the following result:

P_2O_5	0.28
Fe	1.58

If the ore were all to come from the andesite, and it be assumed that the percentage of iron in the andesite shown by analysis be entirely leached out, about 607,046,000 cubic feet of andesite would be required to yield a million tons of 58 per cent iron ore, or a mass 100 feet thick and less than one-half mile square, or a mass 10 feet thick and about 2.7 miles square.

If the ore were all to come from the limestone, and it be assumed that the percentage of iron in the limestone shown by analysis be entirely leached out, about 2,074,000,000 cubic feet of limestone would be required to yield 1,000,000 tons of 58 per cent iron ore, or a mass 100 feet thick and less than a mile square, or a mass 10 feet thick and about 2.7 miles square.

The unit of 1,000,000 tons of iron ore is taken for convenience in calculation and not as an estimate of tonnage present.

The small percentages of iron shown in the analyses of andesite and limestone have not been completely removed and furnished to percolating solutions, but even then it is apparent that the amount furnished by leaching during the erosion of a thin layer over a not considerable area might account for all of the iron ore observed. This is presented only as a possibility and not as a statement of opinion.

PUBLICATIONS ON IRON AND MANGANESE.

A number of the principal papers on iron and manganese ores published by the United States Geological Survey, or by members of the Survey, are listed below:

BARNES, P. The present technical condition of the steel industry of the United States. Bulletin U. S. Geol. Survey No. 25, 85 pp. 1885. (Out of print.)

BAYLEY, W. S. The Menominee iron-bearing district of Michigan. Monograph XLVI, U. S. Geol. Survey, 513 pp. 1904.

BIRKINBINE, J. American blast-furnace progress. In Mineral Resources U. S. for 1883-84, pp. 290-311. 1885.

——— The iron ores east of the Mississippi River. In Mineral Resources U. S. for 1886, pp. 39-98. 1887.

——— The production of iron ores in various parts of the world. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 21-218. 1894.

——— Iron ores. In Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 23-63. 1898.

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CHISOLM, F. F. Iron in the Rocky Mountain division. In Mineral Resources U. S. for 1883-84, pp. 281-286. 1885.

CLEMENTS, J. M. The Vermilion iron-bearing district of Minnesota. Monograph XLV, U. S. Geol. Survey, 463 pp. 1903.

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DILLER, J. S. Iron ores of the Redding quadrangle, California. In Bulletin U. S. Geol. Survey, No. 213, pp. 219-220. 1903.

ECKEL, E. C. Utilization of iron and steel slags. In Bulletin U. S. Geol. Survey, No. 213, pp. 221-231. 1903.

HAYES, C. W. Geological relations of the iron ores in the Cartersville district, Georgia. In Trans. Am. Inst. Min. Eng., vol. 30, pp. 403-419. 1901.

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HAYES, C. W., and ECKEL, E. C. Iron ores of the Cartersville district, Georgia. In Bulletin U. S. Geol. Survey No. 213, pp. 233-242. 1903.

IRVING, R. D., and VAN HISE, C. R. The Penokee iron-bearing series of Michigan and Wisconsin. Monograph XIX, U. S. Geol. Survey, 534 pp. 1892.

KEITH, A. Iron-ore deposits of the Cranberry district, North Carolina-Tennessee. In Bulletin U. S. Geol. Survey No. 213, pp. 243-246. 1903.

KEMP, J. F. The titaniferous iron ores of the Adirondacks [New York]. In Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 377-422. 1899.

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COAL, LIGNITE, AND PEAT.

THE DEER CREEK COAL FIELD, ARIZONA.

By Marius R. Campbell.

INTRODUCTION.

Location.—The Deer Creek coal field of Arizona is an isolated basin of coal-bearing rocks situated in the extreme eastern end of Pinal County. It lies on the south side of Gila River just east of Dudleyville, which is located at the junction of San Pedro and Gila rivers. The field is about 85 miles northeast of Tucson, and at present its nearest railroad point is San Carlos, on the branch road which extends from Bowie, on the Southern Pacific Railway, to Globe, in Gila County. The western end of the field is connected by wagon road with Florence and Tucson and points in the San Pedro Valley. The eastern end is likewise accessible from San Carlos by way of Hawk Canyon, but there are no roads through the field. The coal field is located near the middle of the great copper-producing region of Arizona, which extends from Jerome, on the northwest, to Cananea, Mexico, on the southeast, and includes the great mining centers of Bisbee, Globe, Clifton, and Morenci.

Description.—The region in question lies south of the great Colorado Plateau, and the surface features consist in general of ranges of mountains trending northwest-southeast and separated by undulating valleys, covered for the most part by débris from the adjacent mountain slopes. Along the line of the Southern Pacific Railway these mountain ranges are comparatively narrow, linear ridges, but north of Gila River they show a tendency to coalesce, and the result is a rugged country, of which the Pinal and Superstition mountains are two of the best-known features. The Pinal Mountains proper are limited to the territory north of Gila River, but their southeastern extension is a prominent range which borders the San Simeon plains on the west, and is known by the general name of the Pinaleno Range. Parts of this range, like Santa Teresa Mountains and Mount Turnbull, are extremely rough and rugged, but in the vicinity of Gila River the range is of only moderate altitude and of simple structure. This

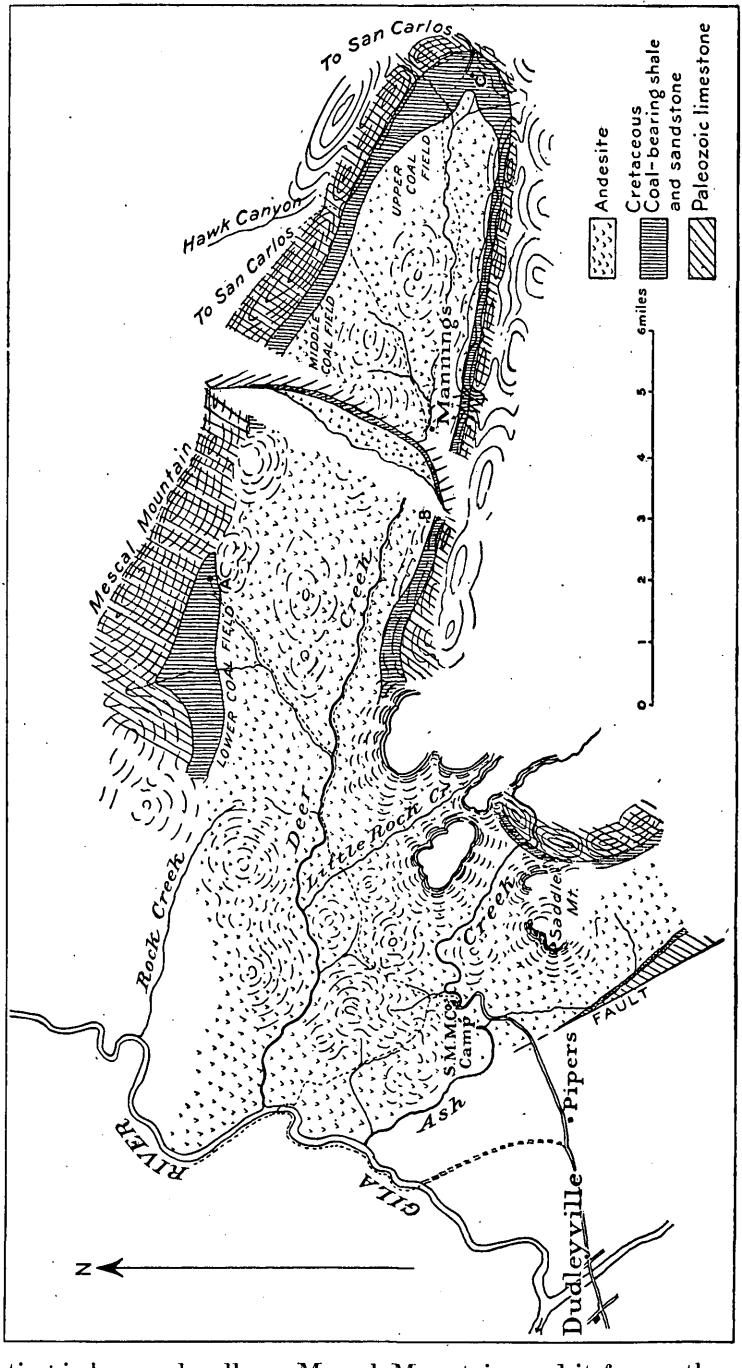

FIG. 7.—Sketch map of the Deer Creek coal field, Arizona.

portion is known locally as Mescal Mountain, and it forms the northeastern limit of the Deer Creek coal field, separating the valley of

Deer Creek, on the west, from that of Hawk Canyon, on the east.

The western border of the coal field is, in a general way, formed by a range of mountains which lies parallel to and east of the San Pedro Valley. South of Aravaypa Creek this range is high, and it is known by the name of the Caliuro Range. Between Aravaypa Creek and Gila River the range is inconspicuous, and it is represented only by a lava-capped mesa just north of Aravaypa Creek and by Saddle Mountain, near Gila River. The topography of the coal field is varied, but, broadly considered, it is a topographic basin surrounded, except on the west, by more rugged country. The basin of Deer Creek is particularly flat in the Upper and Lower coal fields. These are separated by a more rugged region, and between the Lower field and Gila River the topography is rough and mountainous.

The coal field occupies an irregular synclinal basin between the Mescal Range on the north and an unnamed ridge on the south, which separates the basins of Deer and Ash creeks. Within about 5 miles of Gila River the range lying on the south side of the coal field turns to the southwest and merges, in a general way, with the northern extension of the Caliuro Range. The major portion of the coal field is drained by Deer Creek, but the coal-bearing rocks extend to the southwest beyond Saddle Mountain; and this part of the field lies within the drainage basin of Ash Creek. The coal-bearing rocks undoubtedly extend to the northwest beyond Gila River, but they are so broken and disturbed by volcanic rocks that presumably the coal is of no value, and it is not represented on the map.

The field extends 10 or 12 miles in an east-west direction, and it has a known breadth of 3 or 4 miles in the Deer Creek Basin. As previously stated, the coal-bearing rocks are found in the Ash Creek Basin, and it is possible that the coal field may be extended to the outcrop of the limestone west of Saddle Mountain.

Coal beds are also reported as occurring in Hawk Canyon, where the coal-bearing rocks appear on the north side of the great broken anticline forming the Mescal Range, and it seems possible that similar deposits may be found in the basin of upper Ash Creek and in the great Aravaypa Valley to the southeast.

This paper is the result of a rapid reconnaissance of the field during the past autumn. The time was too short to permit of a detailed study of the field relations of all of the rocks involved, but through the kindness of Mr. N. H. Mellor, superintendent of the Saddle Mountain Mining Company, who has given much attention to the geology of the region, the writer was enabled to see many of the critical points and to present the following brief outline of its most important geologic features.

GENERAL GEOLOGY.

Pre-Cambrian schist.—The oldest rocks found within the territory examined are schists, which occur on Ash Creek above the limestone box canyon and on Gila River below the mouth of Ash Creek. No fossils have been found in these schists, consequently their age has not been determined definitely, but undoubted middle Cambrian quartzites and conglomerates rest unconformably on them, and for that reason they are regarded as being of pre-Cambrian age. Provisionally, these schists are correlated with those described by Ransome from the Globe district to the north, and also from the Bisbee region to the south, and by Lindgren from the Clifton-Morenci region to the northeast. In the Deer Creek Basin the schists were seen at one point only, but it seems probable that they show in most of the anticlines where the movement has been sufficient to bring them to the surface. Along the north side of the basin they were not seen at the head of Hawk Canyon, but to the west they undoubtedly come in within this territory, since they form the main mass of the Pinal Range west of the river.

Cambrian sandstone and shale.—Resting unconformably upon the schists just described, and underlying the great upper Paleozoic limestone, is a series of shale, sandstone, and conglomerate from which fossils were found in the Ash Creek Canyon that Walcott pronounces to be of middle Cambrian age. The sandstone and conglomerate are known locally as "the quartzite," and they have a total thickness of about 850 feet. The closing episode of the Cambrian period seems to have been the deposition of 60 to 80 feet of very fine, green shale, which on Ash Creek appears directly beneath the great limestone mass. Provisionally this is correlated with the green shale of the Grand Canyon region which lies above the Tonto sandstone.

Carboniferous limestone.—Above the green shale just described occurs a great mass of limestone which, in the Ash Creek section, has a thickness of about 1,300 feet. The lower part of this mass is sparingly fossiliferous and no collections were made by which to determine its age. The upper part is richly fossiliferous, and a collection from the uppermost beds outcropping in Ash Creek Canyon indicates that this part at least is of Pennsylvanian age. It is possible that the lower part of the great limestone mass may belong to the Devonian or even the Silurian system, but the evidence at present available would refer most, if not all, to the Carboniferous.

This great limestone mass is the most conspicuous geologic feature of the Deer Creek coal field, since in almost all cases it forms the boundary wall of the basin. Mescal Mountain on the north is composed almost exclusively of beds of this limestone, which, in the central part of the basin, must have a thickness of several thousand feet. At the point where it is crossed by the trail from Manning's ranch to San Carlos its thickness is about 1,200 feet. It holds about the same thickness in the small canyon at the extreme upper or eastern end of the field, but in passing to the southern side of the basin the limestone is seen to become thinner and thinner until finally it disappears for a short distance just south of Mount Lou, a little knob in the extreme end of the basin. Whether this disappearance of the limestone is due to faulting or nondeposition was not determined. All along the southern side of the field the limestone is thin and greatly disturbed, and it seems probable that its absence in the eastern end of the basin may be explained by more severe crushing than usual, leaving the coal-bearing rocks in direct contact with the middle Cambrian quartzite.

About 4 miles west of Manning's ranch the small band of limestone shown in the immediate front of the ridge turns to the south and disappears beneath a more recent lava flow that forms a high mesa. At their point of disappearance these rocks strike approximately toward the outcrop of limestone on Ash Creek, and for that reason it has been supposed that they are connected, although concealed by recent flows of lava.

In the basin of Ash Creek the limestone shows in a semicircular line of outcrop just east of Saddle Mountain. The region to the south was not closely examined, but from Mr. Mellor's observations it seems probable that it was forced up by a laccolithic intrusion of volcanic rocks, which now show as a dome-shaped mass directly back of the limestone. If this is truly a laccolith, the limestone beds on its eastern side have been eroded, and since then the whole has been deeply buried beneath extensive flows of lava. In this semicircular line of outcrop the limestone dips away from the center at an angle of about 30°, and to the southwest it seems to form a shallow synclinal trough, which extends southwestward from Saddle Mountain and passes beneath the high mesa lying north of Aravaypa Creek.

The limestone comes again to the surface west of this shallow syncline in a low, anticlinal ridge, which terminates toward the northwest in a fault that cuts out the limestone southwest of Saddle Mountain and south of the road from Dudleyville to the camp of the Saddle Mountain Mining Company. It seems possible, however, that this fault may extend to the northwest beyond the wagon road, and it may have been responsible for the course of Ash Creek below this point.

Fossils were collected from the limestone southwest of Saddle Mountain; in the Ash Creek box canyon; at the point marked "B" on the sketch map, about 1 mile west of Manning's ranch; on the same line of outcrop about 4 miles farther east; and at the head of Hawk Canyon. These fossils have been examined by Dr. G. H. Girty, who pronounces them to be of Pennsylvanian age.

Cretaceous sandstone and shale.—Resting on the Pennsylvanian limestone at every point at which it is exposed in this field is a series of greenish-gray sandstone and shale beds which contain the coal that gives this basin its economic importance. At most points these beds appear to rest conformably upon the Paleozoic limestone, but in the Middle field there is a visible unconformity between the limestone and the overlying sandstone and shale.

Different opinions have been held regarding the age of the coal-bearing beds. Devereux,[a] who reported the field in 1881, noted the occurrence of fossil leaves with the coal, and on the strength of their resemblance to forms with which he was familiar he doubtfully referred the beds to the Tertiary system.

On the basis of their apparent conformity to the limestone below, Blake[b] regarded them as Carboniferous, but probably this conclusion was based upon report and was not the result of an examination in the field.

During the examination made by Walcott[c] in 1885 some fossil plants were collected from the shale associated with the coal beds of the Upper field. These were submitted to Prof. L. F. Ward, who was able to determine the presence of the genera *Sequoia*, *Sabal*, *Phragmites*, *Myrica*, and *Viburnum*. Owing to the fragmentary nature of the material no specific determinations were made, but the formation was doubtfully referred to the Cretaceous. During the present examination similar material was collected from the sandstone overlying the coal in the Lower field and also along the contact between the sandstone and the underlying Carboniferous limestone southwest of Saddle Mountain. This material is so poorly preserved that no specific determinations could be made, but, according to Dr. F. H. Knowlton, one fragment suggested *Sequoia reichenbachi*. The other forms are too indefinite for classification, but they may belong to *Platanus*, *Cinnamomum affine*, or *Asimina eocenica*. The material is so indistinctly preserved that Doctor Knowlton would not venture an opinion as to its age, but the forms given are those which generally are characteristic of the upper Cretaceous. In the Middle field fragments of invertebrates are abundant in a conglomerate bed which is in contact with the Carboniferous limestone. Some were collected and submitted to Dr. T. W. Stanton, who states that they are imperfect specimens of *Ostrea* and *Exogyra*. He states "the latter genus

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[a] Devereux, W. B., The Deer Creek coal fields, Arizona: Eng. and Min. Jour., vol. 32, 1881, pp. 404–405.

[b] Blake, W. P., Reports on Mines and Mining: Reports of the governor of Arizona to the Secretary of the Interior for 1896, p. 42; 1898, p. 67; and 1901, p. 108.

[c] Walcott, C. D., and Bannon, M., Deer Creek Coal Field, White Mountain Indian Reservation, Arizona: Senate Ex. Doc., No. 20, 48th Cong., 2 sess., p. 7.

indicates that the age is Cretaceous, but the exact horizon can not be determined from the material in hand."

Although the evidence regarding the age of these beds is not entirely conclusive, there seems to be a general agreement that they belong to the Cretaceous system and presumably were deposited in the later stages of that period. The contact between the Cretaceous rocks and the underlying Carboniferous limestone is usually marked by a thin bed of conglomerate composed principally of fragments of chert derived from the underlying limestone and cemented by oxide of iron.

On the northern side of the Deer Creek Basin the sandstone and shale of the coal-bearing formation have a thickness of 400 to 500 feet. They are well exposed in the Lower field, the material consisting for the most part of coarse, greenish-buff sandstones, which are well exposed and form conspicuous features of the topography. In the Upper field the measures seem to be composed more largely of shale, and they are generally reduced to a comparatively level surface. Walcott[a] states that the thickness of strata exposed below the lower main workable coal bed has a thickness of 2,100 feet, but probably this thickness is due to reduplication of the measures through minor folding, and it is doubtful if the correct thickness can be determined at any point in the Upper field.

On the south side of the basin the coal-bearing rocks appear to be thinner, but it is difficult to obtain an accurate measure since they stand nearly vertical and run for long distances up the slope of the mountain. Still farther west, where they are cut by Ash Creek, the rocks themselves are not exposed, but the interval in which they are due has a thickness of not over 220 feet. Southwest of Saddle Mountain they are still further reduced, having a thickness of 5 to 20 feet between the Carboniferous limestone and the overlying andesite. Whether this variation in thickness is due to different amounts of sediment being deposited on the two sides of the basin, or whether it is due to nondeposition on the western side is uncertain, but it seems probable that the sediments were laid down in inclosed basins, and consequently that the amount of material may have varied greatly in different parts of the area.

After the deposition of the coal-bearing sandstone and shale the region was the scene of great volcanic activity, and large masses of andesite were poured out. There is no crater visible from which this material was ejected, and it seems probable that it came out through extensive fissures which were opened in the lower part of the basin near Gila River. The change from clastic sediments to igneous rocks is not abrupt nor does it appear to have taken place contemporaneously throughout the basin. The sediments are interbedded with

[a] Deer Creek Coal Field, White Mountain Indian Reservation, Arizona: Senate Ex. Doc. No. 20, 48th Cong., 2d sess., p. 6.

volcanic material as though sedimentation was at times interrupted by volcanic outbursts and was resumed when conditions became more favorable. The zone of transition between sedimentary and igneous rocks is marked by a thick bed of coarse conglomerate composed largely of bowlders of granite, Paleozoic limestone, and quartzite. This is a very characteristic bed and can be traced throughout the Territory, except in the upper part of the Deer Creek Basin. Above this bed of conglomerate the andesite has a great thickness, possibly reaching as much as 1,000 feet. In certain parts of the field sedimentation was resumed from time to time, presumably between lava flows, and consequently the lava is interstratified with sandstone beds, and in places even small coal seams appear to have been deposited in these intervals of quiescence.

GEOLOGIC STRUCTURE.

The structure of the Deer Creek coal field is comparatively simple, consisting of an unsymmetrical synclinal trough, the axis of which corresponds approximately with the course of Deer Creek near the south side of the basin. South of the creek the rocks are sharply flexed and they stand nearly vertical along the front of the mountain. This great uplift terminates about 3 miles west of Manning's ranch, but the disturbance continues to the west as a small anticlinal fold crossing Deer Creek near the point where the Dudleyville trail first reaches the creek. The fold is of sufficient magnitude to bring to the surface at this point the bed of conglomerate and also some underlying sandstones.

The structure on the north side of the basin is simple; the coal-bearing rocks dip 30° to 60° at the outcrop and then gradually decrease in dip until in the center of the basin they lie approximately horizontal. There have been many minor disturbances generally caused by dikes which cut the strata in all directions. The Upper field in particular seems to be disturbed by many minor structural features, the soft rocks being folded in a number of wrinkles parallel with the general trend of the syncline; on these small folds the coal beds outcrop at many points.

In the Ash Creek Basin the structure is less regular, consisting for the most part of a warped, irregular floor with no definite axes to the depressions. On the whole it seems to constitute a synclinal basin extending northwest and southeast, but in the latter direction it is divided by the great laccolithic uplift on Ash Creek into two shallow basins. The one lying between Ash Creek and Deer Creek is not well exposed, being covered by recent lava flows so as to obscure its structural features. The one west of Ash Creek is marked by Saddle Mountain, which occurs in the center of the depression, but farther southwest the synclinal lifts and only a little of the andesite and coal-bearing rocks now overlies the Carboniferous limestone.

COAL.

The existence of coal in the Deer Creek Basin has been known for at least twenty years, but no commercial development has been undertaken and little information has been published concerning it.

In 1881 Devereux[a] noted the discovery of coal in this field as follows: "Coal was discovered in Deer Creek Valley in the early part of the present year by Anderson and Lillie, two prospectors. As soon as the discovery became known a great deal of excitement ensued, and in a short time the whole valley was staked out into claims."

In 1885 a committee, consisting of Mr. M. Bannon, of Baltimore, Md., and Mr. C. D. Walcott, of the United States Geological Survey, was appointed by the Secretary of the Interior to examine this coal field which then constituted a part of the White Mountain Indian Reservation. The report submitted by this committee[b] gives the history of the discovery of coal as follows:

The first discovery of the presence of coal in the Deer Creek Valley was made by David Anderson, a prospector, who at the time was seaching for drinking water in a small wash near the head of the valley. A dark band of dirt in the side of the wash attracted his attention and led him to dig into it and ascertain that it was produced by the decomposition of coal. The date of the discovery was the latter part of January, 1881. Anderson notified the members of the prospecting party to which he belonged, and claims were at once staked out along the line of outcrop of the coal-bearing rocks. The work of development was begun soon afterwards, and carried forward as rapidly as the means at hand would permit. Shafts were sunk along the line of the coal seams first discovered by Anderson, and numerous prospect holes dug wherever the coal "blossom" appeared.

In a letter to the Secretary of the Interior, dated Washington, D. C., February 16, 1884, the Hon. H. Price, Indian Commissioner, states that Indian Agent Tiffany, at the San Carlos Agency, notified the miners that they were within the limits of the reservation by posting notices, dated March 4, 1881, on the trails leading to the mines, on the works about the mines, and also had the notice read to passers. This did not deter the prospectors, and the work of development went on until ———, 1883, when they were removed by order of the Department of the Interior by the military under General Crook.

Recently the south line of the reservation has been changed so as to exclude the Deer Creek coal field, and this has caused greater interest to be taken in the development of the field.

At the time of the examination of the above-mentioned committee apparently the Upper or easternmost field was the only one known, and, consequently, their report deals entirely with this region. They describe the coal as follows:

The strike of the strata in which the coal beds occur averages north 70° west (magnetic); the dip of the coal-bearing bituminous shales and overlying and under-

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[a] Eng. and Min. Jour., vol. 32, 1881, pp. 404-405.

[b] Walcott, C. D., and Bannon, M., Deer Creek Coal Field, White Mountain Indian Reservation Arizona: Senate Ex. Doc. No. 20, 48th Cong., 2d sess., pp. 2-7.

lying sandstone is 65° at the surface, increasing to 80° 100 feet below; the latter statement given by the miners. In the tunnel which cuts through two of the best beds thus far opened, the coal appears in the form of thin layers, interbedded with bituminous shale.

The section of the first bed cut by the tunnel gives—

	Ft.	In.
1. Black, bituminous shaly coal, irregular, shining, but not of economic value	3	0
2. Clear bituminous coal	0	10
3. Bituminous shale with parting of coal, similar to No. 2	4	2
Total	8	0

The second bed is 40 feet beyond, 3½ feet in thickness, with 10 inches of clear coal in one body.

A shaft was sunk on the first bed, and the miners stated that the coal thickened up as they went down, but from the fact that they made no distinction between the bituminous shaly matter and the true coal, little reliance can be placed on the statement as proving the existence of a thicker bed of coal. The displacement of the beds during the uplifting of the strata and the intrusion of the dikes of lava has plicated the coal-bearing shales in places and thus given a greater thickness in spots than the beds had originally. * * *

* * * As now known, those beds that present the fairest prospect are limited to a narrow area, about 3 miles long, in the upper part of the valley, on what we have called the Anderson field. That they extend beneath the lava to the westward is quite probable, but to what extent or how much they have been broken up by the numerous dikes and masses of lava that traverse the strata is unknown.

Mr. James Little stated that he knew of at least 40 different seams of bituminous shale and coaly matter between the limestone and the uppermost bed containing coal, a distance of 2,700 feet on the surface and 2,100 feet in thickness of strata. Of those the two seams shown in the tunnel and the first one beyond and above alone appear to be of economic importance.

It may be that when the work of development is carried forward some of the beds not now opened will give thicker beds of workable coal than those exposed by the work done in the Anderson field, but this is uncertain and doubtful.

* * * * * * *

Toward the lower end of the valley, about 10 miles from the Anderson field, the strike swings around to the east and west, and a few exposures of bituminous beds were observed. With the exception of a few prospect holes, no work has been done toward developing this portion of the field.

Since the first exploitation of the Upper field, as noted in the report just given, two other fields have been prospected on the north side of the basin, viz, the Middle and Lower fields. There is no sharp line of division between these, but, in a general way, the Upper field occupies the extreme eastern part of the synclinal basin and may be regarded as lying entirely east of the trail leading from Manning's ranch to San Carlos. The Middle field lies west of this trail and is separated from the Lower field by some lava-capped knobs which seem to cut off the outcrop of the Cretaceous rocks along the north rim of the basin. The Lower field lies west of these knobs and it is bounded on the west by Corral Mesa, a large, intrusive mass near the head of Rock Creek, which has completely obliterated the coal-bearing rocks.

The Upper field has received very much more attention than the Middle or Lower fields and a number of slopes have been sunk on the coal beds. Great activity was manifest in this region a few years ago and extensive developments were projected but, owing to the inaccessibility of the field, they were never completed. In the meantime claims have been staked in both the Middle and Lower fields and a number of prospect holes have been dug which show that the coal beds are practically continuous throughout the region.

The writer made a hurried examination of the Upper field and found the coals in much the same condition as described in the report just cited. The development was done so long ago that most of the openings are not now accessible, consequently no new information could be obtained regarding the coal. The beds strike parallel with the main axis of the synclinal trough and dip strongly to the south. Although it is extremely difficult to find continuous exposures, the structure seems to be that of a number of minor folds whose axes are parallel with the main axis of the synclinal trough. The result of such a structure is to expose the same set of coal beds a number of times across the basin; consequently the number of beds actually present has probably been greatly overestimated. As stated in the report previously mentioned, 40 distinct seams of bituminous shale and coaly matter have been reported in a distance of 2,700 feet on the surface, included in a mass of strata 2,100 feet thick. The maximum measure of the coal-bearing shale and sandstone in other parts of the basin is not over 500 feet. Hence it seems highly probable that these 500 feet of sediments have been folded in such a way as to measure 2,100 feet across their outcropping edges.

At one place only in the Upper field was the coal exposed, and at this point the following section was measured:

Section of coal in Upper field.

	Ft.	In.
Coal (good)	0	8½
Coal and shale	2	4
Sandstone	0	3
Carbonaceous shale	0	11
Coal (crushed)	0	9
Total	4	11½

As noted by the commission in 1885, these coals show great crushing, and are in poor condition for commercial mining.

The writer saw no coal outcrops in the Middle field, but a number of openings are reported. It seems altogether probable that the same beds are present in this field as shown in the Upper field, and also as were seen at the Reed shaft in the Lower field.

The Lower field has not received much attention, but lately several shafts and slopes have been sunk, which give a fairly good idea of the number and thickness of the coal beds. The oldest work of this kind is a slope 150 feet long, sunk on a coal bed that shows on the north side of the basin, near the old Indian trail from Dudleyville to San Carlos, which crosses Mescal Mountain near the triangulation station. Recently a shaft has been sunk in the next ravine south of the slope, and presumably the same bed of coal has been cut. The shaft section is as follows:

Section of Reed shaft.

		Ft.	In.
Sandstone, coarse		100	0
Shale		37	0
Coal	1. Coal, hard (including lenses of shale 0 to 3½ inches thick) ... 1 foot, 3 inches 2. Coal, crushed ... 1 foot, 2 inches 3. Coal, or carbonaceous shale, crushed ... 6 inches	2	11
Shale		20	0
Total		159	11

The shaft was extended 20 feet below the coal bed in search of other coals, but nothing was found. It was the intention of the prospector to sink to the limestone, but, owing to the great depth and difficulty of hoisting the material by hand, the work was abandoned at a depth of 160 feet. This shaft is 420 feet south of the Reed slope and is generally known as the Reed shaft. In the slope the coal is considerably disturbed by faulting and minor folding, so that it varies in thickness from point to point. The following sections were measured where the coal is undisturbed, and consequently represent its true structure and thickness. About 75 feet from the mouth of the slope the coal has the following section:

Section of coal 75 feet from mouth of Reed slope.

	Ft.	In.
Coal, crushed	0	3
Bone	0	3
Coal:		
Hard, good	1	0
Badly crushed	1	7
Total	3	1

About 150 feet from the mouth of the slope the coal shows the following section:

Section of coal 150 feet from mouth of Reed slope.

	Ft.	In.
Coal, crushed	0	4
Bone	0	1
Coal:		
Hard, good	0	10
Crushed	0	10
Total	2	1

On the south side of the basin, about 1 mile west of Manning's ranch, a shaft, which shows three coal beds, has been sunk well up on the mountain side. This is known as Crowe's shaft, and has the following general section:

Section of Crowe shaft.

			Ft.	In.
Shale and sandstone			50	0
Coal	1. Coaly shale	2 inches	1	7
	2. Sandy parting	2 inches		
	3. Coaly shale	4 inches		
	4. Sandy parting	3 inches		
	5. Coal, very hard	8 inches		
Sandstone and shale			30	0
Coal	1. Carbonaceous shale	6 inches	1	11
	2. Sandstone	3 inches		
	3. Coaly shale	14 inches		
Shale			15	0
Sandstone			2	0
Shale			3	0
Coal	1. Carbonaceous shale	6 inches	2	0½
	2. Coal	18½ inches		
Carbonaceous shale			0	0
Total			105	6½

The highest coal bed in this section is badly crushed and faulted at the point where it is cut by the shaft, and it is doubtful whether the section given above represents its true thickness and structure. The lowest bed shows considerable crushing, but the section given above is about normal.

The correlation of the coal beds found in the Crowe shaft and the coal of the Reed mine is somewhat difficult. This shaft was not sunk through the Cretaceous rocks, but it seems probable that the lowest bed of coal occurs within 10 feet of the top of the limestone, which is well exposed in a near-by ravine. If that be true, the uppermost bed of coal occurs about 60 feet above the limestone. This is nearly the position in which the coal is found in the Reed shaft. It is at least 30 feet above the limestone, and may be as much as 40 or 50 feet. The exposures in the vicinity of the Reed slope are not very satisfactory, but some indications of coal smut were seen near the top of the limestone in the ravine west of the slope, which seems as though it might correspond with the bottom bed in the Crowe shaft. Since the writer visited the field, according to Mr. Mellor, prospecting has been done, for the purpose of determining whether a lower bed is present near the Reed slope, but nothing was found. It seems probable, however, that the coal of the Reed shaft and slope is about equivalent to the highest bed in the Crowe shaft, and that the smut seen near the limestone at the Reed mine is at about the same horizon as the lowest bed in the Crowe shaft.

Mr. Mellor recently has discovered traces of a coal bed near the top of the Reed shaft, but this does not seem to correspond to any of the beds showing in the Crowe shaft, and it is not known whether it has any representation on the south side of the basin.

Although sufficient prospecting has not been done to determine clearly the number of workable coals in the basin, it seems probable that they are limited to two beds, and the occurrence of similar exposures on the two sides of the field is fairly good evidence that the beds extend entirely across the Deer Creek Basin.

The most favorable locality for developing these coals is where the geologic structure is the simplest, and also where the coals are the least disturbed by dikes and other intrusive masses of rock, and also where they can be most easily reached by a railroad from Gila River. So far as could be determined in the hasty examination just made, the Lower and Middle fields appear to be less disturbed by complicated folding than the Upper field, consequently the coal is better disposed for economical mining. The coals in the Upper field make a larger showing at the surface, but, according to the present interpretation, this is due to minor folds, and these would be extremely troublesome in commercial mining.

All parts of the field are much disturbed by igneous dikes and the three fields in question have suffered about equally in this respect.

With regard to transportation facilities the Lower field has a decided advantage, since the surface of the basin in this field is comparatively flat and not diversified by any marked hills or sharp and deeply cut valleys. It is also considerably nearer Gila River and could be much more easily reached by a line of railroad than could either the Middle or the Upper field.

The Lower field is divided into two parts by an extensive dike which trends nearly east and west, and presumably extended from an igneous outflow in the knobs east of the Reed mine. Along this dike there has been considerable disturbance of the adjacent rocks, and this region should be avoided in the development of the field. There is, however, a large area to the north of this dike in which the coal can probably be found within a distance of 100 to 200 feet of the surface and in which the rocks are comparatively undisturbed. Also the region south of the dike in the center of the basin offers promising territory for the development of mines. Only two small dikes were observed between the large dike just mentioned and Deer Creek. These dikes are of small dimensions and probably do not extend for a very great distance. With the present information it is impossible to say at what depth the coal occurs below the surface in the center of the basin, but it seems probable that nowhere does it exceed 600 to 700 feet.

QUALITY OF COAL.

Owing to the large amount of impurities in this coal it is of a comparatively low grade, and if the field were more favorably located the coal would have little or no commercial value, but as the field is situated in one of the most arid portions of the country, in the center of a great copper-producing territory, and in a region which is comparatively rich in gold and silver, the coal may have a local value considerably beyond that which is indicated by its chemical analysis.

In a general way the coal of the Lower field, as seen by the writer, and of the Upper field, as reported by the commission which examined it in 1885, occurs in two benches, in which the coal differs considerably in quality. The first and best grade usually is contained in small benches from 10 to 15 inches in thickness. This is an extremely hard, block coal, and has been little affected by the movements that have upturned the rocks. The other benches are composed of very much softer coal, presumably at first containing much more foreign material. In the movement which has folded the rocks of the basin this softer bench has suffered great crushing, and at all points where it is accessible the coal is crushed into thin laminæ, which show much slickensiding where the particles have crushed together. Doubtless the hard block coal would find a ready market at any of the towns or mines in the vicinity, and, according to laboratory tests, it can be manufactured into coke. The softer coal is so badly crushed that it could be put on the market only as slack, and, as it carries a heavy percentage of ash, presumably it could not profitably be shipped a long distance.

The coal of the upper field was sampled by the commission,[a] and, as analyzed by Mr. Edward Whitfield, of the United States Geological Survey, shows the following percentages:

Analysis of coal from 10-inch layer in bed opened by tunnel in Upper field.

	Per cent.
Moisture	0.48
Volatile combustible matter	19.81
Combined carbon	61.01
Ash, pink in color	18.70
Coke	Poor.

Analysis of coal from 10-inch layer in bed reached by crosscut from tunnel in Upper field.

	Per cent.
Moisture	0.56
Volatile combustible matter	17.50
Combined carbon	60.85
Ash, pink in color	21.09
Coke	Fair.

The commission also reports "the coal is a hard bituminous, and, as tested in the laboratory, will make a fair coke, but not so good as that from the Raton district of New Mexico."

[a] Deer Creek Coal Field, White Mountain Indian Reservation, Arizona: Senate Ex. Doc. No. 20, 48th Cong., 2d sess., p. 3.

The coal beds of the Lower field were carefully sampled by the writer, but the results do not show so good a coal as that shown by the analyses just given. Whether this difference is due to the mode of sampling or whether it is on account of the better quality of the coals in the Upper field can not now be decided. In order to test the coal of the Lower field, a cut was made in the Reed shaft across the bench of hard coal, 15 inches thick (No. 1 in the section on page 251), which, according to Mr. Eugene C. Sullivan, of the United States Geological Survey, shows the following composition:

Analgsis of hard coal from Reed shaft, Lower field.

	Per cent.
Moisture	1.22
Volatile combustible matter	28.80
Ash, almost white	43.74
Fixed carbon	26.24
Sulphur	1.69
Silica in ash	48.3
Coke:	Dull, not swollen, coherent.

In this field the softer parts of the bed seem to have value, consequently a sample was obtained from the lower bench, 20 inches in thickness, including Nos. 2 and 3 in the section given on page 251. According to the same authority the analysis of this crushed portion is as follows:

Analysis of bottom part of crushed coal from Reed shaft, Lower field.

	Per cent.
Moisture	2.98
Volatile combustible matter	23.07
Ash, slightly pink	53.01
Fixed carbon	20.94
Sulphur	1.26
Silica in ash	61.6
Coke	Dull, not swollen, friable.

Of the crushed portion of the bed the upper part, having a thickness of about 14 inches, seemed to be of better quality than the lower, and a sample, according to the same authority, shows the following composition:

Analysis of upper part of crushed coal from Reed shaft, Lower field.

	Per cent.
Moisture	2.60
Volatile combustible matter	23.41
Ash, white	54.43
Fixed carbon	19.56
Sulphur	1.98
Silica in ash	53.4
Noncoking.	

In the Crowe shaft a sample was obtained by making a cut across the lower bench of coal 18½ inches in thickness. This was analyzed by Mr. Sullivan with the following result:

Analysis of lowest coal in Crowe shaft, Lower field.

	Per cent.
Moisture	1.76
Volatile combustible matter	36.65
Ash, light reddish	34.78
Fixed carbon	26.81
Sulphur	1.91
Silica in ash	51.5
Coke	Dull, not swollen, friable.

The striking feature of the above analyses is the high percentage of ash, which in the samples taken runs from 34 to 54 per cent. At first this heavy percentage seems to be prohibitive, but when it is considered that much of the Colorado and New Mexico coal delivered in this region probably does not run under 17 per cent of ash, and some of it exceeds this figure, it is apparent that local coal, even with the heavy percentage shown in the above analyses, may be able to stand in competition. It is possible that the ash may be reduced by washing, if the coal is transported to Gila River, where sufficient water is available for this purpose. The hard bench of the coal, however, has a rather high specific gravity, so that the separation of the coal and shale would not be an easy matter.

One of the greatest demands for fuel in this country is for coke to supply the copper smelters. In the early days this was brought from abroad at a cost of from $50 to $75 per ton, but recently with increased railroad facilities the region is supplied with Colorado and eastern coke at a cost of from $10 to $15 per ton. The commercial value of the Deer Creek coal depends largely on whether it will produce a coke that can be used in the copper smelters and that can be supplied at a cost below that obtained for eastern coke.

As will be seen from the analyses, almost all the coals of this field will produce coke, but as tested in the laboratory the upper bed, or that shown in the Reed shaft, is the most promising. This bench of coal has a thickness of about 15 inches. The lower bed, as sampled in Crowe's shaft, yields an inferior coke, so that probably it can not be depended on unless it is found in actual practice that the coke is of better quality than that produced in the crucible. Generally it is recognized that all laboratory tests of coking coals are inadequate; therefore it is desirable in all cases to make practical tests in the field before beginning operations.

During the process of coking in the ordinary beehive oven the volatile, combustible matter is driven off and also a considerable percentage of the fixed carbon is burned up. Owing to this reduction in the percentage of the fuel part of the coal, the percentage of ash in the coke is increased considerably above that which appears in the coal, so that instead of having to deal with 40 to 43 per cent of ash it is probable that the coke will contain at least 50 per cent, and possibly it may run to a greater figure.

The use of such impure coke in the copper smelters depends largely upon the amount of silica contained in the ash. The ores are generally basic, and there is a tendency for them to combine with the siliceous lining of the furnace. It seems probable that in case the coke contains a heavy percentage of silica this may combine with the basic ores, thus relieving the siliceous lining of the furnace to a considerable extent. In order to determine this, tests were made of the percentage of the silica in the ash, and as shown in the accompanying analyses it runs about 50 per cent.

As previously stated, it is possible that this percentage of ash may be reduced by washing, but this would necessitate the erection of a costly washer plant at the river, and the gain may not be sufficient to warrant the expenditure. It is recommended, however, in case these coals are mined and coked to experiment with washing and see if the percentage of foreign matter may not materially be reduced.

RÉSUMÉ.

From the foregoing facts regarding the coal of the Deer Creek Basin it seems safe to assume that there are two beds of workable thickness throughout the larger part of this basin. The dimensions of the field are approximately 3 by 10 miles; its area is about 30 square miles. The beds are thin, but from the measurements obtained it seems probable that they range from 24 to 30 inches in thickness, and this is within the limits of a workable coal. The tonnage of the field, based upon an estimate of 24 inches of coal throughout a basin 3 by 10 miles in extent, is about 60,000,000 tons. About 50 per cent of this may be available, making 30,050,000 tons of coal.

The coal is fairly well disposed for mining, except where it is subject to local disturbances and where it has been cut by igneous dikes. These disturbances are generally apparent at the surface and may be avoided in the location of commercial mines.

In a general way the coal is of two qualities, the first being a hard, block coal, which is fairly well adapted for transportation and for commercial use, and also may be manufactured into coke. The second grade is a soft, badly crushed coal, which carries a heavy percentage of ash, and which, owing to its peculiar condition, probably can not be marketed. It carries, however, a fairly large percentage of volatile matter, and it may be utilized in one or two ways, either by being manufactured into gas and the gas piped to the place of consumption, or to generate electricity in the field and the power carried by wire to the place where it is needed. By the latter method only a small percentage of the fuel value of the coal would be utilized; therefore it seems probable that the former method would be the most economical means of using this deposit. By the modern methods of making producer or water gas the whole of the fuel value of this coal might be utilized.

The facts so far presented are those which concern the geologic occurrence of the coal, and these alone are of interest in the present connection. The development of the field and the best mode of utilizing the fuel is a question which concerns the engineer and should be approached only by one who is thoroughly familiar, not only with local conditions, but also with the best method of handling fuels of this character.

THE CUMBERLAND GAP COAL FIELD OF KENTUCKY AND TENNESSEE.

By George H. Ashley.

GENERAL DESCRIPTION.

Location and limits.—The Cumberland Gap coal field forms part of the eastern edge of the Appalachian coal field in southeastern Kentucky and northern Tennessee. It lies between Pine and Cumberland mountains, and extends from Fork Mountain to the heads of Poor and Clover forks of Cumberland River, having a length of 90 miles and a width of from 15 to 20 miles. These boundaries are not merely topographic, for associated with Pine and Fork mountains are notable faults, making distinct breaks between this field and the coal fields to the west and north; and while this field was originally part of the same general coal field, as are the coal areas to the west and north, more detailed work than has yet been done will be required to connect the stratigraphy of this basin with that of the outside fields, or to correlate the coals across the breaks made by the faults mentioned. Cumberland Mountain forms the eastern escarpment of the Appalachian coal field, all that part of the Coal Measures that may formerly have existed to the south having been removed by erosion. This paper is based on field work in the seasons of 1902 and 1903 over the central part of the basin, or the area lying between Log Mountains at the head of Yellow Creek to a north-south line about 10 miles east of Harlan. The data presented, therefore, are not authoritative, except within those limits.

Topography.—Pine and Cumberland mountains are formed by the edges of resistant sandstones upturned at angles of from 20° to 90° from the horizontal, and, following the structure, run nearly straight on northeast-southwest lines. Between them lies a mass of mountains of irregular shapes, with irregular and usually narrow crests.

The drainage of the area studied is entirely into Cumberland River, which is formed by the union of the three forks—Poor, Clover, and Martins—at Harlan, and which escapes from the basin by the gap at Pineville. Wallin, Puckett, Yellow, and Clear creeks are its principal tributaries below the forks. At the Pineville Gap Cumberland River has an elevation of about 980 feet above tide, while the highest points in the area reach an elevation of 3,400 feet. The mountains rise 1,000 to 2,000 feet above adjacent drainage. The lower valleys have commonly broad bottoms with abruptly rising side slopes; the higher valleys are narrow and V-shaped. At Middlesboro there is a broad flat.

Structure.—This basin is structurally a flat-bottomed syncline or trough with sharply flexed sides. The axis of the syncline lies near but a little southeast of Cumberland River, running between Poor and Clover forks on the east and between Stony Fork of Yellow Creek and Clear Creek west of Middlesboro. From this axis there is a gradual, though not always uniform, rise in either direction, averaging possibly 100 feet to the mile, to Pine and Cumberland mountains, where the rocks are flexed sharply upward at angles varying up to perpendicular, though usually less than 70°. A notable transverse fault belt crosses the area from north to south in the neighborhood of Middlesboro. In this belt were noted several minor faults in the gap at Pineville and in the territory adjacent on the east; a fault with downthrow to the west of over 1,200 feet along the west face of Rocky Face Mountain; a fault with apparently considerable horizontal movement at Cumberland Gap; while all the small hills in or immediately around the plain at Middlesboro give evidence of highly confused structure, as though the shales, which make up a large part of the exposed strata at that point, had given way with folding and probably faulting under the stresses which produced the faults just mentioned. Other faults were noted at Shillaly Creek, on Ewings Creek, and elsewhere. The upturning of the rocks in Pine Mountain is in connection with the great Pine Mountain fault, previously mentioned. The structure in Cumberland Mountain is monoclinal, being part of the western limb of the Powell River anticline. Along some of the distance this monocline is distinguished by the strata being sharply bent at the bottom from an almost horizontal to an almost vertical position, then at the top being bent again into a nearly horizontal position, probably with considerable fracturing at the upper bend.

STRATIGRAPHY AND COALS.

The outcropping rocks of this basin consist of sandstones and shales with coal beds. So far as found, the fossils show that all of the coal-bearing rocks belong to the Pottsville group of the Pennsylvanian series. The lower part of the section is predominantly sandy and often conglomeratic. The name Lee conglomerate has already been applied to that part of the section in adjacent areas. It should be noted, however, that when first applied it was with the impression that these basal sandstones represent all of the Pottsville of Pennsylvania, so that, while the name here is applied to what is believed to be the same series of rocks, a recent study of its fossil plants shows that it represents only the lower portion of the Pottsville. The Lee contains some coal beds, of which at least two reach workable thickness in parts of this area, but as they are exposed only in the enflanking mountains, where they are upturned at high angles and usually more or less crushed, their present value is considered small. Future drilling may reveal their presence in workable thickness under the center of the basin, where, though lying well below drainage, they could readily be worked.

The upper part of the series of rocks shows an irregular succession of shales, sandstones, and coals, the shales and sandstones being in about equal proportions and showing little tendency toward segregation in particular parts of the section.

In studying the stratigraphy and coal content of the upper part of this series of rocks it will be convenient here to consider separately the Log Mountain area west of the fault belt from Cumberland Gap to Pineville, and the Harlan region east of that belt.

Over 2,300 feet of strata occur above the Lee in Log Mountains, which contain at least 40 coal beds, of which 13 are of workable thickness. No doubt many of these are not persistent over the entire area, but many have a wide distribution and 8 are being worked on a commercial scale. Nearly all of the coals are more or less broken up by partings, which in some cases increase so as to make the coal worked in one district unworkable in neighboring districts. As a rule the upper coals are the best, but they lie so high in the mountain as to have rather limited areas.

The principal coals are as follows:

Red Spring coal.—This coal lies immediately above a heavy sandstone that makes prominent cliffs around much of the crests of Log Mountains, coming about 200 feet below the highest points and above or level with many of the gaps. It has an altitude of 2,600 to 3,000 feet above sea level. Three coals have been found above it, one 3 feet 3 inches thick, and one 4 feet thick, the latter badly broken up with partings. Two sections of the Red Spring coal are as follows:

Section of Red Spring coal in Log Mountains.

	Ft.	In.
Coal	5	3

Section of Red Spring coal in Bryson Mountain.

Shale roof.	Ft.	In.
Coal	3	8½
Clay	0	10½
Coal	1	6
Clay	0	2½
Coal	0	3
Total	6	6½

This coal has not yet been mined, and though of good thickness will yield but small areas on account of its elevation.

Upper Hignite coal.—This coal has attracted some attention in Log Mountains at the heads of Hignite Creek, Little Clear Creek, and Bear Branch of Big Clear Creek, but does not seem to be generally workable, unless what has been called the Lower Hignite coal elsewhere may in places be the Upper Hignite. It lies 400 to 450 feet below the Red Spring coal, in which space six or more coals occur, of which one is workable in places. This coal shows the following section on Hignite Creek:

Section of Upper Hignite coal on Hignite Creek.

	Ft.	In.
Clay-shale roof.		
Coal	1	0
Clay	0	6
Coal	1	0
Clay	1	0
Coal	2	8
Clay	0	3
Coal	0	2
Fire clay.		
Total	6	7

Lower Hignite coal.—This coal lies 10 to 20 feet below the Upper Hignite and an equal distance above a sandstone which makes rather prominent cliffs, probably more prominent than those made by any other sandstone above the Mingo coal, to be described on another page. On account of its good section and quality, though yielding only comparatively small areas because of its elevated position in the mountains, this bed has been considered one of the best in the region. Typical sections show as follows:

Section of Lower Hignite coal on Hignite Creek.

	Ft.	In.
Shale roof.		
Coal	3	4
Fire clay.		

Section of Lower Hignite coal, Bryson Mountain.

	Ft.	In.
Shale roof.		
Coal	3	5
Clay	0	2
Coal	1	0
Clay	0	1½
Coal	0	8
Total	5	4½

The first commercial opening on this coal was being made in 1903 on New Cabin Fork of Bennett Fork.

Klondike coal.—This coal lies 300 to 400 feet below the last-described coal, in which interval occur eight or more coals, none of which is workable. This coal presents a good area under the main ridges, but small areas under the spurs, as Mingo Mountain. It appears not to be workable in most of the area north of Stony Fork of Yellow Creek. At one mine its parting changes from nothing to 4 feet in a short distance. Two sections follow:

Section of Klondike coal in Log Mountains.

	Ft.	In.
Shale roof.		
Coal	3	11

Section of Klondike coal at Klondike mine, Mingo Mountain.

	Ft.	In.
Sandstone.		
Clay shale	2	0
Coal	3	10
Clay	0	1
Coal	2	0
Hard, smooth clay.		
Total coal	5	11

This coal is being mined at the Klondike and Nicholson mines on Mingo Mountain.

Poplar Lick coal.—This coal lies 36 to 125 feet below the last. It would appear to be the most valuable coal between Big Clear Creek and Stony Fork, where a large number of measurements show a thickness of between 4 and 5 feet. It is less important south of Stony Fork. Three sections show as follows:

Section of Poplar Lick coal on Mingo Mountain.

	Ft.	In.
Coal	1	10
Clay	0	2
Coal	1	10
Total	3	10

Section of Poplar Lick coal on Coal Creek, Log Mountains.

	Ft.	In.
Shale roof.		
Coal	0	8
Coal, soft	0	½
Coal	1	1
Clay	0	1½
Coal	2	0
Clay	0	7½
Coal	1	6
Total	6	½

Section of Poplar Lick coal on Little Clear Creek, Log Mountains.

	Ft.	In.
Coal	2	8
Clay	0	3
Coal	3	0
Total	5	11

This coal has an elevation of about 2,000 feet in Log Mountains, where it is estimated to underlie 11,000 acres, and of about 2,200 to 2,300 feet in Mingo Mountain, where its area is comparatively small. This coal is worked on Mingo Mountain and on Stony Fork and Coal Creek in Log Mountains.

Sandstone Parting coal.—From 160 to 250 feet below the Poplar Lick coal, the interval increasing from north to south, is a coal that shows in most sections a hard sandstone parting. It is not certain that the sandstone parting occupies the same stratigraphic position in the coal at different points, as sometimes it comes near the top, sometimes near the bottom. It has been much used by engineers in the field as a key coal, especially in tracing the Poplar Lick coal. It is mined commercially at the Yellow Creek, Nicholson, and Ralston No. 2 mines on Mingo Mountain. Two sections are given:

Section of Sandstone Parting coal in Log Mountains.

	Ft.	In.
Coal	2	2
Sandstone	0	2
Shale	0	2½
Coal	0	6
Total	3	½

Section of Sandstone Parting coal, Mingo Mountain.

	Ft.	In.
Coal	0	3
Clay, none to	1	0
Coal	0	3½
Clay	0	1
Coal	2	10
Sandstone	0	3
Coal	1	2
Total	5	10½

This coal is hard and the sandstone tends to stick to the coal. It would hardly be classed as workable in Log Mountains.

Mingo coal.—This is the most important coal in the Bennett Fork region and to the west. It is not workable on Stony Fork or to the north. On Bennett Fork it lies about 250 feet below the last-named coal, five or more coals occurring in the interval. Its position can readily be determined, as it comes about 40 feet above the upper of two sandstones that make almost continuous cliffs through this area. The uppermost of these cliffs, which is the more prominent, was used as a key rock in this part of the field and followed around the mountain to connect the coal of the different valleys. The Mingo coal is about 1,500 to 1,600 feet above sea level in the valley of Stony Fork and 1,700 to 1,800 feet along the upper part of Bennett Fork. It has a regular parting of 6 to 8 inches, which toward the lower and upper parts of Bennett Fork tends to increase to 4 feet or more. A single section will give a good idea of how it averages at most of the mines working it.

Section of Mingo coal on Mingo Mountain.

	Ft.	In.
Coal	2	8
Clay	0	8
Coal	1	5½
Clay	0	2½
Coal	0	5½
Total	5	5½

This coal is worked at the Mingo Nos. 1 and 2 mines, the Fork Ridge, the Reliance, Bryson Mountain, and Ralston No. 1 mines. From its low position in the mountain it occupies a much larger area than any of the higher coals, but probably is not workable over so large an area as some of the others.

Chenoa coal.—At Chenoa, on Big Clear Creek, a cannel coal has been extensively mined. It is estimated to lie more than 500 feet below the Sandstone Parting coal. Its presence led to the building of the railroad up Big Clear Creek from Pineville. Mining has shown it to occur in a very limited basin, as is usual with cannel coals, not over 600 feet wide, though it has been followed 4,000 feet into the mountain. It showed the following section:

Section of cannel coal at Chenoa, Big Clear Creek.

	Ft.	In.
Coal, cannel	3	9
Coal, bituminous	2	0
Total	5	9

On account of the change in the thickness of the strata in going from Big Clear Creek to Bennett Fork its exact equivalent on the latter stream is uncertain.

Bennett Fork coal.—This is the coal at the Bennett Fork mine and other openings near the mouth of Bennett Fork. It is below drainage over most of this area, so that little is known of its extent or workability.

Section of Bennett Fork coal at Bennett Fork mine.

	Ft.	In.
Sandstone roof.		
Coal	0	6
Clay	0	6
Coal, bony	0	1½
Coal	1	0
Clay	0	2
Coal	1	8
Clay	0	2
Coal	0	3
Total	4	4½

From 8 to 16 feet below this bed occurs another bed, of which the following section was measured:

Section of coal below Bennett Fork coal.

	Ft.	In.
Coal	2	10
Clay	0	2
Coal	0	6
Total	3	6

Turner coal.—In the low hills east of the mouth of Bennett Fork occur two coals whose nearness to each other suggests the Bennett Fork coals, but which it is believed lie 200 feet below them. The lowest of these coals is worked at the Turner mine and at other openings on both sides of the ridge. Almost nothing is known of its workability outside of the region mentioned, as it is below drainage level. A typical section shows:

Section of Turner coal in Mingo Mountains.

	Ft.	In.
Coal	2	4
Shale	1	5
Coal	1	11
Total	5	8

The following analyses of these coals are reported by Prof. A. R. Crandall; analyst not mentioned, probably R. Peters:

Analyses of coals from Cumberland Gap Basin, west of Middlesboro.

	Mingo.	Sandstone Parting.	Klondike.	Hignite.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	3.11	2.00	3.11	2.00
Volatile combustible matter	32.65	33.00	32.05	33.44
Fixed carbon	59.83	57.00	59.83	60.85
Ash	4.41	7.20	4.41	3.10
Sulphur	.750	.551	.760	.513

STRATIGRAPHY AND COALS OF HARLAN DIVISION OF FIELD.

Unlike the western portion of the field just discussed, this eastern part has seen no development and very little exploration. The facing of a coal bed in this area is an operation calling for the service of two men, usually for two or three days, and, in view of the lack of transportation facilities and the fact that good workable coal is usually found low in the mountains in the eastern part of the field, the necessary incentives have been lacking, and as a result the data obtained have had to be almost all gotten from the few and scattered exposures naturally faced in stream cuttings. Therefore the knowledge of the extent and workability of many of the coals is very imperfect. Of the coals found, two only have been so widely exploited as to show beyond doubt more or less continuous workability, the Neal and Harlan coals, described below. Several coal horizons were widely recognized which, though showing workable coal in places, on the whole were not promising, while at still other horizons coals of good workable thickness were found in a few localities, but extensive facing will be necessary to show whether or not they will prove workable over wide areas.

The Neal and Harlan coals mark two rather distinct horizons that divide the stratigraphic column into three divisions.

Above the Neal coal are about 900 feet of strata to the tops of the mountains. The physiographic conditions almost entirely prevent natural outcrops of the coals, so that while coal blooms were found suggesting thick coals, almost nothing is known of their thickness or workability. Their extent in all cases would be small. Several coals have been exposed within the lowest 200 feet of the uppermost series of rocks, of which one coal reaches a thickness of from 3 to nearly 4 feet.

About 320 feet above the Neal coal is the top of a sandstone which in a wide range of localities yields small quartz pebbles, being often a coarse grit. As such pebbles are found only in what appears to be a single sandstone within a vertical range of 50 to 60 feet, that sandstone becomes a valuable rock for the identification of the coals. About 100 feet below its top and at 180 feet above its top occur two cliff-making sandstones, of which the upper especially is a prominent object around many of the mountain summits. It makes the Hanging Rock at the head of Saylors Creek. About 160 feet beneath the Neal coal is another sandstone which makes prominent cliffs over most of the area. These four sandstones and the Neal coal, which is the thickest coal in this field, having fairly constant intervals between them, can generally be recognized through the eastern part of the field and serve to show the structure of the upper part of the measures.

Neal coal.—This coal, to which frequent reference has already been made, has a thickness of from 5 to 13 feet, commonly yielding 7 feet of minable coal. Owing to its elevation in the mountains, it offers rather limited areas. It occurs about 2,500 feet above sea level. On account of its thickness and stratigraphic value, several outcrops of the coal were faced by members of the Survey. Several sections follow:

Section of Neal coal in ridge at head of Forrester Creek.

	Ft	In.
Roof shale.		
Coal	5	10
Coal, bony	0	3
Coal	1	0
Clay	0	7
Coal	0	8
Total	8	4

Section of Neal coal above Hurst.

	Ft.	In.
Roof shale.		
Coal	5	5
Clay	1	0
Coal	0	8
Total	7	1

Section of Neal coal in Gray Knob.

	Ft.	In.
Roof shale.		
Coal	0	4
Clay	0	1
Coal	4	3
Coal	0	0
Clay	0	5½
Coal	0	4
Clay	0	1
Coal	4	4
Total	9	10½

The 6 to 12 inch clay seam in many of the sections has a characteristic white color. In its greatest thickness, as reported by McCreath and d'Invilliers,[a] it shows as follows:

Section of Neal coal on Gray Knob.

	Ft.	In.
Shale roof.		
Coal	0	5½
Knife-edge parting	0	0
Coal	3	3
Fire clay	0	8
Coal	0	1
Shale	0	1
Coal	0	5
Shale	0	⅛
Coal	0	7½
Shale	2	4
Coal	5	7
Total	13	6⅛

The Neal coal also reaches a thickness of 11 feet at the head of Puckett Creek, though badly split up.

Interval between Neal and Harlan coals.—Between the Neal coal and the Harlan coal is an interval of from 900 to 1,000 feet, in which workable coal has been found at a number of horizons, though at none of these could enough data be obtained to prove that workable coal occurs at those horizons over any considerable part of the field.

[a] McCreath, Andrew S., and d'Invilliers, E. V., Resources of the upper Cumberland Valley, Louisville, Ky., 1888, p. 79.

Ninety feet below the Neal coal on Gray Knob, McCreath and d'Invilliers report a coal as follows:

Section of coal 90 feet below Neal coal on Gray Knob.

	Ft.	In.
Shale roof.		
Coal	2	4
"Slate bl'ck clay"	0	3
Coal, splinty	1	11
Fireclay parting	0	11
Coal	0	11
Shale	0	3
Coal	0	3
Shale	0	2
Coal	2	1
Total	9	1

A coal in the same position relative to the Neal coal on Puckett Creek gave as follows:

Section of coal 80 feet below Neal coal on Puckett Creek.

	Ft.	In.
Sandstone roof.		
Coal	3	8

In several sections coals from 1 to 2 feet thick were found between 75 and 100 feet below the Neal coal, and seemed to suggest that a coal in that position is not generally workable.[a]

Creech coal.—About 450 feet below the horizon of the Neal coal there is found in Jackson Mountain a coal running from 4 to over 5 feet in thickness. Knowledge of this coal has been derived entirely from facings made by the direction of Mr. Robert Creech in 1902 in Jackson Mountain, and is a good illustration of the possibility of workable coals existing in this district, which are not exposed by natural outcrops. This coal was accidentally discovered in 1901 and, though facings on Jackson Mountain a half mile apart showed it to run through that mountain with great persistence and regularity, it has not been discovered outside of that limited area. It is of course possible that it is thin outside of the area of Jackson Mountain and that it corresponds in horizon with one of the numerous thin coals found scattered through every well-exposed section. Two sections may be given from Jackson Mountain.

Section of Creech coal on Toms Creek.

	Ft.	In.
Sandstone roof 12 to 15 feet thick.		
Coal	4	4
Fire clay.		

[a] Since this report went to press a reconsideration of the evidence in the light of some additional data makes it seem probable that the 13-foot coal on Gray Knob, the 11-foot coal on Puckett Creek, and coal sections of 3 to 4 feet found 100 to 150 feet above the Neal coal represent a coal at a horizon distinct from that of the Neal coal and 100 to 150 feet above it. As there is a slight doubt as to the coal at the Neal farm occurring at the lower horizon, the coal at the lower horizon will be called the Wallin Creek coal, from the number of excellent exposures of it around Wallin Creek, while the upper coal will be called the Smith 11-foot coal.

Section of Creech coal on Blacksnake Branch of Puckett Creek.

	Ft.	In.
Sandstone roof.		
Coal	0	3½
Shale	0	⅛
Coal	0	6
Clay, dark	1	3
Coal	4	0
Total	6	⅝

This coal lies between two massive sandstones and at an elevation of about 2,000 feet above sea level. If widely workable it would therefore yield areas of fair extent all over this district.

Kellioka coal.—About 200 feet lower, or 250 feet above the Harlan coal, occurs the Kellioka coal, usually a thick coal, but generally so badly broken up with partings as to be doubtfully workable. A series of sections scattered over this part of the field will show its variability.

Section of Kellioka coal on Toms Creek.

	Ft.	In.
Shale roof.		
Coal	0	3
Clay	0	7
Coal	1	7
Clay	1	8
Coal	0	9
Total	4	10

Section of Kellioka coal, head of Puckett Creek.

	Ft.	In.
Sandy shale roof.		
Coal	0	4
Shale	1	10
Coal	1	2
Shale	0	1
Coal	4	0
Total	7	5

Section of Kellioka coal, Catron Creek.

	Ft.	In.
Drab shale roof.		
Coal	1	5
Clay	0	6
Coal	1	5
Clay, dark drab	0	3½
Coal	0	3½
Clay	0	8
Coal	2	3½
Clay, black	0	1
Coal	1	0
Total	7	11½

Section of Kellioka coal on Poor Fork.

	Ft.	In.
Sandstone roof.		
Sandy shale (4 inches).		
Coal	0	3
Shale	1	5
Coal	0	9
Coal, bony	0	5
Coal	0	5
Coal, bony	0	1
Coal	0	3
Coal, bony	0	1½
Coal	4	0
Total	7	8½

On the whole this bed gives promise of much workable coal, but, unless future exploration reveals better sections than those now known, large areas of it will not be workable.

Coals of but little more than workable thickness have been found at a number of other horizons between the Neal and Harlan coals, but they are either thin at other places or have escaped observation, so that they must at present be considered as generally not workable or as unproved.

Harlan coal.—As far as our present knowledge goes, this is the most valuable coal in the eastern part of the field. Its position, low in the mountains, has led to its being opened up for local use at a large number of points scattered all along the banks of the three forks of Cumberland River. Measurements at these openings show the coal to maintain a good workable thickness, at least in all the area drained by the three forks of Cumberland River, in the district here discussed. Between Wallin Creek and Puckett Creek it is somewhat thinner, or else has not been found. Between Puckett and Yellow creeks occurs a coal of good workable thickness at what is believed to be the same horizon, and it will therefore be discussed under this head.

Its thickness between Puckett and Yellow creeks may be indicated by one section giving the thicker developments which it shows in places, and by two showing the average development.

Section of Harlan coal on Williams Creek (above average thickness).

	Ft.	In.
Clay-shale roof.		
Coal, weathered	0	8
Coal	1	0
Coal, soft	0	¼
Coal	0	9
Clay	0	1½
Coal	3	4
Total	5	10¾

All through this locality there appear to be two coals, of which in some cases the upper is the thicker, in other cases the lower; in some cases the two coals are of about equal thickness, as in the following section:

Section of Harlan coals on Hances Ridge.

	Ft.	In.	Ft.	In.
Shale roof.				
Upper coal.				
Coal	3	3½		
Clay	1	0		
Coal	0	3	4	6½
Shale, brown			5	0
Shale, light drab			10	0
Lower coal.				
Coal	2	1		
Clay	0	1½		
Coal	1	9	3	11½

Between Puckett and Wallin creeks the coals correlated as Harlan usually run between 2 and 3 feet thick.

The following sections are typical of this coal through the region of the three forks of Cumberland River:

Section of Harlan coal, head of Puckett Creek.

	Ft.	In.
Shale roof.		
Coal	3	0
Coal, bony	0	1
Coal	0	11
Total	4	0

Section of Harlan coal, upper Martins Fork.

	Ft.	In.
Clay-shale roof.		
Coal	0	9½
Clay	1	4
Coal	2	2
Coal, cannel	1	2
Total	5	5½

Section of Harlan coal on Catron Creek.

	Ft.	In.
Coal, 2 feet	2	7
Clay, 2 inches	0	1
Coal, bottom cannel	2	0
Clay	0	8
Coal	1	2
Total	6	6

Section of Harlan coal in Gray Knob.

	Ft.	In.
Shale roof.		
Coal	2	6
Clay	0	2
Coal	1	5
Total	4	1

Section of Harlan coal on Crummies Creek.

	Ft.	In.
Coal	0	6
Clay	0	4
Coal	3	3
Total	4	1

Section of Harlan coal in Little Black Mountain.

Shale roof.	Ft.	In.
Coal	4	0
Clay	0	7
Coal	1	0
Total	5	7

Section of Harlan coal in Big Black Mountain.

Sandstone roof.	Ft.	In.
Coal	4	0

On account of the narrowness of the valleys and its nearness to drainage, this coal will probably be found to underlie considerably more than half the total area of this part of the basin, not including Pine and Cumberland mountains. It characteristically lies between two fairly massive sandstones and about 250 feet above the sandstone that makes almost continuous cliffs along Clover Fork and Martins Fork, so that its recognition is not usually difficult, and its correlation in the various parts of the eastern field is probably correct.

Durham coal.—Between the Harlan coal and the top of the Lee conglomerate is an interval of about 500 feet. The most conspicuous member of this interval is the sandstone last mentioned, which it was believed was traced continuously through the area drained by the three forks of Cumberland River. Considerable effort was given to tracing it westward to Yellow Creek, but as in that direction it is no more conspicuous than several other sandstones close above or below it, it is uncertain whether the final correlations are correct. Though the coals between the Harlan coal and the Lee formation in places are of workable thickness, on the whole they do not promise large areas, for many of these horizons at most points showed coals less than 3 feet thick. A short distance above the sandstone so prominent on Clover Fork occurs a coal which is slightly over 3 feet thick at several points, and future exploration may show small areas over which it will prove workable; especially may this prove true in the western part of this area, near Yellow Creek. Two sections will show its thickness near Yellow Creek.

Section of Durham coal on Hances Creek.

	Ft.	In.
Shale roof.		
Coal	2	6
Shale	0	1
Coal	1	6
Total	4	1

Section of Durham coal on Williams Creek.

	Ft.	In.
Shale roof.		
Coal	1	3
Shale, black	0	1½
Coal	2	0
Shale, black	0	3
Coal	0	6
Fire clay, dark drab	1	6
Shale, black	0	6
Coal	1	6
Total	7	7½

Howard coal.—Below the sandstone so prominent on Clover Fork is an interval of shale containing several coals, which are usually thin and often of the cannel variety. In a few places one of these coals reaches workable thickness, as near the mouth of Wallin Creek, where it shows the following section:

Section of Howard coal on Terry Creek.

	Ft.	In.
Shale roof.		
Coal, cannel	2	0
Coal, bituminous	2	0
Total	4	0

Robbins coal.—Between Yellow Creek and Brownies a coal between the horizons of the Howard and Durham coals reaches workable thickness, as shown by the two following sections:

Section of Robbins coal on Crane Creek.

	Ft.	In.
Shale roof.		
Coal	3	10

Section of Robbins coal on Hances Creek.

	Ft.	In.
Shale roof.		
Coal	2	0
Clay	0	1
Coal	1	3
Total	3	4

QUALITY OF COAL.

The quality of the coals in the eastern part of the Cumberland Gap field is indicated in the following table of analyses; samples obtained by McCreath and d'Invilliers, analyses by McCreath:

Analyses of coals from Harlan district.

	Average percentages.	Remarks.
Water	3.285	Eleven out of 26 show less than 2 per cent.
Volatile matter	36.625	Extremes 34.028 and 39.980 per cent.
Fixed carbon	54.399	Extremes 47.159 and 58.304 per cent.
Sulphur	.852	Extremes .532 and 1.396 per cent.
Ash	4.839	Extremes 1.935 and 11.270 per cent.

A comparison of these analyses with those from other parts of the Appalachian coal field will show these coals to correspond closely in composition with the other coals of the field, being superior to many. They contain about one-tenth of 1 per cent more of sulphur and 1 or more per cent less of ash. In volatile combustible matter they run about the same as the Westmoreland and other gas coals of Pennsylvania, being higher in volative matter than the coking coals of Connellsville.

The better cannel coals of this basin carry from 6 to 17 per cent of ash and from 40 to 49 per cent of volatile matter. A large number of analyses of samples obtained during the progress of the recent survey may affect the above conclusions, but returns already received lead to the belief that they will agree substantially with the above figures taken from the results of an earlier survey.

DEVELOPMENT.

Most of this area has as yet no railroad facilities. It is only a comparatively few years since railroads reached Middlesboro, and already the production from the part of the field immediately around that city has reached an annual output of from 600,000 to 1,000,000 tons. Part of the product is coked at Mingo; the rest goes south and southeast. Between visits to this field in 1902 and 1903 six new mines, or openings on new coals, had been made on a commercial scale. Bennett Fork has become almost a continuous mining town for a distance of 5 miles, and Stony Fork, up which a railroad is just being completed, promises soon to become equally active. During 1902 a railroad survey was made to Harlan by the Southern Railway up Cumberland River from Middlesboro. Right of way is now being secured, and there seems hope that this field may soon have a railroad connection. At the same time railroads have been under construction up Clear Fork of Cumberland, making an outlet for the coal from that part of the field.

Coke is extensively made at the Mingo mines, part of which finds a market at the iron furnace at Middlesboro, and the rest finds ready market at the Ducktown smelters and at other southern points. The coal from this district is largely used by railroads and manufacturing plants that furnish a steady market the whole year through, thus allowing the mines to run regularly summer and winter.

LIGNITES OF THE MIDDLE AND UPPER MISSOURI VALLEY.

By Ernest F. Burchard.

LIGNITE IN NORTHEASTERN NEBRASKA.

In the middle Missouri Valley many unsuccessful attempts have been made either to find coal or to develop a fuel supply from the lignites. Of the States in the western interior coal field Nebraska alone shows no record of production, and a liberal bounty for the discovery of a workable bed of coal within its borders has been offered by this State. Encouraged by this bounty, extensive prospecting was done in 1902 in Dakota County, and the writer was thus afforded opportunity to make detailed investigations into the geologic relations, extent, and chemical composition of the lignite.

This paper is presented for the purpose of explaining the conditions actually existing in the region of which this area is a part, in order that unprofitable prospecting may be avoided.

Geologic relations.—The indurated rocks underlying Dakota County are of upper Cretaceous age. The oldest formation exposed is the Dakota, which comprises sandstones, clays, and shales, with interbedded seams of lignite. The Dakota is overlain by the basal shales of the Benton group, which also contain a thin seam of lignite, and over these shales is a limestone member, very probably corresponding to the Greenhorn limestone of the Benton in the Colorado section. Over the eroded surface of these sediments lie unconsolidated Quaternary materials, consisting of a heavy covering of loess, with thin deposits of glacial till and sands at its base.

Throughout its trough Missouri River has removed these rocks to a depth of 200 to 300 feet, presenting in its escarpment several exposures of the entire sequence. The strata lie nearly horizontal, a succession of broad undulations being traceable in the escarpment section from southeast to northwest through the county.

Prospecting has been confined to the upland region back from the escarpment, experience having shown that in its flood plain Missouri

River has eroded the underlying Dakota formation to such a depth as to carry away the main lignite bed.

Occurrence.—Seams of lignite outcropping in the bluffs near Ponca, in the southeastern part of Dixon County, and near Homer, in the southeastern part of Dakota County, have intermittently furnished a limited supply of fuel to residents of those localities. The discovery, late in 1899, of lignite at a depth of 91 feet in a well being drilled on the farm of C. H. Goodfellow, in Dakota County, in sec. 22, T. 29 N., R. 7 E., together with the careless report of the drillers that it had a thickness of 6 feet, led to extensive prospecting in this vicinity.

Extent as evidenced by prospecting.—In the summer of 1900 some business men of Jackson, Nebr., sunk an 80-foot shaft in the bottom of a ravine in sec. 14, T. 29 N., R. 7 E., a few rods back from the river flood plain. At the top this shaft was 65 feet above the mean level of Missouri River, and it passed through a bed of lignite at 60 feet, reported to be nearly 3 feet thick. The lignite was roofed by several feet of light, sandy clay, and was underlain by 8 feet of good, white fire clay. From sands below the fire clay water entered the shaft in such volume that a steam pump was necessary to keep the water low enough to enable the bed to be worked. Lignite obtained here was burned in the engine which operated the pump and hoist.

Unforeseen accidents and delays, caused by the careless methods of men inexperienced in mining, soon permitted the water to become too difficult to control, and this, together with other considerations, finally caused the owners to abandon the prospect. They report that the bed was becoming thicker and of a better and more uniform character as they drifted under the bluff. At the time this shaft was visited it was nearly full of water. The dump still contained much lignite which was identical with that from other parts of the county.

The next development work was undertaken by business men of Sioux City, Iowa, incorporated as the Nebraska Coal Company. This company leased several sections of land in the central part of Dakota County, about 3 miles north-northwest of Jackson, extending from the escarpment into the dissected upland, and drilling was begun in secs. 22 and 23, T. 29 N., R. 7 E., in March, 1902. At least 10 drill holes were sunk on the Nebraska Coal Company tract, with a range in depth of 85 to 400 feet. Many of the drillings were located at random; no careful records were kept at first, and had the relative surface elevations been ascertained much fruitless drilling might have been avoided.

Sections of the last five drill holes were recorded by the writer, two from personal observation, the others from an examination of the drillings and notes of Mr. Goodfellow. These records indicate the presence of lignite at three horizons:

(1) A fragmentary bed, 6 to 10 inches thick, exists in places and is

absent elsewhere. This bed lies from 25 to 50 feet above the mean level of Missouri River, the difference in elevation being due to the broad undulations of the strata.

(2) A bed of lignite at a depth corresponding to 91 feet in the Goodfellow well underlies several square miles. It has a thickness of 1½ to 2 feet, and varies in elevation from 20 feet below to 10 feet above the mean level of Missouri River.

(3) A bed 42 inches thick was reported in one of the first holes drilled, at a depth of 275 feet, or at 190 feet below the mean level of Missouri River. For a time all efforts were directed toward establishing the continuity of this third bed, but it was encountered in only one other place, a drill hole 20 rods south of the place where first discovered, and it was only 6 inches thick.

Notwithstanding these unfavorable showings, the Nebraska Coal Company sunk a well-timbered shaft, 7 by 14 by 82 feet, in the NW. ¼ SE. ¼ sec. 22, and the writer was present shortly after the second bed of lignite was reached. The section passed through by the shaft bore out the neighboring drill records. The first bed was but a few inches thick and of soft, charcoal-like material. A large volume of water began to enter the shaft at 35 feet, and a 2-inch pump had to be kept in operation day and night to keep the shaft dry enough for work to be continued. When the second bed of lignite had been cut through the work was stopped. The roof over the bed was a sandy clay, and would not remain in place without timbering. The bed was 22 inches thick, not entirely homogeneous in texture, and was underlain by a bed of fire clay containing an admixture of sand and splinters of lignitic material.

A second locality prospected is in the southeast corner of Dakota County, about 18 miles southeast of the first locality. This work was carried on by Sioux City capitalists. Three miles southeast of the village of Homer, in sec. 20, T. 27 N., R. 9 E., in a ravine about one-half mile back from the escarpment and about 60 feet above the mean level of Missouri River, a 15-inch bed of lignite outcrops from the shales in the Dakota formation. In leased land in secs. 27 and 28 holes were drilled to depths of from 190 to 280 feet, and a bed of lignite, 6 to 18 inches thick, was found at practically the horizon indicated by the outcrop. Near the drill hole in sec. 28 this bed was uncovered by digging a well 40 feet deep. This well disclosed a succession of clays, shales, and sandstones, with an upper bed of lignite, 5 to 7 inches thick, at a depth of 26 feet. The second bed underlies about a foot of carbonaceous earthy material, somewhat shaly. This material had evidently been mistaken by the drillers for lignite, and in this way the thickness of the bed had been overestimated. Above the carbonaceous shale was a grayish shale, familiarly known to the drillers as "soapstone," and below the lignite was a gray, sandy clay. Very little water was encountered in this shaft, its elevation being above the horizon of copious ground water. The lignite at the bottom of the shaft was drifted into for about 10 feet, but in this distance it did not vary in character or thickness. This development was carried no further, the fruitlessness of such work becoming readily apparent.

It is evident that this bed is represented in the second horizon exploited in sec. 22, T. 29 N., R. 7 E., and at Sargents Bluffs,[a] on the Iowa side of the river, 11 miles northwest of Homer, Nebr.

Owing to the distance between the two localities where lignite has been shown to exist in Dakota County and the absence of intermediate prospecting or outcrops, it may not positively be stated that there is a continuity of the beds from one locality to the other. Stratigraphically the two second beds are equivalent, and it is probable that a seam of lignite at that horizon should be fairly constant through the whole strip of land bordering the escarpment, except where removed by the erosion of the lateral drainage. The bed should, however, thin and disappear to the west. Conditions favorable to the origin and development of such a bed of lignite probably prevailed in Dakota time, the shallow, swampy area being delimited by the shore line to the east and deeper waters to the west.

Further well drilling will shed more light on the extent of the lignite, and it is likely, now that some interest has been aroused in the matter, that drillers will more carefully preserve future records.

Physical character.—When freshly mined the lignite is very moist, and by drying in the air loses 15 to 18 per cent in weight. When thus dried its specific gravity is 1.28 to 1.35. It is nearly black, has not a uniform texture, as it contains many fragments and streaks of soft, charcoal-like matter with woody structure, and its average hardness is much less than that of bituminous coal. Its most significant characteristic is its disintegration upon exposure. When the material has given up the greater part of its moisture the consequent shrinkage of the particles and opening of joints causes it to lose its cohesiveness and to fall to pieces at the slightest jar. If exposed again to moist air the movement between the particles consequent upon the rapid absorption of water still further aids disintegration of the mass, so that after a few alternations of wetting and drying it can be carried only in dust-tight receptacles.

Chemical composition.—Both proximate and ultimate analyses of the lignite from the second horizon were made by the writer. The results of the ultimate analyses were used as a basis for calculating the heating value of the fuel. Tests were also made of the relative gas-producing

[a] Bain, H. F., The geology of Woodbury County: Iowa Geol. Survey, vol. 5, 1895, pp. 259-260, and fig. 35.

capacities of the Nebraska lignite and of cannel coal. These several results are indicated in the following tables:

Proximate analyses of air-dried lignites from Dakota County, Nebr.

Sample and locality.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1. Drillings, sec. 22, T. 29 N., R. 7 E.	4.99	41.63	27.14	25.72	1.20
2. Drillings, sec. 22, T. 29 N., R. 7 E.	4.03	51.40	33.66	10.91	([a])
3. Lumps from shaft, sec. 22, T. 29 N., R. 7 E	6.85	31.05	45.08	16.15	.86
4. Lumps from shaft, sec. 22, T. 29 N., R. 7 E	6.47	[b] 27.24	49.27	16.23	.86
5. Lumps from outcrop, sec. 20, T. 27 N., R. 9 E	17.85	44.27	26.00	10.91	1.14
6. Lumps from shaft, sec. 28, T. 27 N., R. 9 E	6.77	54.16	28.66	8.65	1.75

[a] Sulphur not determined.
[b] Heated only to low, red heat.

Ultimate analyses of air-dried lignites from Dakota County, Nebr.

Sample and locality.	Moisture.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1. Lumps from shaft, sec. 22, T. 29 N., R. 7 E	6.47	58.90	2.70	1.48	0.86	10.41	19.18
2. Lumps from shaft, sec. 22, T. 29 N., R. 7 E	6.50	60.54	2.64	1.26	1.08	13.98	14.00

Calorific power of air-dried lignites from Dakota County, Nebr., based on elementary percentages.

Sample and locality.	Calories per kilogram.	B. T. U. per ton.
1. Lumps from shaft sec. 22, T. 29 N., R. 7 E. (Second table, 1)	5,297	9,534
2. Lumps from shaft sec. 22, T. 29 N., R. 7 E. (Second table, 2)	5,260	9,468

Gas-producing capacity of air-dried lignite from Dakota County, Nebr.

Sample and locality.	Gas yielded per ton.	Coke.
	Cubic feet.	*Per cent.*
1. Lumps from shaft, sec. 22, T. 29 N., R. 7 E	[a] 12,279	71.2

[a] Average of ten tests.

Gas-producing capacities of other lignites and standard gas coals.

Sample and locality.	Gas yielded per ton.	Coke.
	Cubic feet.	*Per cent.*
1. Lignite, Rock Springs, Wyo.[a]	11,069	55.8
2. Cannel coal, Kentucky[a]	10,661	42.0
3. Lignite, Ouachita County, Ark.[b]	11,386	....
4. Cannel coal, Beaver County, Pa.[b]	10,160	....
5. Cannel coal, Kentucky[b]	12,540	....
6. Cannel coal, Scotland[b]	12,350	....
7. Bituminous coal, Newcastle, England[b]	10,760	....
8. Bituminous coal, Upper Monongahela River[b]	10,000	....

[a] Experiments by the writer.

[b] Taff, J. A., Preliminary report on the Camden coal field of southwestern Arkansas: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 329.

In chemical composition the Dakota County lignites are fair representatives of their class of fuels. Unfavorable points are the high content of moisture in fresh samples and the high percentage of ash. In total combustibles they take a medium rank and the low percentage of sulphur is worthy of note.

Gas-producing capacity.—The high percentage of volatile, combustible matter first suggested that the lignite should be of value as a gas coal. The experiments verify this idea. The foregoing tables present a comparison between the gas yield of this lignite and various standard gas coals. The illuminating power is weak, however, and the gas would have to be enriched to be made a good illuminant, but for fuel purposes it might prove satisfactory.

Possibility of better coal at greater depth.—There is no evidence to show that the lignites improve in quality with depth, nor to support the popular misconception that lignite seams outcropping from a bluff are likely to be of better quality farther back under the hill. The deeper lignites and those within the body of the bluff are at present subject to slightly greater pressure than those nearer the surface, but the additional pressure is too slight to be of significance. By analysis lignite from the third bed was proved to be of poorer quality than that from the second bed, while material from outcrop and shaft in the same vein showed but little variation in composition.

It likewise seems highly improbable that bituminous coal will ever be found in this locality. Deep wells have been drilled at Sioux City, Iowa, and at Ponca, Nebr., neither of which encountered any indications of coal. The well at Sioux City is 2,011 feet deep. It reached limestones at 540 feet which have been doubtfully referred to the Carboniferous.[a] The well at Ponca is 698 feet deep and entered

[a] Bain, H. F., Iowa Geol. Survey, vol. 5, 1895, p. 258.

limestone strata at 455 feet. It is possible that the Carboniferous rocks which are so extensively developed in Iowa and Nebraska to the southeast of this region once extended as far as the southeast corner of South Dakota, but probably for the most part they were removed by erosion before the deposition of Cretaceous strata. Some limited outliers of these rocks may remain, deeply buried, but, if so, it has not been demonstrated that they are coal bearing, and the cost of the extensive drilling that would be necessary to shed light on this point would doubtless far exceed the returns to be expected in the event of finding a remnant of a coal bed.

Conclusions.—Several factors enter into the consideration of the economic value of this lignite. A steady demand for a suitable fuel is assured in this region. This narrows the question to (1) character of fuel; (2) its extent; (3) practicability of mining it.

The lignite is of equal fuel value with the widely used brown coals of Europe, and with those of Texas and Arkansas, which are locally in use. The physical character of the lignite, however, offers a fatal objection to its use in more than a very restricted local area. Its tendency to disintegrate or slack while drying precludes its being handled or transported without great loss. Even if it could be satisfactorily delivered in neighboring cities at an advantageous price, especially constructed grates would be necessary to its economical combustion, whether it were used for steam or domestic purposes. This would be a handicap to it in competition with better coals. Its immediate value in the restricted area in which it occurs depends upon the cost of production, for this region along the river escarpment is still well wooded and so provided with cheap fuel. Therefore, at present, the value of the lignite as a fuel is extremely doubtful.

As to extent, the bed at the second horizon may be said to have a satisfactory areal extent, but its average thickness (20 inches) is not sufficient. Beds of good bituminous coal of this thickness are sometimes profitably worked, but it is clear that the Dakota County lignite does not occur in paying quantity, when it is compared with the lignites of southwestern Arkansas, which are from 3 to 6 feet thick; with those of Texas, which are from 4 to 6 feet thick, occasionally reaching over 15 feet, and usually occur as outcrops; and with those of Wyoming and North Dakota, which are 20 feet or more in thickness.

The practicability of mining the lignite depends on its character and extent, in conjunction with such local conditions as affect actual mining operations. In this region it is certain that only such beds can be worked as are above the ground-water horizon or above the level of the river flood plain, so that they may be drained without pumping. The nature of the roof over the bed is of the greatest importance. In this region, where lumber is comparatively expensive, if the roof of a tunnel must be timbered the cost of material and labor would amount to nearly as much as the value of the fuel removed. No satisfactory roof has been found over any of the Dakota County lignites. Thus there are two hindrances to practicable mining of the lignite where found in its nearest approach to sufficiency, and these, together with its doubtful fuel value and its limited quantity, constitute good reasons why, at present, such deposits in this region must be considered as having no commercial value as a general fuel supply.

Many writers have suggested that lignites and other inferior carbonaceous deposits in the United States might be made productive by briquetting. Economic conditions do not yet warrant such an attempt in this region, but it may be considered as a remote future possibility.

Dakota County is well situated for manufacturing and distributing purposes, and the lignite areas are easily accessible for railroad spurs. Certain thoughts suggested by the conditions may be worthy of consideration. If the bed of fire clay, apparently so constant beneath the lignite, could be mined with it, the latter might be used near by to burn fire brick from the clay. The lignite might be thus used directly as a fuel or be first converted into fuel gas. Some of the sands of the Cretaceous may be found to be suitable for the manufacture of glass. A gaseous fuel is best adapted to such an industry. Thus in more than one way the high gaseous content of the lignite might be utilized in the immediate vicinity; but not until thorough tests have shown such utilization to be practicable can any encouragement be offered for the production of this lignite.

LIGNITE IN NORTH DAKOTA.

Contemporaneously with the writer's study of the Nebraska lignites the State geological survey of North Dakota was carrying on preliminary investigations of the fuel resources of that State. From the comprehensive report by Doctor Wilder[a] a few facts are here presented, some of which, aside from their local significance, have an important bearing on the general problem regarding the utilization of lignite as a fuel.

Boundaries of the lignite area.—Workable seams of lignite have been found scattered throughout the whole western half of the State and beyond its boundaries to the north, west, and south. The eastern limit of workable seams of lignite is roughly along a line beginning at the northern boundary of the State, 10 miles east of Mouse River, longitude 101° 45′ W., and extending thence to the west-central part of Wells County, at latitude 47° 30′ N., longitude 100° W.; thence south to the southern boundary of the State. The Turtle Mountains

[a] Wilder, Frank A., The lignite coal fields of North Dakota: Second Biennial Report of the State Geological Survey of North Dakota, 1903.

plateau, a little east of the middle and at the north boundary of the State, is an outlier of the lignite area. Within the area proper are Williams, Billings, Stark, Mercer, Oliver, Burleigh, and Morton counties, the greater parts of Ward, McLean, and Emmons, and portions of Bottineau, McHenry, Wells, and Kidder counties—an area equal to at least half of the State of Ohio.

The centers of mining development have been determined mainly by the number and extent of local outcrops and by proximity to railroads or a market. Lignite is mined for shipment in Burleigh, McLean, Morton, and Stark counties, and in several of the other counties in the area there are local "banks" from which lignite is stripped to be used for domestic purposes by the owners or is sold at the mine to neighboring ranchmen who haul it away, perhaps 20 miles.

General geologic relations.—The badlands with their characteristic topography constitute the very heart of the lignite area. The innumerable "breaks," opening into larger stream valleys and presenting vertical sections of hundreds of feet, are admirably adapted to reveal the stratigraphy and mineral wealth of this portion of the State. In the lignite area, outlined above, the rock formations are restricted practically to the uppermost formation of the Cretaceous, the Laramie, and the overlying glacial drift. The Laramie, which contains all the workable lignite of North Dakota, consists of sands, sandstones, lignite, and thin bands of hematite, clay ironstone, and shaly limestone. The clays, which constitute perhaps three-fourths of the entire formation, are in part of great purity, and such are of considerable value for brickmaking. The strata lie practically undisturbed, with a broad slope from the high badlands on the west to the drift-covered plains east of the Missouri.

Number, thickness, and extent of the seams.—In the western part of the area the seams are most numerous, five to nine being reported as observed in natural exposes along the Little Missouri and Missouri valleys and other stream cuttings. Their number decreases toward the eastern edge of the area, where one to three seams exist at certain points. It is noteworthy here that this evidence rests solely on visible outcrops. Future deep well records and prospect holes doubtless will reveal the existence of much more lignite below the surface. Already two deep wells,[a] one at Medora, the other at Dickinson, have been sunk about 1,000 feet, and each passed through 16 lignite seams varying in thickness from a few inches to over 23 feet, the total aggregating more than 60 feet.

In thickness the seams vary from 1 inch to 40 feet. The 40-foot bed outcrops in Billings County, in sec. 31, T. 135 N., R. 101 W., but thins rapidly to 15 feet within a quarter of a mile. Near Sentinel

[a] Darton, N. H., Preliminary report on artesian waters of a portion of the Dakotas: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 664.

Butte, on Government land, in sec. 20, T. 133 N., R. 104 W., are extensive seams 25 feet thick, while seams 15 feet thick are not uncommonly exposed along Little Missouri River, and more rarely to the north and east. A large number of seams 6 to 10 feet thick are described in that part of Doctor Wilder's report which treats of the deposits by counties, and it is stated that seams 2 feet or less in thickness were so abundant in the western part of the lignite area that in the preliminary work being done it was not practicable to minutely note them all.

Especial attention was given to the correlation of seams in one locality with those of another, but in general it was not found practicable to correlate seams in exposures more than 4 or 5 miles apart. The nature of the seams hardly admits of close correlation without much detailed work, on account of great variations in thickness and elevation. In some instances the lateral persistence of seams is considerable and can be demonstrated, but "while a single seam was often traced for 6 miles or more along the banks of the Little Missouri, others seen at the same time thinned out and gave place to new ones a little above or below them." An interrupted seam often is seen to be present after a break of a half mile where the lignite has been replaced by bituminous or nearly pure clay. Neither can it be shown that certain horizons in the Laramie are notably richer in lignite than others, except in given localities. The thicker seams appear to exist as lens-shaped masses, some of which are of considerable areal extent, and of the thinner seams often two or more lie so close together, separated by a foot or so of clay, that they may be mined as one.

Methods of mining.—The methods of mining may be summarized as follows:

Practically all the lignite of North Dakota is mined by three well-known systems—the strip pit, drifting in on the seam, and shafts, vertical or sloping. The system that is in use at a given locality depends on two factors—the stage of development that the seam has reached and the nature of the seam. The strip-pit system is the simplest, but a coal bank begun in this way generally passes with time into a drift mine. Later it may be found desirable to abandon the drift and sink a shaft. Local conditions, however, may interfere with this natural development, arresting it before the second and third stages are reached. Where capital is sufficient and other conditions are favorable, the preliminary stages are omitted and a shaft is sunk at once.

The overlying clay has not been found satisfactory for a roof, and it is generally necessary to leave 6 inches to 1 foot of the lignite at the top of the seam. Consequently this amount must be deducted from the thickness of a seam in measuring its available thickness. With part of the lignite thus left for a roof, timbering is generally unnecessary.

Lying between clays, the lignite usually carries some water, and springs often issue from its outcrops. The water is not excessive, requiring a moderate amount of pumping in some mines, and, being of good quality, mine water may be utilized to advantage during part of the year in irrigation. It would appear from their elevations relative to the valleys that many mines might be drained without pumping, at least in the early stages of development.

In strip-pit mining no outfit is necessary beyond a plow and scraper, but labor conditions render the use of mining machinery operated by electricity desirable in the larger underground mines. The character of the lignite renders the use of undercutting machines of advantage in some places, and in others drilling and "shooting from the solid" is most effective.

Physical properties.—Physically, these lignites do not differ greatly from the Nebraska lignites previously described. The content of moisture, 31 per cent, is somewhat higher than that of the Nebraska product, and the same tendency to slack or to crumble to pieces while drying has been observed. Another objectionable feature is the presence of a layer of "slack" which often forms the top of a lignite seam, sometimes attaining a thickness of 8 feet and sometimes composing the whole of a thin seam. Such material is soft, gives a high percentage of ash, and has a low fuel value. It is apparently due to the decay of lignite which was exposed to the air during a large part of the time the deposit was undergoing alteration.

Chemical properties.—Analyses of 60 samples of lignite show a fair accordance in percentages, computed on a dry basis, of fixed carbon and of volatile combustible matter, whether taken from different parts of the same seam or from seams in widely separated localities. The percentage of ash varies more widely. From 23 samples fresh from the mine the moisture ranges high, and the sulphur, determined in 5 samples only, ranks low. No data are given showing the per cent of moisture retained in dry air, but inspection of analyses of 37 samples, partly dry when analyzed, places this at about 10 per cent as the minimum. Computed on this basis, which is the usual method of grouping the proximate constituents of a coal, a general estimate of percentages is made.

Analyses of North Dakota lignites.

	Fixed carbon.	Volatile combustible matter.	Ash.	Sulphur.	Moisture.
Ranges in percentages	[a]43.47-60.95	[a]31.59-43.18	[a]1.20-23.92	[b]0.35-1.10	[c]14.25-35.00
Averages of percentages	[a]51.21	[a]35.63	[a]8.50	[b].78	[c]31.08
Estimated percentages, usual basis	47.88	33.32	7.95	.70	[d]10.00

[a] 60 samples, dried.
[b] 5 samples, dried.
[c] 23 samples, fresh from mines.
[d] Moisture retained in dry air.

Comparison of these figures with analyses of other lignites shows the North Dakota product to be of a high grade, and, judged by the standard of chemical composition alone, it ranks well with the bituminous coals of Iowa, Missouri, and Kansas.

Evaporative tests.—Practical tests affording direct comparisons between the evaporative powers of the lignite and standard bituminous coals burned under the same conditions are much more reliable and satisfactory than chemical tests. Several such tests have been made, viz, at the asylum for the insane at Jamestown, N. Dak., at the Fargo-Edison Company's plant at Fargo, N. Dak., at the State University, and at a number of flour mills and electric-lighting plants in the State. From these tests it is shown that, conservatively taking the evaporative power of the lignite at 4.1 pounds per pound of fuel consumed, the lignite possesses 63 per cent of the power of Youghiogheny coal, 70 per cent of that of Missouri coal, and 75 per cent of that of Iowa coal. In all but one of the tests it was demonstrated, considering the relative costs of the fuels at the point where tested, that the use of lignite is the more economical, and this would appear to be corroborated by the fact that it is being very generally used in the State for steam and domestic purposes.

Locomotive tests.—Railroads have been very slow to adopt lignite as a fuel for locomotives. However, the question whether it may be so used has become so important in the Northwest that a locomotive has been especially constructed with reference to this problem by the Baldwin Locomotive Works for the Bismarck, Washburn and Great Falls Railway. Detailed reports concerning two trips, each of 106 miles, by this locomotive hauling a heavy train and using lignite for fuel are given, which indicate a saving of over 40 per cent of the cost of eastern bituminous coal for the same work.

Deductions as to fuel value.—Notwithstanding the favorable evidence of both chemical analyses and boiler tests, a definite relative fuel value can not safely be assigned to lignite coals at present. Their peculiar physical characteristics complicate the question by directly and indirectly lowering the apparent value. The expense of shipping nearly one-third by weight of the lignite as moisture, while not strictly an element affecting its value as a fuel, does enter into the cost of production. As the evaporation of the moisture contained in the fuel results in a direct loss in the calorific power, since it absorbs heat, it appears that a gain would be effected by burning the lignite in an air-dried state. As yet, however, no practical method has been devised for drying the lignite on a large scale at the mines. If this were accomplished, not only would the fuel value be increased, but the cost of transportation would be lowered. It should also be noted that specially constructed grates and fire boxes are essential to economical combustion of lignite when it is air dried, for in this condition it easily crumbles to fine fragments and dust. It is well known that stokers prefer to handle bituminous coal in firing their boilers, and the additional labor necessary to feed twice the weight of fuel to an engine must at length increase the cost of using that fuel.

Plants using large quantities of fuel might advantageously reduce the lignite to a fine condition and dry it before burning. Automatic stokers are found to handle the fuel conveniently in this condition, and when they are used in combination with forced draft, hollow grates, and fire-brick arches, effect very satisfactory combustion of fine fuel. The efficiency of pulverized fuel in this connection might even be increased by feeding it to the fire by means of a blast.

Local significance.—While all may not yet be clear as to the status of the lignite-producing industry in relation to that of higher-grade coals, the rapid increase in its development within the last three years in North Dakota is indicative of its great importance in that region. Situated as the State is, remote from bituminous coal fields and with no local fuel supply, other than a very limited and rapidly disappearing quantity of timber, besides the vast deposits of lignite, it is important that attention should be intelligently directed to the latter resource.

With the active interest that is certain to follow the geologist's study of the question will come improvements in the crude methods of mining, and experimental investigations into the mechanical difficulties besetting the preparation of the product for fuel purposes, and the people will become better educated in the methods of using lignite. With this should come also a decrease in the cost of production, and a larger volume of trade should justify lower freight rates, so that the lignite may, even in the eastern part of the State, compete with eastern coal.

Doctor Wilder has concisely pointed out the far-reaching significance of this resource to the State. He touches upon its possibilities as an aid to the rapid settlement of unoccupied lands, and of its relations to diversified manufacturing interests, the clay industries, municipal improvements, and irrigation.

COAL DEPOSITS BETWEEN SILVER PEAK AND CANDELARIA, ESMERALDA COUNTY, NEV.

By J. E. Spurr.

The occurrence of coal within the desert region of Nevada, even if it is not of superior quality, is of great interest on account of the scarcity and high price of all fuel and other means of securing machine power here.

Location.—At the north end of the Silver Peak Range, in Esmeralda County, just south of the road between Silver Peak and Candelaria, coal beds occur in Tertiary sandstones, shales, and volcanic tuffs that contain fresh-water shells and Tertiary plants.

Geological conditions.—These sediments abut abruptly on the south, only a short distance from the road, against a massive cliff or scarp of rhyolite, itself also probably of Tertiary age. Between the rhyolite on the south and the sediments on the north there is probably a very heavy fault running in an east-west direction. The coal-bearing beds dip to the northeast at comparatively slight angles, but the dip increases as the fault is neared, and in the immediate vicinity of the fault the beds acquire a reversed dip and constitute a local anticline running parallel to the line of displacement. The beds on the south limb of this fold sometimes have considerable dip. This phenomenon seems to be due to the dragging down of the strata along the fault. It is believed that the downthrow has occurred on the south side, and that the present greater height of the rhyolite on the south is due to its superior hardness, the soft sandstones and shales having been worn away relatively more rapidly. In support of this belief the downdragging of the beds near the fault just described may be appealed to, together with the fact that several minor faults near the main fault were found to have a downthrow to the south. Also it seems probable that the rhyolites on the south side represent a higher horizon in the Tertiary than the beds on the north.

Description of the coal.—The coal in this district is said to have been discovered by William Grozenger, of Candelaria, in 1893, and the outcrops of the seams are now continuously located. The chief seams are four in number. Some of them extend for a distance of 3,000 to 4,000 feet in outcrop in a northwest-southeast direction. Mr. Grozenger, who is very familiar with the district, has classified the seams, counting from the top, as the first, second, third, and fourth. The perpendicular distance between the first and the second seam is estimated by him to be 150 feet; between the second and third, 70 feet, and between the third and fourth, 130 feet. The uppermost seam, No. 1, seems to be relatively poor and small, and, as exposed in outcrop, of little value. No. 2 seam is in coal shale and is several feet thick. Openings on this seam show the coal to be thin bedded and to occur in connection with beds of rhyolitic tuff. There is a good deal of slate parting or bone present. No. 3 is also in coal shale and is of better quality and thicker than No. 2. No. 4 lies close to the fault, is in sandstone, and shows 6 to 8 feet of coal of much better quality than the upper seams. Some of this coal has a brilliant luster, while the coal of the other seams is of a dull color. It has been opened up in only one place, where it is overturned and dips against the fault. Here the lower 2½ feet is cleaner coal than the rest. It is used as a forge coal by Mr. Grozenger and affords a coke. Analysis by Mr. George Steiger, of the United States Geological Survey, of a general sample taken from a picked block 8 inches thick, is as follows:

Analysis of coal from Esmeralda County, Nev.

	Per cent.
Moisture	0.94
Volatile matter	37.35
Fixed carbon	42.63
Ash	19.08
Total	100.00

Coke good.

This analysis was made after the sample had been lying exposed to the air about six months. The amount of moisture given is therefore probably less than when the coal was taken from the mine. The important fact that the coal does not slack on exposure was, however, determined by this experiment. The analysis shows a light, bituminous coal, somewhat poorer than the Colorado bituminous coal, and, except for the larger amount of ash, comparable with some of the high-class Pennsylvania coals. It is a fairly good steaming coal and an excellent gas coal.

An analysis of coal from the Elder-Morgan prospect, taken from unpublished manuscript of Mr. H. W. Turner, of the Geological Survey, is as follows:[a]

Analysis of coal from Elder-Morgan mine, Esmeralda County, Nev.

	Per cent.
Moisture	3.53
Volatile combustible material	31.71
Fixed carbon	35.95
Ash	28.81
Total	100.00
Sulphur	1.05

This analysis, according to the writer's best information, seems to be of coal from seam No. 2.

Outlook for development.—These prospects have been bonded several times, the last time by the Tonopah Mining Company. The chief prospecting has been done on the upper seams. The coal as developed is of so light a nature and contains so large a proportion of ash that the enterprise has always been abandoned. It seems, however, that the lowest seam (No. 4), whose outcrop is limited and broken near the fault, but whose underground extent must be great, has been neglected in prospecting, and possibly this may be found to be available as fuel. Inasmuch as the beds underlying this seam are not exposed, on account of the fault, it is possible that still other seams may occur beneath it. All these seams of coal must extend a considerable distance to the north with the dip of the strata, and a considerable supply is thus indicated.

Similar Tertiary strata exist in the Monte Cristo Mountains to the north, in the same general line with the Silver Peak Range. These mountains have not been explored by geologists, but prospectors have located coal seams in them and brought away specimens, some of which are dull and evidently full of ash, while some are brilliant looking, light, bituminous coals, allied to lignite, and are claimed to be good coking coals. It is reported that the seams in these mountains are considerably broken by faulting. Within the field at the north end of the Silver Peak Range, just described, there has also been probably a moderate amount of faulting, which would complicate any possible future work. It is possible that the failure to trace the known coal seams along their strike any farther than has been done is due to the action of northeast faults.

Probable value.—In conclusion it may be reiterated that these coals in general are undoubtedly light and of poor quality. Nevertheless, a poor fuel may be better than none in a region like this, where there is very little wood supply, no water power, and where transportation

[a] Dr. W. F. Hillebrand, of the U. S. Geological Survey, who made this analysis, notes that the coke is coherent, but not much swelled.

is very expensive. If a sufficient supply of the brilliant, light, bituminous coal could be developed, it would probably be directly available for fuel. All these coals contain a large percentage of volatile matter, and the gas which they contain might be separated and profitably used for fuel.

The incoming of large mining enterprises into the region should give impetus to a careful and well-considered study of the utilization of this important natural source of energy.

COAL FIELDS OF THE WHITE MOUNTAIN REGION, NEW MEXICO.

By Cassius A. Fisher.

The coal fields of the White Mountain district occupy the highlands lying east and south of Sierra Blanca Peak, in the west-central part of Lincoln County, N. Mex., on the headwaters of the Rio Hondo. The area in which exposures are found is from 4 to 5 miles wide and extends from southwest to northeast, toward El Capitan Mountain. It is in a region of high, rocky hills, traversed by deep, relatively narrow, flat-bottomed valleys. Altitudes range from 7,500 to 9,000 feet. Coal occurs in somewhat metamorphosed deposits, comprising alternating beds of limestone, sandstone, and shale, traversed by innumerable dikes of dark, igneous rocks 6 to 30 feet in width. These dikes extend in various directions, but generally radiate outward from the main uplift. In some localities the dikes are of such frequent occurrence as to form a complicated network. Throughout the entire region the beds have been considerably distorted, and in many places there are indications of faulting. Further evidence of the strain to which the strata of the region have been subjected is seen in the numerous shearing planes which have been developed in the coal, causing it to have a loose texture and to be easily broken.

There are at least two coal horizons, and possibly more, separated by a considerable thickness of sandstones and shales. The lowest deposit occurs in a series of dark-green shales and sandstones of undetermined thickness and is itself about 2½ feet thick. In appearance it is black, with bright, shiny luster and even texture, but the body of the coal is characterized by a lack of firmness. Another layer of about the same thickness occurs considerably higher in the series. No material difference was noted in the quality of the coal of these two horizons, both being greatly shattered and offering slight resistance to weathering. The coal is bituminous and burns freely, but leaves considerable clinker in the ash.

The region as a whole is not promising. The coal is only of medium quality, the quantity is not great, and the conditions for development are extremely unfavorable. In working either of the above-mentioned horizons dikes penetrating the coal deposits would be encountered at frequent intervals, and there are minor folds which probably would often render the bed too irregular for profitable working. Usually where an igneous dike has penetrated a coal bed in this general region (as is illustrated at the Capitan mines) the material on either side of the dike for a distance of 15 feet or more is converted into a so-called coke or slag, which is noncombustible. In mining such a deposit it is necessary to drive the tunnel through unproductive material for a distance of 40 or 50 feet, the distance dependent on the size of the dike, which materially increases the cost of the operation. The outcrops of the above-described deposits occur high in the hillsides and in rather inaccessible places. This district probably will furnish a small amount of coal to supply local demand, but, owing to the distorted and broken condition of the strata in which the coal occurs and the presence of innumerable dikes which cut the deposits at various angles, the field can not be regarded as one deserving of extensive development.

At Capitan, N. Mex., there are coal fields in which coal is mined to some extent, but with great difficulty, owing to the broken condition of the strata. Here, however, the beds are relatively uniform in structure and contain but few dikes as compared with the White Mountain region.

THE BARNESBORO-PATTON COAL FIELD OF CENTRAL PENNSYLVANIA.

By John Shober Burrows.

INTRODUCTION.

Within the past ten to fifteen years an important coal field has been developed in the northern part of Cambria County, Pa. This field has had a phenomenal growth, due to the quality of the coal, to the transportation service afforded by the Pennsylvania Railroad on the south and the New York Central Railroad on the north, and to the scarcity of fuel caused by the great anthracite strike of 1902.

The last-mentioned condition has probably been the most potent, and within the past two years more new mines have been opened than during any similar period in the history of the field. Not only have mines been opened in all parts of the field, but the coal lands of the surrounding region have been bought up by operators and speculators, and numerous branch railroads have been built. Development has extended to most of the territory in which the coal beds show in natural outcrop, and active preparations are being made to reach the coal in the deeper parts of the basins.

Location.—The Barnesboro-Patton coal field covers an area of about 80 square miles in the northwest corner of Cambria County. The most important operations are in the vicinity of the towns of Barnesboro, Spangler, Bakerton, Carrolltown, Hastings, and Patton. The New York Central and the Pennsylvania railroads run to all of these towns, the New York Central coming from the north by way of Patton and Cherrytree, and the Pennsylvania entering the field from the south, where it connects with the main line at Cresson, about 25 miles distant. The recent extension of the Pennsylvania line from Cherrytree west into Indiana County has caused much activity among the operators of this part of the field in pushing the limit of development well over the county line, and already mines are being opened at Pleasant Valley and Possum Glory, 9 and 7 miles, respectively, west of Barnesboro. This new addition promises to be the most important part of the Barnesboro-Patton field, as the coal is reported to be superior to any coal heretofore mined in the region.

GENERAL GEOLOGY.

Stratigraphy.—The rocks exposed at the surface of this field are all of Carboniferous age (Pennsylvanian series) and belong to three formations, Pottsville, Allegheny, and Conemaugh. In this district the only exposure of Pottsville sandstone, which is the lowest of the formations, occurs at Thomas Mill, about 2 miles north of Patton on Chest Creek, where it is shown in the wagon road 50 feet above railroad grade. Immediately above it the "A" coal outcrops in the road. Just above the Pottsville formation occurs the Allegheny, which is the coal-bearing formation.

The coal beds of this region were named by early workers in the the field, "A," "B," "C," etc., extending from coal "A" at the base to coal "E" at the top of the Allegheny formation. Later the geologists of the second survey of the State correlated these beds with those of the type locality in the Allegheny Valley. This correlation has not definitely been established, but as commonly used the terms for the workable beds are as follows: "E"=Upper Freeport; "D"=Lower Freeport; "C′"=Upper Kittanning; "B"=Lower Kittanning.

The rocks of this region are so similar in composition that it is extremely difficult to use them in tracing and correlating the coal beds. The Mahoning sandstone, which normally closely overlies the Upper Freeport coal, is well developed about Patton, where it caps the hills and makes well-defined dip slopes, but over the major part of the territory it is inconspicuous and probably is absent in many localities. The most conspicuous sandstone of the region lies from 200 to 250 feet above the Upper Freeport coal. This seems to correspond with the heavy cliff-making sandstone along the Conemaugh River below Blairsville, which was named by Stevenson[a] the Saltsburg sandstone. This bed is particularly prominent on the plateau about Nicktown, on the ridge about Plattsville, and in the syncline west of Cherrytree.

Structure.—The Barnesboro-Patton field occupies a roughly ellipsoidal area, with its major diameter at right angles to the great structural features of the region. As a consequence of this fact the coal beds vary greatly in altitude in different parts of the field, and the dips are in directions depending on the relation of the point of observation to the structural features of the region. Thus the "D" or Lower Freeport coal, which is the most extensively developed bed in the field, rises from an altitude of about 1,800 feet at Patton to 2,050 feet near Carrolltown, on the crest of the Laurel Hill anticline. From this axis the coal bed descends to the northwest, reaching an altitude of 1,500 feet in the center of the syncline at Barnesboro. Beyond the axis of this basin the coal rises slightly to an altitude of

[a] Stevenson, J. J., Report of progress in the Fayette and Westmoreland district of the bituminous coal fields of western Pennsylvania: Second Geol. Survey of Pennsylvania, Rept., K^3, 1878, p. 22.

about 1,600 feet on the Nolo anticline, a little west of Garmans Mills. Northwest of this anticline the coal dips rapidly into the great synclinal basin lying between Nolo and Chestnut Ridge anticlines. The dip is so steep that the coal passes below water level on the west branch of the Susquehanna, about 1 mile above Cherrytree, and in much of the basin to the northwest it is revealed only by the diamond drill.

COALS.

UPPER FREEPORT OR "E" COAL.

The Upper Freeport coal is not very extensively worked except in the vicinity of Barnesboro, where it outcrops in most of the ravines at an altitude of about 1,550 feet. This coal has a columnar structure, is rather hard, shows a bright fracture, and is generally free from sulphur and iron nodules.

Thickness of the coal.—The bed is from 39 to 44 inches thick. It carries some partings of slate and bone of variable thickness and persistence, and is everywhere, so far as known, underlain by 4 to 6 inches of coal. This lower stratum is separated from the main bed by about 8 inches of shale that changes very much in character in different parts of the field, and is replaced entirely in some localities by fire clay and lentils of bone. The lower coal is not worked. The following sections, taken from different mines on this seam, show more definitely its bedding:

Sections of Upper Freeport coal in the vicinity of Barnesboro, Pa.

No. 1.

	Ft.	In.
Shale roof.		
Coal	1	0
Binder	0	2
Coal	3	8
Shale	0	8
Coal	0	4
Fire-clay floor.		
Total	5	10

No. 2.

	Ft.	In.
Shale roof.		
Coal	2	8
Binder	0	1½
Coal	1	0
Fire clay	0	5
Coal, bony	0	4
Fire-clay floor.		
Total	4	6½

No. 3.

	Ft.	In.
Shale roof.		
Coal	3	0
Shale	0	5
Coal	0	5
Fire-clay floor.		
Total	3	10

No. 4.

	Ft.	In.
Shale roof.		
Coal	2	8
Binder	0	1½
Coal	0	10
Coal, bony	0	8
Fire-clay floor.		
Total	4	3½

Few clay veins have been encountered in this bed, which generally seems to be free from the irregularities that affect the lower coals.

Quality of the coal.—In order to determine the quality of the coal, a sample was obtained from one of the mines near Barnesboro by making a cut entirely across the bed of coal at one of the working faces, exclusive of the partings. According to Dr. Eugene C. Sullivan, of the United States Geological Survey, the composition of the coal is as follows:

Analysis of Upper Freeport coal from near Barnesboro, Pa.

	Per cent.
Moisture	0.70
Volatile hydrocarbons	25.06
Fixed carbon	61.72
Ash	12.52
Sulphur	2.84
Coke	Much swollen, very porous.

The noticeable feature of the above analysis is that the percentage of ash is unusually high for coals of this field. Since the coal is reported as giving excellent results under the boiler, it seems possible that the sample analyzed contains a larger amount of earthy matter than is generally present in this coal.

MINES.

The mines actively working Upper Freeport coal are: Lancashire Nos. 9 and 10, operated by Barnes & Tucker; Allport mine of the Allport Coal Company; Walnut Run Coal Company's mine No. 1; Manion mine of the Maderia Hill Coal Mining Company, and Cymbria mine of Cymbria Coal Company. The Rich Hill Coal Company is also preparing to open up this coal at Hastings.

Lancashire mines Nos. 9 and 10.—These are the only mines on this bed having independent equipment. They lie on opposite sides of

Porter Run, about one-half mile north of Barnesboro. Mine No. 9, on the north side of the ravine, was opened in 1902, but was not very extensively worked until the summer of 1903, when No. 10, on the south bank of Porter Run, was opened. A tipple with tramways graded to handle the loads by gravity from the drift mouth of No. 9 and from the two openings on No. 10 was then erected and electric haulage installed. Cars are gathered by motor and the coal is cut by machine.

Usually in this district the coal from the Upper Freeport bed is loaded into the same car as the coal from the Lower Freeport, and the consumer has no means of knowing from which bed the coal is obtained. In the present case, however, the coal is shipped independently of that from the lower bed.

Allport mine.—This mine is properly on the "D," or Lower Freeport coal, and will be more fully described under that head. The present "E" mine originally was a country bank, and after the lower coal had been opened an inside plane was run up to the "E," the interval between the beds at this point being 40 feet. The empties are drawn up the plane by the loads coming down; the coal is all mined by hand, but not much work is being done on this bed at present, the company devoting its energies to the lower bed.

Walnut Run No. 1.—The Walnut Run Coal Company also is working both seams. This mine is about 1½ miles east of Barnesboro. The Upper Freeport here lies 38 feet above the lower bed and about 60 feet above the railroad. The entrance, which is some distance west of the tipple, is reached by a tramway running around the face of the hill. The grade of this road is about 4 per cent, and mules are the only means of haulage in both mines. The mine on the "E" coal has been opened very recently, but, considering that the coal is all mined by hand, a very good daily tonnage is maintained. Ventilation is by furnace.

Cymbria mine.—This is one of the oldest in the field, having been opened in 1892. It is located a short distance east of Walnut Run mine, and mining is carried on in both the "D" and "E" beds. Until the summer of 1903 the coal from the upper mine was brought down to the tipple over a plane, the upper opening being directly over the lower, but now an opening has been made farther to the east and the coal is all brought to the tipple over a well-constructed electric road which is able to accommodate more cars than the old plane. At present the coal is being mined by hand, but electric machines are very soon to be installed and the furnace to be replaced by a fan.

Manion mine.—This mine is located on the north side of Walnut Run, nearly opposite Cymbria and about 2 miles from Barnesboro. At present the owners are paying little attention to the upper coal, apparently holding it in reserve. The ventilation of the mine is by furnace, the haulage by mules, and all mining is done by hand. The coal shows a thickness of 3½ feet and lies 40 feet above the lower bed.

Rich Hill mine.—The Upper Freeport coal passes below the surface at the Manion mine, but it reappears to the east near Hastings, where the Rich Hill Coal Company has recently opened a mine on it. The development has not gone far enough to demonstrate the presence of a large body of workable coal in this bed in the Hastings region.

Many of the companies in various parts of the field report this coal as being of workable thickness on their property and are holding it in reserve, as it is estimated that the Lower Freeport coal will be exhausted before many years.

LOWER FREEPORT OR "D" COAL.

This is regarded as the equivalent of the famous Moshannon bed of Clearfield County, and it is the most widely known and extensively developed coal in the field. It underlies a large area and probably it is best developed in the vicinity of Barnesboro and Spangler, where it is fast becoming exhausted.

A characteristic feature of this coal is a very persistent binder of shale, ranging from 1 to 3 inches in thickness and occurring from 8 to 12 inches above the bottom of the bed. This has caused erroneous correlation by the miners, for both higher and lower coals carry similar partings over large areas. Aside from the binder the bed presents much the same appearance as the Upper Freeport, possessing about the same hardness and fracture, but the columnar structure is probably more sharply defined than in any of the other beds.

Thickness of the coal.—The normal thickness of this bed, based on averaging a great number of measurements from all over the field, is 47½ inches, or nearly 4 feet. The greatest measure, 61 inches, was obtained in the center of the basin near Barnesboro. The smallest natural thickness reported is 37½ inches. The following sections from various parts of the field show the slight variations in this coal:

Section of Lower Freeport coal at Hastings.

	Ft.	In.
Shale roof.		
Coal	4	0
Binder	0	1
Coal	1	0
Fire-clay floor.		
Total	5	1

Section of Lower Freeport coal at Barnesboro.

	Ft.	In.
Shale roof.		
Bone	0	2
Coal	4	2
Binder	0	1¼
Coal	0	10
Fire-clay floor.		
Total	5	3¼

Section of Lower Freeport coal near disturbed zone at Barnesboro.

	Ft.	In.
Sandstone roof.		
Bone	0	8
Slate	0	6
Coal	3	4
Binder	0	2
Coal	0	8
Limestone.		
Total	5	4

Section of Lower Freeport coal at Carrolltown.

	Ft.	In.
Shale roof.		
Coal	3	0
Binder	0	2
Coal	0	10
Fire-clay floor.		
Total	4	0

Clay veins are a great source of trouble in this bed, and in places they are so large as to make the working of the coal unprofitable. The majority, however, are not more than 14 to 20 inches in thickness and are cut through in the regular course of the work. Scarcely a mine in the entire field is free from them. Besides clay veins, some of the mines are greatly troubled with "roof rolls" (unconformity of roof and coal), and along the west branch of Susquehanna River, between Barnesboro and a point south of Spangler, there exists a zone of disturbance that appears to be caused by a fold running about S. 20° E. This disturbance is accompanied by local thinning and crushing of the coal, which has given considerable trouble in the West Branch, Susquehanna No. 1, and Gussie mines. Disturbance in the intervening area is plainly shown by diamond drill records, but its extent is not accurately known.

Quality of the coal.—The Lower Freeport coal carries a large amount of sulphur in the form of "knife blades" and iron nodules in many parts of the region. Impurities seem to decrease west of Barnesboro and the coal becomes suitable for coking. The coal of the Greenwich mines near Garmans Mills is shipped to the Maryland Steel Company at Sparrows Point, Md., where it is coked in by-product ovens with excellent results. Three reported analyses of the coal from these mines show the following composition:

Analyses of the Lower Freeport coal from near Garmans Mills, Pa.

	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	(a)	(a)	(a)
Volatile combustible matter	25.34	26.48	26.86
Fixed carbon	65.81	65.84	67.88
Ash	8.85	7.68	5.26
Sulphur	.80	.71	.64
Phosphorous	.008	.005	.003

a Not determined.

Following is a comparison of the average of 10 determinations of coal from the Greenwich mines and an average analysis of the Connellsville coal furnished by the H. C. Frick Coke Company.

Comparative analyses of Connellsville and Lower Freeport coals.

	Connellsville coal, H. C. Frick Coke Co.	Lower Freeport coal, Greenwich mines.
	Per cent.	*Per cent.*
Moisture	1.130	([a])
Volatile combustible matter	29.812	25.099
Fixed carbon	60.420	66.300
Ash	7.949	7.757
Sulphur	.689	.840
Phosphorus	([a])	.004
	100.000	100.000

[a] Not determined.

No moisture determinations were made of the Lower Freeport coal in these analyses, but a number of others show the moisture to be much less than 1 per cent.

The approximate ratio of volatile hydrocarbons to fixed carbon of both coals is, Connellsville 1:2; Lower Freeport 5:13; that is, the Connellsville coal contains about twice as much fixed carbon as volatile hydrocarbons and the Lower Freeport between two and three times as much. This is the only locality in the field from which coal has been taken for the manufacture of metallurgical coke in by-product ovens.

As previously mentioned the quality of the coal appears to improve near the western margin of the field as at present determined. Recently a private analysis of a drill core from a point still farther west is reported as showing a much smaller percentage of ash and a ratio of volatile hydrocarbons to fixed carbon equal to that of the Connellsville coal.

MINES.

There are about 40 mines in this field working the Lower Freeport coal on a commercial scale, and as they all employ similar methods and equipment a description of the several centers of activity will suffice.

At Hastings the largest mine as well as the oldest in the field, having been operated since 1887, is Pennsylvania No. 20, formerly Sterling No. 8, operated by the Pennsylvania Coal and Coke Company. The main heading of this mine extends down the dip for more than 2 miles, and haulage for nearly its entire length is by rope. Mules gather the cars from the headings, and with this system one of the largest daily outputs of the field is maintained. The coal is undercut by machine and the mine is ventilated by fan. At Mitchell's mines, three-fourths of a mile south of Hastings, the Lower Freeport was opened in 1892. This mine, which is about 100 feet above railroad level, has a complete electric equipment, comprising machines for mining the coal and motors for inside haulage. The coal is lowered to the tipple on a plane, the weight of the loads pulling the empties up. Ventilation is maintained by fan. After the coal reaches the tipple, it is charged together with Lower Kittanning or "B" coal into beehive ovens, and the resultant coke, although it lacks the beautiful cellular structure of Connellsville coke, possesses fair hardness of body. The mines and coke plant are owned and operated by the Pennsylvania Coal and Coke Company.

Van Dusen & Cosgrove operate the Oak Ridge mine, which is situated just south of Hastings. This mine has been worked since 1888. It is equipped with rope haulage and compressed-air mining machines, and most of the product of the mine is converted into coke.

The Rich Hill Coal Company opened a mine on the Lower Freeport coal in this vicinity in 1891. It is a small operation and has none of the modern mechanical equipments.

At Bakerton the Sterling Coal Company has two mines, Nos. 2 and 4, on the Lower Freeport coal. Mine No. 2 was opened in 1903. It is equipped with electric haulage and fan ventilation, but at present the mining is done by hand. The output is small, but probably this will be greatly increased in the near future. Mine No. 4, which is operated in conjunction with Nos. 3 and 5, on the Lower Kittanning or "B" bed, is inadequately equipped, and as considerable trouble is experienced from water in the forward end of the mine it is only intermittently worked.

Two miles northeast of Bakerton, in the vicinity of Carrolltown, on the New York Central Railroad, are two very large mines, operated by Peale, Peacock & Kerr, namely, Victor No. 2 and Victor No. 3, formerly known as Brauley and Snyder, respectively. The coal from these mines is hauled to the tipple by electric motor, and the same power is applied in cutting the coal, with excellent results. The mines were opened in 1901, and are ventilated by fan.

One of the greatest centers of activity in the region is on Walnut Run just east of Barnesboro. The easternmost mine in the valley is Manion, which is operated by the Maderia Hill Coal Mining Company. This mine was opened in 1900, and both Upper and Lower Freeport coals are worked. The plant is equipped with fan ventilation, rope haulage, and compressed-air mining machines. No effort is made to keep the coal from each bed separate, and it is mixed indiscriminately for the market. Farther down the run is the Cymbria mine with its very complete equipment of electric coal cutters, haulage, and fan, in addition to which there is a complete sawmill and car shop, making this mine practically independent. In immediate proximity is Walnut Run No. 1. The method of working here is the same as used for the upper bed, described on page 299. The Allport mine, nearly opposite Walnut Run No. 1, works both Freeport coal beds. It is hampered in working out its entire territory on the lower bed by a "fault" or thin section of the coal, the direction of which is about northeast and southwest, or parallel to the main heading. In this "fault" a bed of sandstone comes down on the coal, replacing the slate roof, and there is also directly over the coal about 10 inches of "niggerhead" that is not present elsewhere in the mine. Although this mine was opened in 1893, it still adheres to mule haulage, but the coal is cut by air machines and recently there has been installed a fan driven by steam. The output is far above the average for mines with mule haulage.

At the town of Barnesboro the extensive operations of Barnes & Tucker are rivaled only by the two large mines of the Clearfield Bituminous Coal Corporation. The former operate Juniata, and Lancashire Nos. 6, 7, 8, and 11, on the north side of the town, and Lancashire No. 3 on the south. The last-mentioned mine is the oldest of the group, having been one of the first opened at Barnesboro. The original rope-haulage system is still in use, and this is the only power used about the mine except for a steam pump, which is run almost constantly to keep down the water. Ventilation is by a large furnace. Lancashire No. 6 and Juniata are not regularly worked, but Nos. 7, 8, and 11 supply nearly all the coal shipped by this company. These mines are admirably planned and equipped. No. 8, at the head of Porter Run, is a slope mine. No. 11, about 100 yards below, connects with No. 8 as also does No. 7, the entrance to which is in the town. With the exception of steam supplied to a pump in No. 8 for raising the water up the slope, the only kind of power in these mines is electricity, electric motors being used for haulage, and electric chain machines for cutting the coal. In Nos. 7 and 11 there are electric pumps that run constantly, requiring little attention. Power is furnished by two independent plants, one at mine No. 8, and one at mine No. 7. These also supply the town with light and each is of sufficient capacity to do all of the work alone, although they are arranged to be thrown into the same circuit. The three mines are operated independently of each other, but the advantage of their connection is obvious, permitting, in case of accident or burning of a tipple, the hauling of all of the loads out of one opening, as well as quick and easy transportation for motors and machines to the very complete machine shop recently completed at No. 7.

West Branch and Empire mines are located in the immediate vicinity of Barnesboro, the former being located just south of town and the latter back of North Barnesboro. They were opened, respectively, in 1896 and 1897. A large percentage of the coal furnished by the

Clearfield Bituminous Coal Corporation to the New York Central Railroad for locomotive purposes comes from these mines, their combined daily output exceeding 1,500 tons. The similarity of arrangement and equipment of these mines shows a policy of uniformity characteristic of the large corporations that have but recently gained a strong foothold in this field. Both mines are tolerably free from water, they are ventilated by fan, have electric haulage, and cut their coal by air machines. The surface arrangements at the Empire are crowded, necessitating a sharp curve in the sidetrack, which prevents quick communication with the motor by signal and imposes a great strain on the cars. The West Branch mine has ample room for its railways and buildings and with the exception of the part in which the "fault" occurs, is symmetrically laid out, giving to the mine an air of permanence and safety that is lacking in many of the hastily developed mines of the district.

The only mining operations of note northwest of Barnesboro are in Punkey Hollow, where the Greenwich Coal and Coke Company have opened three mines since 1901. This company proceeded very cautiously at first, opening and working No. 1 in a most inexpensive manner. Finding that the quality of the coal warranted more elaborate methods, they opened two other mines, one in 1902, and the other in 1903, built a power house for compressing air to supply the cutters and erected steam fans at Nos. 2 and 3. They are now preparing to install electric haulage in Nos. 2 and 3, but contemplate no improvements in No. 1 as it is soon to be abandoned.

In the vicinity of Spangler a large amount of coal is being shipped from Summit, Victor No. 4, Gussie, Susquehanna No. 1, Maucher, and Eclipse mines. The first of these was opened in 1894 and is located in the town of Spangler, about 75 feet above and some distance back from the railroad. The coal comes down to the tipple over a plane crossing the county road. The inside hauling is done by mules and the mine is ventilated by furnace, as there is no power supply here. The mine is operated by the Maderia Hill Company. Victor No. 4, the most active of these mines, was opened in 1892, but recently it has passed into the hands of Peale, Peacock & Kerr. The coal is mined entirely without power. The section of the coal in this mine is somewhat abnormal, a thin bed of very clean cannel coal coming in on top of the main bed, from which it is separated by a shale parting varying from 6 to 8 inches in thickness. Where the cannel coal attains a thickness of 6 inches it is taken down and used locally for domestic purposes. Gussie and Susquehanna No. 1, the former operated by Spangler Coal and Coke Company and the latter by Derringer Brothers, lie just across the ravine from Victor No. 4, and extend back into the disturbed zone previously mentioned. They are greatly hampered by this "fault," frequently having to change the course of their headings and take out quantities of rock in order to preserve the grade of their haulage ways. Susquehanna No. 1 is worked on a very small scale and has a very primitive equipment. The Gussie mine still adheres to mule haulage, but it is ventilated by a fan and the coal is cut by air machines.

East of Spangler there are two mines on the Lower Freeport coal, the Eclipse mine, owned by the Clearfield Bituminous Coal Corporation, and the Maucher mine, owned by Peale, Peacock & Kerr. The former is located at the point of the long ridge on which is situated the new town of St. Benedict, and the latter just south of and a little below the Spangler and Barnesboro reservoir. Both of these mines were opened in 1900, and are worked by hand and have mule haulage. Maucher is ventilated by fan, the Eclipse mine by furnace.

Directly west of Spangler, in the ravine cut by Moss Creek, are located three new mines of the Pennsylvania Coal and Coke Company, on the Lower Freeport coal. Those on the west side of the creek are known as Nos. 1 and 2, and a smaller one, No. 3, on the east bank, extends to the property line of the West Branch mine. The entire plant and system is a model of completeness and efficiency. The buildings are substantial structures, the power house, containing dynamos of sufficient capacity for lighting and mine work, being built entirely of stone and steel. The tramways from the three mines lead to one tipple from which a part of the coal is conveyed to the bank of 180 beehive ovens for coking, the remainder being loaded on cars for the market. Electric chain machines are used for cutting, and electric pumps for freeing the mine of water. The coal is rather disappointing in thickness and quality, since it carries a number of bony partings besides the binder. Clay veins are tolerably abundant and there are also slight folds in Nos. 1 and 2. As might be expected, the coke produced here is ashy and dense, but is fairly hard and has a silvery lustre, coming from the ovens in pieces of about 2 to 2½ feet in length. Moss Creek marks the present western limit of the field and is one of the most recently developed localities, work here having begun in June, 1902.

UPPER KITTANNING OR "C′" COAL.

This coal bed, which lies from 50 to 90 feet below the Lower Freeport coal, is known to be of workable thickness only in the eastern part of this field. It was developed first at Hastings, but it is most extensively worked at the present time in the vicinity of Patton, where it has an average thickness of 55 inches.

Thickness of the coal.—The bed carries a number of shale partings near the bottom that interfere seriously with mining this part of the bed. The general practice is to cut above these partings, but this reduces the available coal to about 43 inches in thickness. Besides these shale partings, "knife blades" of sulphur are abundant, but generally the coal bed is free from clay veins and "faults."

The following sections show the general character of the coal:

Section of Upper Kittanning coal at Patton, Pa.

	Ft.	In.
Shale roof:		
Coal	4	0
Coal, including lenses of bone	1	10
Fire-clay floor.		
Total	5	10

Section of Upper Kittanning coal at Patton, Pa.

	Ft.	In.
Shale roof:		
Coal	4	2
Shale	0	4
Coal, dirty, not worked	1	6
Fire-clay floor.		
Total	6	0

Section of Upper Kittanning coal at Hastings, Pa.

	Ft.	In.
Shale roof:		
Coal	1	0
Shale	0	1½
Coal	3	10
Bone and coal, not worked	1	0
Fire-clay floor.		
Total	5	11½

Directly beneath the coal lies a fine bed of fire clay about 6 feet thick that makes good tile when worked up in a pure state and a good grade of buff brick when mixed with its own bulk of brown shale.

Quality of the coal.—Very little data are at hand to show the uses to which this coal is put. The Beech Creek Coal and Coke Company report it an excellent steam coal, but as it is not coked in this region its fitness for that purpose will have to be judged from its composition.

A sample about 2 inches wide and 1 inch thick was cut from roof to floor of a working face of the bed in the Beech Creek No. 3 mine at Patton. In sampling, all partings were excluded, and the following analysis was made by Mr. W. T. Schaller, of the United States Geological Survey:

Analysis of Upper Kittanning coal from Beech Creek Mine No. 3, Patton, Pa.

	Per cent.
Moisture	0.91
Volatile, combustible matter	23.74
Fixed carbon	67.55
Ash	7.80
Sulphur	1.38
Color of ash	White.

This analysis indicates a ratio of volatile hydrocarbons to fixed carbon of 8.34 : 23.74, or, in whole numbers, of nearly 1 : 3. Assuming that 40 per cent of the sulphur contained in this coal would be volatilized during the process of coking, this coal would yield theoretically 76.17 per cent coke. That is, it would take 1.24 tons of coal to yield 1 ton of coke. Mr. Schaller reports that in his laboratory tests of this coal "good coke" was obtained, but the practical coking qualities could be determined only by actual oven tests.

MINES.

The operations of the Beech Creek Coal and Coke Company in the vicinity of Patton are the most important on this bed. Mine No. 3, the largest and best arranged mine working the "C′" coal, was opened in 1893, during the early development here. It is ventilated by fan, has rope haulage, and the coal is cut by air machines. The Patton Clay Manufacturing Company also is operating a mine on this coal at Patton. To get the clay underlying the coal is the real object of the mine, but the coal is taken out first for use about the plant and in the kilns. The westernmost opening on this coal is at Hastings, where the Rich Hill Coal Mining Company has put down a slope to reach the coal where it does not show in outcrop. Very little work is being done at this mine, but rope haulage is being installed and a fan will be obtained. The coal here shows a maximum thickness of 58 inches.

LOWER KITTANNING OR "B" COAL.

This is the lowest bed worked in the field, being from 130 to 175 feet below the Lower Freeport coal. Its outcrop is confined to a limited area in the vicinity of Bakerton, where it is exposed near the bottom of the deeply cut ravines on the flank of the anticline. Extensive prospecting with the diamond drill has shown this coal to be present and probably of workable thickness throughout the entire field. This bed is regarded as one of the most valuable coals, but it has been considered too far below the surface to receive much attention until the higher beds are exhausted. The seam is very much broken up and separated by a number of partings of shale and fire clay, but these readily part from the coal in mining, and are picked out in loading the coal.

Thickness of the coal.—The average thickness of this bed is 38 inches, the thinnest measurement reported being 36 inches. Following are sections of this coal taken from the mines at Bakerton and near Elmora, a half mile south of Bakerton:

Section of Lower Kittanning coal at Bakerton, Pa.

	Ft.	In.
Sandstone and shale roof.		
Coal	3	0
Shale	0	3
Coal	0	8
Shale	0	4
Coal	1	3
Shale and fire-clay floor.		
Total	5	6

Lower Kittanning coal at Bakerton, Pa.

	Ft.	In.
Sandstone roof.		
Shale	1	2
Coal	3	2
Shale	0	5
Coal	0	5
Fire clay	0	4
Coal	1	2
Fire-clay floor.		
Total	6	8

Section of Lower Kittanning coal near Elmora, Pa.

	Ft.	In.
Sandstone roof.		
Coal	3	0
Shale	0	4
Coal	0	6
Shale	0	4
Coal	1	2
Total	5	4

Quality of the coal.—The Lower Kittanning coal is generally regarded as a very superior coal for steam purposes, and this opinion seems to be borne out by an analysis recently made in the chemical laboratory of the United States Geological Survey by Mr. W. T. Schaller. The sample from which this analysis was made was cut from a working face of Sterling No. 3 mine, at Bakerton, and is of the entire bed, exclusive of partings. This analysis shows the following composition:

Analysis of Lower Kittanning coal from Bakerton, Pa.

	Per cent.
Moisture	0.43
Volatile hydrocarbons	23.24
Fixed carbon	70.93
Ash	5.40
Sulphur	1.12
Color of ash	White.

The Lower Kittanning coal is coked only at Mitchell's mines, but as it is mixed with Lower Freeport coal, the results obtained there are of little value in determining its coking properties.

The above analysis indicates a ratio of volatile hydrocarbons to fixed carbon of 6.60:20.15, or 1:3 +, and a calculated coke value of 77 per cent. Theoretically, the charge required to produce 1 ton of coke would be 1.23 tons of coal. On comparing the composition of this coal with that of some of the standard coking coals, it is found that it contains 10 per cent more fixed carbon and 8 per cent less volatile hydrocarbons than Connellsville coal. It very nearly equals Broad Top and Pocahontas coals in fixed carbon, but contains a larger percentage of volatile hydrocarbons. In composition it probably is more like Broad Top coal than any of the other standard coking coals.

MINES.

The largest mines on this bed belong to the Sterling Coal Company, and, with the exception of one, are all in the immediate vicinity of Bakerton. No. 1, on the west side of the ravine, is one of the largest of the mines. It is ventilated by fan, has electric haulage, and the coal is mined by machines. Nos. 3 and 5, on Leslie Run, are very similar in plan and equipment, the coal being cut by machine and hauled by electric motor to the same tipple. Ventilation is by fan. The largest output of "B" coal in the field is being obtained at these mines. Mine No. 6 is located at Elmora, where electric haulage and machines have recently been installed. This mine is ventilated by fan. There is another small mine with mule haulage and furnace ventilation at Bakerton, known as Nant-Y-Glo No. 2, of the Nant-Y-Glo Coal Company. The only other mines on this bed are Logan No. 5, of the Logan Coal Company, located near Carrolltown Road, and the Pennsylvania Coal and Coke Company's slope mine at Mitchell's mines, near Hastings. Logan No. 5 was opened in the summer of 1903. The work is all done without power, ventilation being necessarily supplied by a furnace. In the slope mine at Mitchell's mines the coal is very irregular in thickness, varying from 12 to 30 inches, and there are a number of "roof rolls." The mine is ventilated by fan, and the cars are hauled up the slope to the tipple by steam. Mules are used for inside hauling, and the coal is mined by hand. As already stated, this coal is mixed with Lower Freeport coal and coked at the mine. Just east of Spangler, Peale, Peacock, and Kerr began a slope to reach the "B" bed during the latter part of the past summer, and intend to develop this coal very extensively, the coal showing a thickness of 3 feet 4 inches in this part of the field. This is the only mine of the "B" coal in the Barnesboro district and marks the western limit of its development.

THE ELDERS RIDGE COAL FIELD, PENNSYLVANIA.

By Ralph W. Stone.

GENERAL DESCRIPTION.

The Pittsburg coal seam underlies about 2,000 square miles in the southwestern part of Pennsylvania. In Greene and Washington counties it is deeply buried beneath the surface, but to the north and east the geologic structure is such that the coal is brought to a higher elevation, and shows hundreds of miles of outcrop along the border of the main field and in detached synclinal basins. The northernmost remnant of the Pittsburg coal is a small area which lies to the northeast of the main body of the coal and is separated from it by the valley of Kiskiminitas River. The field on the north side of the river lies along the Armstrong-Indiana county line and terminates in the valley of Crooked Creek. This detached portion of the great Pittsburg coal field takes its name from the village of Elders Ridge, which is situated near the middle of the area.

Extent.—Geographically the limits of the Elders Ridge coal field are clearly defined. It is bounded on the north by Gobbler Run, on the east by Blackleg Creek, on the south by Kiskiminitas River, and on the west by Long Run. It is about 9 miles long and 2½ miles wide, with the long axis in a northeast-southwest direction. This belt of coal is divided transversely into three large blocks by the valleys of Whiskey Run and Big Run, which have cut through the horizon of the coal and expose long lines of outcrop on both sides of the streams. The middle one of these three blocks, which lies between Olivet and Clarksburg, is the largest, and the northernmost is the smallest. All three have irregular outlines. There are a number of outliers of a few acres in extent on the northern and western sides of the field. Roughly estimated, there are about 14 square miles of coal in this area, or between 8,500 and 9,000 acres. Over probably 600 to 700 acres the coal has been mined out. The thickness of the bed will average close to 7 feet.

Structure.—This coal field lies in a structural basin known as the Elders Ridge syncline. The position of the axis is shown on the accompanying sketch map (fig. 8). It crosses the river above Edri, passes close to the Foster mine (No. 12), a few rods east of the Robert Fritz bank (No. 8), and through Elders Ridge near the academy. It enters the northern block between the W. B. Davis and John D. Hart heirs' banks (No. 6), passes west of West Lebanon, and leaves the field near Holsten Brothers bank (No. 1). The beginning of the sharp deflection to the east, which takes the axis to Crooked Creek, nearly 2 miles east of Shelocta, is shown north of the coal banks on the Hugh Blakley (No. 2) and Madison Craig (No. 3) farms. All of the coal on the east side of this syncline rises toward Blacklegs Creek, and all on the west toward Long Run. The basin is deeper in the vicinity of Elders Ridge than at Edri or West Lebanon, so that the structural shape of the field is a broad canoe-like fold, with the rocks dipping from all sides toward the center. The dip is gentle, being just enough to aid the operations of the miner.

The profile of the axis of the basin is shown by the elevations of the Pittsburg coal above mean sea level. From the northeast to the southwest along the bottom of the syncline the elevations at six points are as follows:

Elevations of Pittsburg coal above sea level.

	Feet.
Holsten Brothers, No. 1	1,180
John D. Hart, No. 6	1,112
Elders Ridge, deep well near creamery	1,070
Robert Fritz, No. 8	1,022
Foster, No. 12	1,100
West side of Kiskiminitas River	1,150

This shows that the deepest part of the syncline lies between Elders Ridge and the point where the axis crosses Big Run. The axis rises slowly from Big Run to the northeast, but more rapidly from the Fritz farm to Foster, the coal rising in this direction about 60 feet in little more than a mile.

DEVELOPMENT.

It may be well here to define certain terms in common use. An opening is a small excavation which reveals the coal in place and the thickness of the bed. A coal bank is a small mine in which a few men, from 1 to 10, are employed, and in which the coal is mined and brought out to the scaffold without the use of machinery. A coal mine employs enough men to require a mine boss, probably uses machines for undercutting the coal, and hauls by means other than hand. Coalpit is a term applied without discrimination to openings, banks, and mines.

On the accompanying sketch map of the Elders Ridge coal field most of the points where a clean face of the Pittsburg coal may be seen are

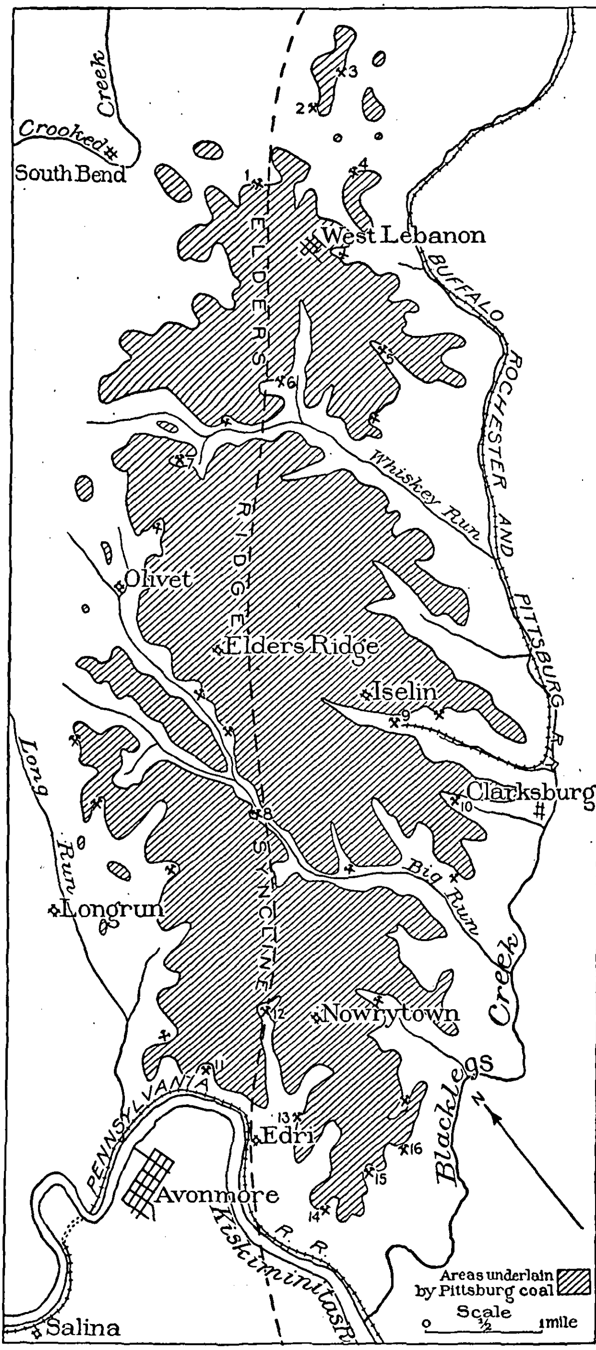

FIG. 8.—Map of the Elders Ridge coal field, Pennsylvania.

indicated by crossed hammers, the usual symbol for a mine or quarry.

Some of these are numbered, for ready reference in description, as follows:

List of properties where exposures of Pittsburg coal occur.

1. Holsten Bros.
2. Hugh Blakley.
3. Madison Craig.
4. Wilson Blakley.
5. Harry Hart.
6. John D. Hart.
7. Simon Townsend.
8. Robert Fritz.
9. Pittsburg Gas Coal Company.
10. Thomas Hart.
11. Avonmore.
12. Foster.
13. Edri.
14. Bowman.
15. Conemaugh.
16. Mrs. Arnold.

The figures in parentheses in the text refer to the same numbers on the sketch map.

A large number of openings have been made on the outcrop of the coal. Many of these were abandoned after a small quantity of coal had been taken out and have been closed for years. Other banks to the number of ten or twelve are kept open and are operated by one or two men throughout the greater part of the year. Among these country banks are those of Holsten Bros., Madison Craig, Wilson Blakley, John D. Hart, Harry Hart, Robert Fritz, Samuel White, McComb, Thomas Hart, and John Hart. These small banks supply fuel for only a narrow belt of farms, because the Upper Freeport coal is mined less than 2 miles west of this field on Roaring Run and on Crooked Creek below South Bend, and to the east not more than 3 miles from Blacklegs Creek both the Upper and Lower Freeport coals are mined.

Extensive mining has been done only near the river. Between forty and fifty years ago, when there was a canal along the river, a large mine was worked on the Rhea property, near Avonmore, but developments here terminated about 1865, when the Western Pennsylvania division of the Pennsylvania Railroad was built and the canal was abandoned. Coal mining on a large scale began again about fifteen years ago, and at present there are five or six mines which ship their output to distant markets by rail.

Three mines in which the Avonmore Coal and Coke Company have an interest had the following force and daily output December 1, 1903:

Output of mines of Avonmore Coal and Coke Company.

	Men.	Tons of 2,000 pounds.
Avonmore mine	150	500
Foster mine	70	250
Edri mine	50	200

Mr. L. W. Hicks, of Leechburg, is superintendent of this company and authority for the above statement.

The Avonmore mine (No. 11), which is operated by the Avonmore Coal and Coke Company, is situated at Hicksville on the bluff 350 feet above the river. The working faces are from one-half to three-fourths of a mile from the mine mouths. The cars are collected in the mine by mules and hauled out to the top of the bluff by cable; they are lowered to the tipple on the railroad by a double-track gravity incline. This mine has been working continuously since 1889.

The Foster mine (No. 12) is owned by the Saltsburg Coal Company and was reopened in the fall of 1903 after standing idle a number of years. The coal is hauled down the run and around the face of the river bluff to the tipple on the railroad by a narrow-gage steam locomotive. The management hopes soon to be producing 750 to 1,000 tons per day. At the Edri mine (No. 13), which is situated on the hill east of the station of that name, the cars are brought out by mules, and lowered about 200 feet to a tipple on a spur from the railroad. A double-track gravity incline is the method for lowering and raising cars. This mine is operated by the Edri Coal Company.

The Bowman Coal Mining Company, S. J. Robinson, superintendent, operates a mine (No. 14) near the southern extremity of the field on the hill about three-fourths of a mile south of Edri. The company employs from 40 to 60 men at this time and ships about 150 tons daily. Mules are used for hauling the coal from the breast out to the brow of the hill, where it is lowered by an incline to a railroad tipple.

The Conemaugh Coal Company, of Blairsville, Pa., F. M. Graff, superintendent, has opened within the past year a mine (No. 15) a half mile east of the Bowman Company mine. There were about 50 men on the pay roll December 1, 1903, and they were getting out about 3,000 tons per month. This mine has been opened so recently that development work is large and output small. A large tipple has been built over a railroad spur at the sheet-steel mill and cars are handled on the incline by steam power.

The Pittsburg Gas Coal Company is starting a new coal town on Harper Run, about 1½ miles south of Elders Ridge. This company began operations in the summer of 1903 by building a dam across the run, erecting power houses, and starting 6 headings on the coal. Three of these headings are on the east side of the run and have natural drainage. The other 3 on the west side of the run are down the dip of the rocks, so a heading is being run almost due west to Big Run to give natural drainage to all the workings in that part of the mine. Electric haulage and all modern improvements, both inside and outside, will be used at this mine.

The company expects to erect 350 to 400 houses on its town site, known as Iselin, and to employ between 2,500 and 3,000 men within two years. Fourteen houses are now built, and several hundred men are on the pay roll engaged in driving headings and on outside construction.

The Buffalo, Rochester and Pittsburg Railway is being extended from Creekside, Indiana County, to Iselin. A large part of the road bed is graded, and it is hoped that it will be hauling coal early in 1904. The company expects to be able to ship 400 to 500 tons of coal daily as soon as the railroad is completed, and to be producing from 5,000 to 7,000 tons daily by January, 1906.

THICKNESS OF THE COAL.

The Pittsburg coal bed in the Elders Ridge field is slaty and much parted in some places; in others it is clean and almost unbroken. It varies in thickness, including its partings and roof coal, from 7 to 10 feet. Generally the roof coal is not taken, being so much parted by thin bands of shale that it has little value. Moreover the shales over the roof coal are so soft and friable that the coal has to be left to support them. The bed has been opened at a great many places in this basin, but there are hardly more than twenty localities where accurate measurements of the seam can easily be made. A few measurements are given in detail to show the character of the seam.

Northern block.—That portion of the Elders Ridge field which lies east of Whiskey Run is the smallest of the three blocks into which the field is divided. The small outliers of a few acres in extent which are seen near West Lebanon are the most northern remnants of the great Pittsburg coal bed. Beyond this point the bed would be carried above the present surface by the rising axis of the Elders Ridge syncline, if projected beyond the outcrop.

Holsten Bros. own a coal bank (No. 1) about two-thirds of a mile north of West Lebanon, which was opened many years ago but has been worked actively only during the past two years. The coal dips southeast and is practically free from partings and horsebacks. The section is as follows:

Section at Holsten Bros. coal bank.

	Ft.	In.
Coal	2	2
Shale and coal	0	4
Coal	2	5
Shale	0	½
Coal	2	2
Total	7	1½

Wilson Blakley owns a bank (No. 4) in a small outlier of the coal, a short distance east of West Lebanon, which is being worked by H. L. Dillinger. The coal in this bank shows the following thickness:

Section at Wilson Blakley coal bank.

	Ft.	In.
Coal	1	8
Shale	0	11
Coal	3	11
Shale	0	1
Coal (seen)	1	3
Total	7	10

In the fall of 1903 this bank was delivering 2,500 bushels a month to the steam shovels working on the B. R. and P. Railroad cut near Parkwood, and the Madison Craig bank (No. 2) was working on a similar order.

These northern banks in the Elders Ridge field furnish a large part of the local supply in the Crooked Creek Valley. Being compact and hard, the Pittsburg coal comes out of the mine in firm blocks, which, in spite of their impurities, are preferred by the farmers for use in stoves and grates to the softer coal from the Upper Freeport seam as mined on Crooked Creek.

At the J. D. Hart bank (No. 6) on Whiskey Run, 1 mile southwest of West Lebanon, the entire thickness of the coal was not seen. Two bands of roof coal, 8 and 3 inches thick, are said to be above the draw slate and are not taken down. The main part of the seam comprises 5½ feet of good coal, with only two thin partings.

Partial section of J. D. Hart coal bank.

	Ft.	In.
Coal	1	8
Shale	0	½
Coal	1	8
Shale	0	1
Coal	2	1
Total	5	6½

The thickest section of Pittsburg coal measured by the writer is in this northern block on the farm of Thomas Campbell. Back of his house, which is 1½ miles south of West Lebanon, there is a small ravine in which the coal is well exposed and headings have been driven. The seam is in three benches, the middle one being nearly 5½ feet thick. The section is as follows:

Section on Thomas Campbell farm.

	Ft.	In.
Coal	1	10
Shale	0	11
Coal	5	5
Shale	0	9
Coal	1	3
Total	10	2

Middle block.—Under this heading is included all that portion of the field which lies between Big and Whiskey runs. Sections at all of the working banks can not be given, and four or five will be enough to show the variable characters of the bed.

Twenty-five years ago the local trade about Elders Ridge was supplied by a pit on the H. Ewing farm. This coal pit was a short distance east of the Simon Townsend bank (No. 7). Here the bed is at its thickest, and the following detailed section was measured by the second geological survey of Pennsylvania:

Section at the Ewing coal bank.

	Ft.	In.
Roof division:		
Slate and coal	2	0
Coal	0	7
Slate	0	1
Coal	0	2
Slate and clay, main parting	0	10
Coal	1	6
Slate	0	1
Coal, slaty	0	10
Slate	0	1
Coal	1	3
Slate, 4 inches to	1	6
Coal	1	6
Slate, ½ inch to	0	3½
Coal	1	8
Slate	.	...
Total	12	4½

The seam shows more slate partings than is usual, and the coal in the different benches is said to be slaty and poor. This much-parted condition of the seam may be local, however.

The Pittsburg coal is mined on Harper Run by John Hart. A section obtained there shows all of the bed except perhaps a thin layer in the roof shales. The following measurement was made:

Section at John Hart coal bank.

	Ft.	In.
Coal	0	10
Shale	1	0
Coal	4	0
Shale	0	1
Coal	1	2
Shale	0	6
Coal	1	8
Total	9	3

At the new mine of the Pittsburg Gas Coal Company a measurement was made in heading No. 2. This mine is just across the run from the bank mentioned above, but shows fewer partings. The section is:

Section at Pittsburg Gas Coal Company mine.

	Ft.	In.
Coal	6	6
Shale	0	6
Coal	2	0
Total	9	0

The bottom bench, which runs from 20 inches to 2 feet thick, is not being taken out at present. The great thickness of the main bench of coal promises well for the mine if the visible conditions continue. It is overlain by a draw slate which varies from 6 to 12 inches in thickness, but whether there is more coal above this or not has not been ascertained.

Mr. Thomas Hart is operating a bank (No. 10) on a small run near Clarksburg to supply local trade. The main bench of coal is 4 feet 10 inches thick, with one shale parting less than an inch thick a little above the middle. The roof coal was not seen, but it is separated from the main bench by 10 inches of shale.

At the southern end of the middle block of coal in this field there is an opening on the James Crawford heirs' farm, which has not been worked for some time, but which was still accessible when seen in 1902. It showed a good body of coal in two benches, but not so thick as in an old opening on the Samuel Gailey farm, a mile farther up Big Run. The sections in these two banks are as follows:

Sections on Crawford and Gailey farms.

	Crawford.		Gailey.	
	Ft.	*In.*	*Ft.*	*In.*
Coal	1	8	2	7
Shale	1	0	0	10
Coal	5	4	5	0
Total	8	0	8	5

A detached area of coal containing about 200 acres and lying between the forks of Big Run on the west side of the syncline has been prospected a little, but is not being mined at the present time.

Southern block.—The southern block of the coal field is very irregular in shape. It lies between Big Run and Kiskiminitas River, and by reason of its position has been mined on its river side more than in any other part of the field. The variations in the thicknesses of coal benches and shale partings are much the same as already described in the northern and middle blocks.

At the northern extremity of the block on the C. J. Palmer farm there is an old pit which was open although not working when seen by the writer. The section at this point is fairly typical of all that portion of the field, and compares very closely with a measurement made at a bank about 1 mile southeast of Long Run, although the latter had a few inches more of coal at the point where the seam was measured. The section at the Palmer bank is as follows:

Section at Palmer coal bank.

	Ft.	In.
Coal	1	3
Shale	0	5
Coal	1	5
Shale	0	8
Coal	1	9
Shale	0	5
Coal	1	11
Total	7	10

Mr. Samuel White owns and operates for country trade a bank about a mile northeast of Long Run, and Robert Fritz has an opening (No. 8) on Big Run. Complete sections were not obtained at these points, but the bed is known to be over 6 feet thick.

The Avonmore mine (No. 11) is operating on the Pittsburg seam, where the average thickness of merchantable coal is over 6 feet. The usual thickness in this mine, exclusive of the roof coal, is as follows:

Partial section at Avonmore mine.

	Ft.	In.
Coal	2	11
Shale	0	1
Coal	3	8
Total	6	8

At the Foster mine (No. 12) the seam carries about the same amount of coal. The parting or "band slate" in all of these mines varies in thickness; near the river it seems usually to be only 1 or 2 inches thick, but increases in places to a foot or more. The total thickness of the bed in the Edri mine (No. 13) changes from 5 feet 9 inches to 8 feet in a few spots, where the parting thickens from 1½ inches to 3 feet.

In the Bowman mine (No. 14), at the southern end of the field, that part of the bed which is taken out is 80 inches high and contains only one noticeable parting. The section is as follows:

Partial section at Bowman mine.

	Ft.	In.
Coal	4	2
Shale	0	1½
Coal	2	5
Total	6	8½

The main bench, which is over 4 feet thick, contains a very thin streak of shale, but its exact position was not noted.

Two other mines, also on the southern lobe of this block, are the new one owned by the Conemaugh Coal Company (No. 15) and the mine on the Arnold farm (No. 16), which used to supply the American Sheet Steel Company mill at the mouth of Blacklegs Creek, but is now operated only for country trade. At the Conemaugh mine the parting or "band slate" is usually from 1 to 2 inches thick, but it thickens in places to 1 foot. The "draw slate," from 6 inches to 1 foot thick, is taken down in entry, but can be held in rooms. The total thickness of coal is practically the same as in other mines at this end of the field.

TONNAGE.

Allowing 1,560 tons to the acre for each foot, the Pittsburg seam, which averages 7 feet of workable coal in this field, contains 10,920 tons to the acre. There are probably 8,000 acres of merchantable coal remaining in the field, or 87,360,000 tons. If by most advantageous methods of working 70 per cent of this coal can be mined, the total product of the field as it now stands would be 61,152,000 tons.

QUALITY OF THE COAL.

In the following table nine analyses of the Pittsburg coal in the Elders Ridge field are given. Four of these, made by Mr. A. S. McCreath, were published by the second geological survey of Pennsylvania, in the reports of Armstrong and Indiana counties, in 1878. The other five are new, and, so far as is known, are published here for the first time.

The Avonmore analysis was furnished by the superintendent of the mine, and the method of sampling the coal was not stated.

The Arnold analyses were furnished by the Conemaugh Coal Company, with the statement that the samples "were taken in the usual way in which this work is done, viz, a narrow slip from top to bottom, getting in an equal amount of both bench and breast coal."

The samples for the Iselin and Holsten analyses were collected by the writer. In taking the samples a cut was made at a working face from top to bottom of that portion of the seam which is marketed. The samples were mixed and quartered and sealed in glass fruit jars. The analyses of the Iselin and Holsten coal samples were made in the chemical laboratory of the United States Geological Survey by Mr. George Steiger and Mr. Eugene C. Sullivan, respectively.

Analyses of Pittsburg coal from Elders Ridge field.

Locality.	Fixed carbon.	Volatile matter.	Mois-ture.	Ash.	Sulphur.	Fuel ratio.	Coke.	Authority.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Avonmore	56.432	35.040	0.720	6.810	0.988	1.61	64.23	L. W. Hicks.
Arnold 1	55.17	32.99	.51	10.33	.98	1.67	66.48	C. B. Dudley.
Arnold 2	56.47	30.02	.63	11.83	1.02	1.88	69.32	Wuth & Stafford.
Iselin	56.34	31.48	1.76	10.42	1.25	1.79	68.01	George Steiger.
Ashbaugh	53.639	37.555	1.110	6.260	1.436	1.43	61.335	A. S. McCreath.
Ewing	50.230	36.900	.800	9.030	3.040	1.36	62.30	Do.
Evans 1	50.850	36.940	1.040	9.705	1.465	1.38	62.02	Do.
Evans 2	53.788	31.995	1.460	11.760	.997	1.68	66.545	Do.
Holsten	56.25	33.41	1.61	8.73	1.87	1.68	66.85	E. C. Sullivan.

The Avonmore analysis, furnished by Mr. L. W. Hicks, superintendent of the Avonmore Coal and Coke Company, shows that the coal in the Avonmore mine (No. 11) runs high in fixed carbon and low in ash in comparison with that from other parts of the field. Although the fuel ratio is not high, the total amount of combustible matter is the highest of the nine samples. The percentages of sulphur and of ash are both very low, and the amount of phosphorus in this sample was .010 per cent. Judging from the above analyses alone, it is evident that the coal in the Avonmore mine is the best in the field for steaming purposes.

The Conemaugh Coal Company has furnished, through Mr. F. M. Graff, superintendent, two analyses of the coal in the Arnold mine (No. 16), one made by C. B. Dudley, of Altoona, the other by Wuth & Stafford, of Pittsburg, Pa. Both analyses run high in ash and low in moisture. Arnold 2 runs higher in fuel ratio than any other sample from this field. This is due to a low percentage of volatile matter. It also shows the highest per cent of coke. The high ash, however, keeps this from being the best sample in the above list. Arnold 2 shows a phosphorus content of .028 per cent.

The Arnold mine has about 8 acres of coal, and lies within a few hundred feet of the main entries of the Conemaugh mine. The Conemaugh Coal Company owns the coal all around it, and these Arnold analyses probably represent the character of the immediately surrounding coal.

The Iselin analysis was made from a sample collected by the writer in No. 2 heading of the Pittsburg Gas Coal Company mine (No. 9) at Iselin. It shows the composition of the coal of the main bench, 6½ feet thick, which is now being taken out. The percentage of ash and moisture is high, but the fuel ratio is excellent. The coke per cent and total amount of combustible matter are high. Nine tons of this coal sent to Adrian to be tested made a good coke.

The Ashbaugh analysis, published more than twenty-five years ago, is from a sample of the coal taken at Ashbaugh's steam mill on Harper Run, 1 mile above Clarksburg. The lower bench of the bed has a cannel appearance and is very rich in hydrocarbons, which probably accounts for the high percentage of volatile matter. The location is very near the new mine of the Pittsburg Gas Coal Company, but the analyses of the coal at the two points differ considerably. The Ashbaugh analysis shows next the highest amount of combustible matter of any locality in the field.

The coal of the Ewing bank in all the different benches is slaty and poor. Some of it is overloaded with iron pyrites, and none of it in its raw state could be considered marketable fuel, except for local supply. Although not the lowest in total amount of combustible matter, it is the lowest in fuel ratio, and carries so high a percentage of sulphur as to make it unsalable for many purposes.

At the mill of Mr. J. Evans, close to West Lebanon, the Pittsburg coal was mined many years ago. The bed is somewhat slaty and more pyritous than at most other localities. Mr. McCreath analyzed a specimen representing about the average run of the main benches, and the results are given in the accompanying table as Evans 1. One bench (that next to the lowest) in this bank assumes a cannel appearance and Evans 2 is an analysis of the same.

The coal in the Holsten bank (No. 1) takes third place in the list for total amount of combustible matter, stands high in fuel ratio and coke per cent, and it is also high in sulphur. The analysis of the coal at this bank was made by the Survey chemists from a sample collected by the writer at a fresh breast.

On the basis of the analyses which give the coal in the Avonmore mine first place, there would be difficulty in making a second choice. The coal at the Holsten and Arnold pits is no better than that on Harper Run.

COKE.

There are no coke ovens in the Elders Ridge field at present. The coke percentage, which is the sum of the fixed carbon, ash, and sulphur, is highest in the Arnold and Iselin analyses. The analyses suggest, however, only the strength and purity, and fail to indicate the essential qualities of a good coking coal. The coking and noncoking properties of the soft coals are not yet clearly understood.

The only sure method for determining the adaptibility of coal for coking is to have a quantity of it tested in a coke oven and then to make a careful study of the physical and chemical properties of the product.

Comparative analyses of coke.

	Elders Ridge.	Connellsville.
	Per cent.	*Per cent.*
Fixed carbon	90.532	89.509
Voltatile hydrocarbons	....	.880
Moisture	....	.070
Ash	7.411	8.830
Sulphur	2.057	.711
	100.000	100.000

Two analyses of coke made from Pittsburg coal are given above. The first was made by A. S. McCreath from coke made in the laboratory of the second geological survey of Pennsylvania by coking coal in a platinum crucible. The coal was from the Saltsburg Coal Company mine in the southern block of the Elders Ridge field. The second is the average of a number of analyses of typical Connellsville coke made by the H. C. Frick Coke Company. The amount of sulphur in the Elders Ridge coke is too high for a first-class product, but this might be remedied by washing the coal to get rid of part of the sulphur.

COAL MINING ALONG THE SOUTHEASTERN MARGIN OF THE WILMORE BASIN, CAMBRIA COUNTY, PA.

By Charles Butts.

For many years coal mining has been carried on actively along the main line of the Pennsylvania Railroad east of Johnstown, Pa. It is probable that the early development of this field was not due to thicker beds and better quality of coal than in the surrounding region, but to better transportation facilities to the seaboard and to the manufacturing cities of the East. The scene of greatest development extends from the village of South Fork, situated at the mouth of the stream of the same name, to Bennington, which lies at the eastern end of the Pennsylvania Railroad tunnel that marks the extreme summit of the Allegheny Mountains.

Structure.—The Wilmore basin consists of a comparatively long and narrow synclinal trough lying parallel with and just west of the Allegheny front. The basin is so deep that the principal coal-bearing beds, which are exposed on the eastern side, lie far below water level in the center of the basin, and even on the northwestern side are seldom exposed except in the valley of Conemaugh River, near the town of South Fork. Mining operations so far have been confined almost exclusively to the outcrop of the coal beds on both sides of the basin, and in many places the coal, which was easily available, has been mined out. The operations are now approaching the center of the basin, and the time is not far distant when the interior parts of the field will be the scenes of greatest activity.

Geologic work.—In anticipation of this condition, the present survey of a portion of the Wilmore basin was undertaken with the hope of showing, by means of contour lines on some important bed of coal, the depth at which it may be found in all parts of the basin, and also the form and shape of the basin itself. The western side of the basin was not examined during the present survey, but part of the eastern side, including mines in the vicinity of Bennington, Gallitzin, Cresson, Lilly, Bens Creek, Portage, Lloydell, and Dunlo, was examined with considerable care.

Stratigraphic relations.—The coal-bearing rocks involved in the Wilmore basin are known as the Allegheny formation, or Lower Productive Coal Measures. The top of the formation is marked by the

Upper Freeport coal, known throughout this region as the "E" or Lemon seam. This coal lies probably 350 feet below the surface at the town of Wilmore, or at an altitude above sea level of about 1,200 feet. This is probably about the deepest point in the basin, as the coal appears to rise along the synclinal axis in both directions. Where the axis crosses South Fork of the Conemaugh, about one-half mile above the site of the old Conemaugh reservoir dam and a short distance west of the quadrangle, the Upper Freeport coal is also about 350 feet below the surface, or about 1,230 feet above sea. The coal rises northward along the axis and is probably about 1,340 feet above sea at Munster and about 650 feet below the surface. These figures are presented subject to change when the data now in hand are thoroughly digested, but it is believed that they are close to the truth.

Mining operations.—Mining operations are confined almost exclusively to two seams—the Upper Freeport and to what is known in the region as the "B" or Miller seam, the latter lying from 180 to 200 feet below the former. This is probably to be correlated with the Lower Kittanning seam of the Allegheny Valley, and it will be so called in this paper. Both of these seams run from 3 to 4 feet in thickness. Three and one-half feet of merchantable coal is probably a fair average. Both coals are rather soft as a whole, and cleave into prismatic pieces, having a highly lustrous surface. Both are excellent steaming coals, and a large portion of the output is shipped to the Atlantic seaboard to be used for steaming purposes. The Upper Freeport coal makes a good coke, and a large part of the coal from that seam is coked at the mines. The Lower Kittanning is highly regarded as a blacksmithing coal.

Mining is at present confined to the regions of outcrop of the coal beds, and, with the exception of the operations at Cresson and Gallitzin, mainly to the valleys cut into the mountain side by Bear Rock Run, Bens Creek, Trout Run, South Fork of the Conemaugh, and Yellow Run. These streams have deeply trenched the coal-bearing strata, and also opened a way by which the coal beds can be easily reached by spurs from the main line of the Pennsylvania Railroad, thereby facilitating the loading and transportation of the coal from the mines on either side of the narrow valleys. Accessibility to the railroad has determined the location of operations at Gallitzin and Cresson.

The Upper Freeport coal is worked in the vicinity of Bennington and Gallitzin, at the Bennington No. 1, Webster No. 1, and Webster No. 11 mines, belonging to the Pennsylvania Coal and Coke Company, and at the Taylor and McCoy mine. Bennington No. 1 and Webster No. 11 are drifts; Webster No. 1 is a shaft or slope mine, and the Taylor and McCoy is a shaft mine. Near Bennington is the Reed and Bradley mine, a small operation in the Lower Kittanning, and there is also a small mine in that coal in the hill south of Bennington; both are drifts. In addition to these working mines, the Lower Kittanning coal was formerly worked at the Bennington shaft of the Cambria Iron Company and at the Dennison and Porter shaft, about 1½ miles southeast of Gallitzin. The Upper Freeport coal was mined many years ago near the old Portage Railroad, on the Lemon property, at the head of Blairs Gap Run. To this fact the name "Lemon seam" doubtless owes its origin. The coal was reached by a shaft 60 feet deep. The Lower Kittanning coal was also formerly mined along this run, and there are several country banks at which it is mined at present. There is but one mine at Cresson, the Webster No. 9, working the Upper Freeport coal, which it reaches by a shaft 300 feet deep. Much of the Upper Freeport coal mined at these places is made into coke.

Between Cresson and Lilly, about one-half mile southwest of Dyerstown, there is a small drift mine in the Upper Freeport coal.

Bear Rock Run, which enters the Little Conemaugh at Lilly, has cut deep into the flank of the mountain, making easily accessible a large body of coal in the hills on both sides of its valley. The Upper Freeport coal comes to the surface from the Wilmore syncline along the Little Conemaugh from the village of Lilly nearly to Bens Creek, and rises thence rapidly along both sides of the valley of Bear Rock Run, and finally outcrops high up on the mountain side. The Lower Kittanning coal rises to the surface on Bear Rock Run about one-half mile above Lilly and rises parallel with the Upper Freeport and in turn outcrops still higher up on the mountain side. Much of the Upper Freeport coal made accessible along this valley has already been worked out and the old workings may be seen in the vicinity of Lilly as well as southward along the Little Conemaugh nearly to Bens Creek. Mining on Bear Rock Run is therefore confined to the Lower Kittanning coal. The mines are all drifts and are in ascending order along the run as follows: The W. H. Piper, about three-fourths of a mile above Lilly; the Lilly Mining Company's mine, one-half mile beyond the Piper; the Sonman No. 4, belonging to W. H. Piper, one-fourth mile still farther up the run, and the Bear Rock Mining Company's mine 2 miles above Lilly.

About 1 mile south of Lilly, on the Little Conemaugh, the Upper Freeport coal is being worked at the Moshannon mine. This mine enters on the outcrop of the coal and is working down the dip into the Wilmore syncline.

On all the other streams previously mentioned the conditions of physical geography are similar to those on Bear Rock Run, and it is necessary only to describe the mining operations located along their courses. These will be mentioned in the order of their occurrence above the mouths of the streams.

On Bens Creek the Laughman Coal Company's mine and the Sonman mine, operated by the Loyal Hanna Coal Company, are about one-half mile above its mouth. The former mine is a drift on the Lower Kittanning coal at the point where it crops out, and the latter reaches the same coal by a shaft. Next come the Webster No. 2 and the Piper No. 1 mines, on opposite sides of the creek, about a mile up. Both are working the Lower Kittanning coal by drift. The latter mine is owned by A. C. Blowers. An interesting feature of this mine is the occurrence of a seam of coal, 4 to 5 feet thick, 14 feet above the Lower Kittanning coal. This coal is known at other points, but nowhere else is it of workable thickness, unless it be so in the vicinity of the Piper mine, on Bear Rock Run, where it is reported 4 feet thick. There may be a considerable body of this coal of workable thickness between Bens Creek and Bear Rock Run. About 1½ miles up Bens Creek are the Webster No. 2 and the Metzger mines, nearly opposite each other. Both are drifts, the former in the Lower Kittanning, on the south, and the latter in the Upper Freeport coal, on the north of the creek.

At Sonman, midway between Bens Creek and Portage, are two operations—the Shoemaker mine, a drift on the Upper Freeport coal, and the Sonman mine, in the Lower Kittanning coal, which it reaches by a shaft.

On Trout Run the first working mine is the Hopfer, a drift in the Upper Freeport coal near the level of the creek, about 1½ miles above Portage. There are a number of abandoned openings at this place in the Upper Freeport, showing that it has formerly been worked here to a considerable extent. Three-fourths of a mile farther up the run is the Lukens and Haupt mine, a drift in the Upper Freeport. At Puritan, a short distance beyond, is the shaft of the Puritan Mining Company to the Lower Kittanning coal. A short distance above this shaft and north of the run is a drift in the Upper Freeport belonging to George Pearse & Son. A short distance farther up Pearse & Son are mining the "D" or Cement seam, which corresponds to the Upper Kittanning coal of the Allegheny Valley. This coal also is worked at the mine of the New York Coal and Transportation Company directly south of the run from the Pearse mine. These are the only mines in the quadrangle in the Upper Kittanning seam. Near the pit mouth of the Pearse mine the coal is 93½ inches thick, the lower 46½ inches being clear coal and the upper 47 inches being composed of two benches of coal and two of slate. Farther in the mine the upper slaty portion dies out and the lower bench of coal is reduced to 41 inches. The New York Coal and Transportation Company also operates a mine in the Upper Freeport coal on the hillside above its mine in the Upper Kittanning coal. The interval between the two beds at this point is 90 feet. A short distance up the run from the mines just described the Lower Kittanning rises to the surface, and a number of mines are working it. The Plymouth Mining Company's mine reaches the

Lower Kittanning by a slope which descends 30 feet to reach the coal, and a little farther up the run the Cambria Mining Company and the South Fork Mining Company each have drift mines in that coal within a few feet of each other. From this point, about one-fourth mile west of Martindale, the Lower Kittanning coal is above the stream. There is one small mine in it near the mine of the South Fork Mining Company, the name of which is not known to the writer, and another, the Eleanor mine, about three-fourths mile above Martindale, belonging to Charles Hughes.

On the South Fork of the Conemaugh mining operations are confined to the territory between Beaverdale and Onnalinda. At Beaverdale is located the shaft of the Webster No. 10 mine, in the Lower Kittanning coal. The Logan Coal Company is preparing to mine the Upper Freeport coal by drift just below Beaverdale, and the Beaverdam Coal Company has sunk a slope to the same coal still farther down the creek. At Lloydell are the Alton and Wagner mines, drifts in the Lower Kittanning, on opposite sides of the stream. Just below these, the Logan Coal Company is opening a slope into the Lower Kittanning. A short distance above Lloydell and south of the stream is the mine of the Cambria Mining Company, and on the hillside below Onnalinda is a mine belonging to the Loyal Hanna Mining Company. Both of these mines are in the Lower Kittanning coal. The Loyal Hanna Company is preparing to open a mine in the Upper Freeport coal, near the summit of the hill at Onnalinda.

On Yellow Run there are three mines at Dunlo, one at Llanfair, and one about a mile south of the latter place. The Yellow Run mine, belonging to the Berwind White Company, is the first west of Dunlo. It works the Lower Kittanning coal, which it reaches by shaft. Near this mine is a drift in the Upper Freeport coal belonging to the Mountain Coal Company. Just west of Dunlo the Logan Coal Company has a drift in the Lower Kittanning coal. At Llanfair, and about 1 mile south of that place, the Henriette Coal Company has sunk shafts to the Lower Kittanning coal, which it is mining extensively.

THE MEADOW BRANCH COAL FIELD OF WEST VIRGINIA.

By Marius R. Campbell.

GENERAL DESCRIPTION.

This coal field lies in an isolated syncline of lower Carboniferous rocks near the eastern extremity of the State of West Virginia. The mountainous ridge forming the eastern margin of the field is only about 6 miles west of Little North Mountain, which constitutes the boundary of the Shenandoah Valley. In the early days of the colony this ridge was the third hill to be crossed in passing from the Piedmont Plateau, and consequently it was designated "Third Hill Mountain." The ridge forming the western limb of the syncline is known as Sleepy Creek Mountain, and throughout most of its course it constitutes the dividing line between Berkeley and Morgan counties. The basin has an extreme length of about 15 miles, a breadth of about 2 miles, and at its northern end comes to within 4 miles of Potomac River.

The presence of coal beds in this syncline was recognized near the beginning of the last century, and various attempts have been made to utilize them, but without success. As early as 1835 Prof. William B. Rogers, then director of the geological survey of Virginia, described the stratigraphic position of the coal beds of this field and also gave a general description of the geologic structure of the syncline.[a] In this report the coal is referred to as follows:

"In Berkeley County, on Sleepy Creek and elsewhere, openings have been made, from which an anthracite of the very purest character is obtained." In the report covering the operations of the survey for the year 1838 Professor Rogers describes the stratigraphy and structure of the basin in considerable detail. He discusses this field under a heading[b] "Semibituminous coal of Sleepy Creek," etc.; but in the body of the text he speaks of the Meadow Branch coal as being "as pure as anthracite." This report of Rogers was not published until 1884, but in the meantime desultory prospecting had been carried on in the Meadow Branch region, apparently with little understanding of

[a] Rogers, William B., Geology of the Virginias, reprinted 1884, p. 99. [b] Op. cit., p. 225.

the geologic structure and of the relation of the coals to the other rocks. Recently interest has been revived in this field, additional

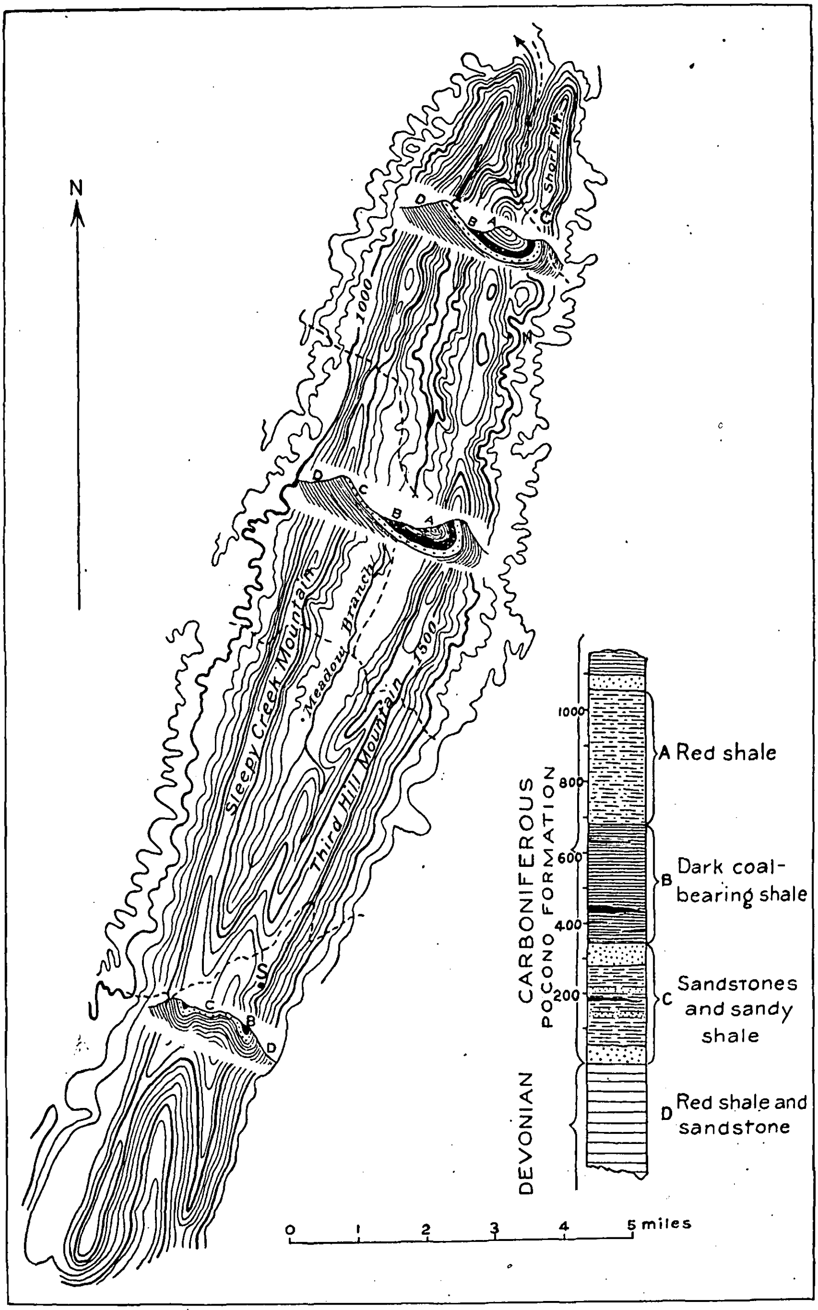

FIG. 9.—Map of the Meadow Branch coal field, West Virginia.

prospecting has been done, and the field has been visited by a number of engineers and geologists, but no satisfactory tests have been made of the coal. In 1902 the basin was examined by Mr. William Griffith,[a] who gave a very interesting and exact description of the geologic relations of the coal beds, but he made no tests, and simply accepted the current statements regarding its anthracitic character.

The greatest thickness of coal has always been found on the southeastern side of the basin, where the rocks are standing nearly vertical or overturned and where the coal has been severely crushed during the crustal movements that have thrown the rocks into the great folds of which this synclinal basin is a part. The overturned or southeastward dipping beds on that side of the syncline have given rise to the impression that the coal beds dip generally to the southeast, and consequently underlie all of the territory between Third Hill Mountain and the Shenandoah Valley. Several deep wells have been drilled in this region to find the coal, and considerable money has been expended in fruitless search.

In order to obtain additional information regarding the general geology of this region and to determine the commercial value of the coal, the writer spent a few days of the past season in the field. This brief preliminary examination, which, though not revealing satisfactorily the characters of the coal beds, is sufficient to throw light on their stratigraphic position and on the geologic structure of the basin.

GENERAL GEOLOGY.

Age of the coal-bearing rocks.—In 1838 Professor Rogers decided that the coal-bearing rocks of this basin belong to formation X (Pocono), but his report was not published until 1884, and in the meantime persons interested in the field had been pleased to regard them as the southwestward extension of the anthracite fields of Pennsylvania. The confusion resulting from the different age determinations was conclusively settled in 1902 by Mr. David White, who visited the field and made a collection of fossil plants from the coal-bearing horizon. As stated in the appended report of Mr. White, this evidence corroborates in every respect the early determinations of Rogers and shows conclusively that the coal beds are contained in the Pocono formation.

Mr. White's report on the fossil plants of the Meadow Branch coal field is as follows:

The shales associated with the coals opened on or near Short Mountain, in the Sleepy Creek basin, are generally prolific in fossil plant remains. The flora is, however, meager in species, notwithstanding the abundance of material. This poverty in species is characteristic of the older Mississippian in general and is in strong contrast with the floras of the Pennsylvanian series.

Plants were collected by me in December, 1902, from the drift near the turn in the road and from the shaft known as Chappelle, near the top of Short Mountain.

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[a] Griffith, William, The anthracite of the Third Hill Mountain, West Virginia: Jour. Franklin Inst., vol. 154, 1902, pp. 431–439.

They represent the following species: *Palæophycus* sp.; *Sphenopteris vespertina* n. sp.; *Triphyllopteris* sp., cf. *T.* (*Cyclopteris*) *virginiana* (Meek); *Lepidodendron scobiniforme* Meek; megaspores (*Triletes*).

This flora is typical of the Pocono, the second and fourth species in the list being nearly always present in that formation. The *Sphenopteris* is present at practically all localities from the Schuylkill River gap, below Pottsville, Pa., to the old coal mines on Stony Creek, Wythe County, in southwest Virginia. At several of these points it has been identified as *Sphenopteris floccida* Crepin.

The *Triphyllopteris* is closely related to *T. virginiana*, and is abundant at the Pocono coal mines in Price Mountain, Montgomery County, Va. The trunks listed as *Lepidodendron scobiniforme* are nearly as common as the *Sphenopteris vespertina*. By some paleontologists this species has been combined with *T. corrugatum* of Dawson, which is similarly characteristic of the basal Mississippian of Nova Scotia and New Brunswick. Many of the fragments are in a state of preservation recently described by Kidston as *Eskdalia*, and since the American species does not conform, in its generic characters, with *Lepidodendron*, it should probably be designated as *Eskdalia scobiniforme*. So far as known, the genus *Eskdalia* is characteristic of the "Calciferous sandstone series," which in Great Britain corresponds to the American Pocono.

It is greatly to be desired that additional paleobotanical search may be prosecuted in the rocks of the Mississippian in the United States in order that additional plants may be brought to light and our knowledge of the floras of this interesting series enriched.

Stratigraphy.—In a broad way, the Pocono rocks of this district consist of massive sandstone or conglomerate beds alternating with thin bands of soft shale, which easily breaks down and seldom shows in outcrop. The débris from the heavier beds tends to obscure the softer shales, and unless they are of such a color as to show prominently by their débris they may be passed over without notice. Gradation from the Devonian shales below into the Pocono rocks above seems to be fairly regular and complete, and at present no paleontological evidence has been obtained to show where the division line between these two systems occurs. The red sandstones and shales of the upper Devonian are well exposed along the sides of both Sleepy Creek and Third Hill mountains, and presumably extend upward to the base of the coarse, quartz-pebble conglomerate which is here regarded as constituting the base of the Pocono formation. At several points on the eastern side of the syncline a still lower bed of heavy sandstone makes its appearance, but presumably it is of Devonian age and occurs interbedded with the upper Devonian shales.

The coarse conglomerate just mentioned is succeeded upward by a mass of soft material which has an approximate thickness of 250 feet. This is bounded on its upper side by a very massive sandstone, or fine conglomerate, which is the most conspicuous stratigraphic member of the Pocono formation, and constitutes most of the crest of Sleepy Creek, Third Hill, and Short mountains. This sandstone is of a sugary whiteness, and seems to range in thickness from 40 to 60 feet.

The rocks above this massive sandstone are generally poorly exposed, so that it is extremely difficult to obtain a clear comprehension of their composition and thickness. In fact, they appear to be variable in both characteristics, but generally they consist of soft material, the outcrop of which is often obscured by blocks of sandstone from the overturned lower member, and they seem to range in thickness from 150 to 300 feet. Economically they are the most important beds of the basins, since they carry most of the coals that are of workable thickness. In places beds of coal of considerable size appear within 15 to 20 feet of the top of the sandstone, but occasionally the most attractive beds seem to belong from 200 to 300 feet above the same horizon. It seems probable that the interval is made up of a number of coal beds of different sizes separated by dark shales, and probably some thin sandstone layers.

The next succeeding formation is a bright-red shale, which is one of the most conspicuous beds of the region. Unless it is deeply covered by débris from some adjacent sandstone ridge, its outcrop is almost always apparent from the color of the soil. Its exact thickness could not be determined, but presumably it ranges from 350 to 400 feet.

The rocks above the red shale just mentioned are but little known, and the present investigation was not extended enough to determine definitely the sequence and thickness of the superjacent beds, but at the north end of Third Hill Mountain, which here occupies nearly the center of the syncline, the red shales are clearly overlain by a bed of massive sandstone at least 20 feet in thickness. Above the sandstone is dark shale, in which a small bed of coal has been discovered, and in the shales associated with this coal occurs a Mississippian type of *Lepidodendron*, which shows clearly that the entire series exposed in the basin is of Pocono age.

Geologic structure.—The structure of the Meadow Branch field is comparatively simple, consisting in a general way of an open, synclinal fold, but this is complicated by one or two minor flexures and by the slight overturning of the southeastern limb, so that its true structure is not readily apparent.

The beds forming the northwestern limb of the syncline dip to the southeast at angles which vary from 20° to 60°. The massive sandstone underlying the coal-bearing member of the formation has so resisted erosion that it forms the summit of Sleepy Creek Mountain, which extends in an unbroken line from the northern to the southern extremity of the field. In the eastern limb the rocks stand either vertical, or are overturned so as to give southeastern dips which vary from 60° to 90°. In this position the heavy sandstone beds are easily eroded, and consequently the outer rim of the syncline has been breached in many places by small streams flowing to the east. The rim of the syncline, especially near the north end, is not continuous and topographically is not so conspicuous as Third Hill Mountain, which here occupies nearly the center of the basin. Around the northern extremity of the field the rocks pitch gently to the southwest, and they have been deeply dissected by Meadow Branch, which makes its exit from the basin at this point.

The occurrence of heavy beds of sandstone on Third Hill Mountain, in the northern part of the basin, has given rise to the impression that there is a structural disturbance in this part of the field which allows the sandstones composing Short Mountain to appear again near the summit of Third Hill Mountain. The rocks which cap Third Hill Mountain resemble in every respect the heavy sandstone showing in Short Mountain, but an examination of the region shows clearly that the slopes of Third Hill Mountain are composed almost entirely of the red shale which overlies the coal-bearing member of the formation, and consequently the sandstone of Third Hill Mountain is an upper bed occurring about 700 feet above the Short Mountain sandstone.

The overturned southeastern limb of the syncline has also given the impression that southeastern dips are normal and that the coal-bearing rocks underlie the red shales and sandstones which skirt the eastern foot of Third Hill and Short mountains; in other words, that the Pocono rocks underlie the Devonian shales which occur east of the mountain. This is an erroneous impression, and an examination shows that the structure is as indicated in cross section, the southeastern limb being only slightly overturned, and that presumably at a depth of a few hundred feet it would be found bending back to the northwest and uniting with the bed which forms the crest of Sleepy Creek Mountain. In passing to the southwest, the upturned bed of massive sandstone is seen in the series of isolated knobs which occur along the southeastern face of Third Hill Mountain until in the vicinity of Pinkerton Knob the sandstone in the center of the basin disappears and the principal ridge changes from the center to the margin of the syncline and its top is composed of sandstone equivalent to that exposed on Short Mountain.

The structure of the southern end of the basin is much more complicated, the basin itself being divided by a large anticlinal fold which makes its appearance on the eastern limb of the basin where it is crossed by the Meadows road northwest of Jones Spring. At this point Third Hill Mountain throws off a long spur to the southwest which is known as Locust Ridge, and which is continued beyond Roaring Run, a tributary of Meadow Branch, to Middle Ridge. The fold is small at its first inception near the Meadows road, but increases in magnitude to the southwest until on the Martinsburg and Romney road the sandstone forms an immense arch which constitutes the highest part of the mountains. The synclinal basins on either side are greatly compressed, and the two bounding ridges, together with Middle Ridge, form a large mountain mass which is practically the southern terminus of the basin. The main synclinal basin lies on the west side of Middle Ridge, and south of the public road it is so compressed that it forms a single mountain range which extends for a distance of 3 or 4 miles and then is terminated by the lifting of the syncline near the Virginia State line.

On the eastern side of the basin the anticlinal fold just described is bordered by a minor syncline which makes its first appearance near the Meadows road and extends southward lying between Middle Ridge on the west and Third Hill Mountain on the east. The point of maximum development of this syncline is about halfway between the Meadows road and the Martinsburg and Romney road. Toward the southwest the basin lifts and is compressed by the big anticline lying to the west, so that south of the latter road it has but a slight development. The sandstone shows a dip of about 40° on the western limb of the syncline and stands about vertical on the eastern limb. Farther south the eastern limb is eroded and the western limb is continued topographically as a single ridge for a distance of 2 or 3 miles until the syncline disappears and the ridge is broken down by erosion.

The principal synclinal basin is unsymmetrical, the axis or line of greatest depression being generally near the southeastern side of the basin. So far as could be determined in the hasty examination made by the writer the axis lies a little west of Meadow Branch at the northern extremity of the mountain. It passes west of the knob at the northern extremity of Third Hill Mountain, but it corresponds with this ridge for a distance of about 3 miles from its northern end. At Pinkerton Knob, where Third Hill Mountain bends to the east and forms the rim of the basin, the axis follows the western foot of the mountain, and it crosses the Meadows road at Tom Myer's place, which is located at the foot of Third Hill Mountain.

The synclinal basin is slightly complicated by a small fold which lies on the western side of the synclinal axis and extends from the vicinity of Whites Gap to near the southern extremity of the basin. The exact nature of this fold could not be determined. Presumably it is a monoclinal wrinkle in the bottom of the basin, but possibly the rocks may be folded into an anticlinal arch.

COAL BEDS.

The coal beds of the Meadow Branch field are generally poorly exposed. The coal itself is extremely tender and friable, and it has been so badly crushed by the general folding which the rocks have undergone that it disintegrates rapidly, and its outcrop is generally deeply covered by débris from the other rocks. The history of the development of the field dates back to 1835 when an effort was made to develop the coals in the northern end of the basin, but, owing to the magnitude of the undertaking, little more was done than to build a few wagon roads and the coal remained undisturbed. In the latter part of the century many efforts were made to determine the value of the coals, but generally this work was done without a thorough appreciation of the geologic structure and of the stratigraphic position of the coals, consequently little information was obtained from the prospecting. Most of the work has been done on the eastern limb of the syncline and three shafts have been sunk which afford a fairly good idea of the condition of the beds. One of these shafts is near the southern extremity of the basin, but at present the coal is inaccessible through the flooding of the mine. The second shaft is located about a mile and a half northeast of Pinkerton Knob and it likewise is inaccessible at the present time, but from this opening considerable coal was obtained. The third shaft is located on Short Mountain and is the only point at which the coal is exposed at present. Besides these shaft mines on the eastern limb, many prospect pits have been dug and also two or three openings of importance have been made on the northwestern limb, but so far as information can be obtained the thickest coal has been obtained on the eastern limb of the syncline.

Shepperd shaft.—This shaft, marked "S" on the accompanying map (page 331), is located near the southwestern extremity of the mountain and on the eastern side of the easternmost synclinal basin. The rocks are approximately vertical, and a crosscut at a depth of 42½ feet, according to measurements made by Mr. Hammond Hunter, of Martinsburg, gives the following section:

Section of coal bed in Shepperd shaft.

	Ft.	In.
Coal	5	9
Sandstone	1	6
Coal	4	0
Shale and coal (half and half)	3	8
Coal	2	2
Shale	4	0
Coal	3	8
Total	24	9

Although the above section shows a large number of benches of coal, it is probable that there is a considerable amount of shale in each bench. The crushing of the coal usually results in the breaking up of thin shale partings and their dissemination throughout the mass of the coal. No definite information is obtainable regarding the quality of the coal from this shaft, but a large amount was sold and from the fragments remaining on the dump it appears to be of the same quality as that which occurs at the north end of the basin and which will be described on another page.

Mr. Griffith examined the coal in this shaft and reports as follows:[a]

> The writer * * * found the coal bed—which was supposed to be about 10 feet thick—much crushed and faulty * * * and practically worthless. Near the bottom of the shaft the bed seemed to be parted by layers of fire clay or slate and in worse condition than the top.

The history of the attempt to develop this part of the basin is interesting, as it shows how important is a knowledge of the geologic structure and what wasteful expenditures may be made where such a knowledge is wanting. After sinking the Shepperd shaft 60 to 70 feet on this vertical coal bed, it occurred to the prospector that it would be much more economical to drift in horizontally from near the base of the mountain and cut the coal bed at a lower level. It seems to have been assumed that the coal extended down indefinitely and all that was necessary was to drive in until it was reached. Accordingly a drift was run several hundred feet and then a diamond drill was procured and the hole extended to a total distance of about 700 feet without finding any sign of coal. At this point the work was abandoned. If the operator had crossed the next ravine south of the shaft he might have seen the rocks forming a V-shaped trough with the eastern side of the V standing vertical and the whole extending down a little more than 100 feet. The tunnel at the foot of the mountain passed entirely below the coal and presumably was in Devonian rocks throughout its whole course.

Another equally wasteful expenditure was once made in drilling a deep hole on the crest of the mountain at the south end where it is crossed by the Romney and Martinsburg road. This well was located on the crest of the anticlinal fold forming Locust Ridge, on the outcrop of the lowest bed of coal. Of course no other coal beds were discovered, and the drill was in Devonian rocks for almost the entire distance, some 800 feet.

Nihiser shaft.—This shaft is located on the southeastern limb of the syncline, about 2 miles north of Pinkerton Knob, at the point marked "N" on the map. The rocks dip to the southeast about 70°, and the shaft was sunk to a depth of 108 feet. At this depth, according to Mr. Hunter, it had passed through the following section of coal:

Section of coal bed in Nihiser shaft.

	Ft.	In.
Coal	4	4
Slate	1	4
Coal	4	0
Slate	1	7
Coal	2	0
Total	13	3

[a] Griffith, William, Jour. Franklin Inst., vol. 154, 1902, p. 436.

At the present time the shaft is full of water and little can be learned regarding the condition of the coal, but the fragments show a coal of good quality and presumably of equal purity with that at the northern end of the field.

Chappelle shaft.—This mine, marked "C" on the map, is located on the west side of Short Mountain, near the northern end of the basin. It is the only mine in active operation and even here the full thickness of the bed of coal is not at present visible. The writer examined such parts of the coal bed as were accessible, but a recent slide had concealed most of the bottom bench. The section of the bed as observed and reported is as follows:

Section of coal bed in Chappelle shaft.

	Ft.	In.
Coal, badly mixed with slate	4	4
Clay	1	3
Coal, with two or three irregular partings	5	3
Clay	0	6
Coal (reported)	11	0
Total	22	4

The coal in all of the benches is so badly crushed that all of its original lamination is obscured and it is slickensided on almost every face. The original shale partings are broken into small fragments and intimately mixed with the body of the coal. The coal is extremely fragile, appearing originally to have been very soft and tender, and it is difficult to obtain lumps of any considerable size. Upon exposure to the weather it breaks up into small particles, so it is doubtful if lump coal of any considerable amount could be obtained in this part of the Meadow Branch field.

Coal at other points.—Efforts have been made to open this bed on the western side of the syncline, but so far they have not met with great success. An opening recently made at the foot of Sleepy Creek Mountain, northeast of Whites Gap, shows a small coal bed, but it does not in any way resemble the coal at the Chappelle shaft. The entry was not driven far enough to show the coal under cover, and consequently that which is exposed is deeply disintegrated and gives little indication of the true character and thickness of the bed. The section exposed is as follows:

Section of coal bed northeast of Whites Gap.

	Ft.	In.
Coal, badly weathered	1	6
Clay	0	1
Coal, weathered	0	8
Clay	0	3
Coal	1	0
Total	3	6

About a mile farther south an opening has been made which shows about 37 inches of coal badly crushed and greatly weathered. The bed seems originally to have included two shale partings, which are now crushed and thrust out of position in the mass of the coal.

Several prospect pits have been dug near the Meadows road in the southern part of the basin, but they are in such a condition that it is impossible to obtain any idea of the coal. According to Mr. Hunter, two benches of coal were exposed, one showing a thickness of 3½ feet and the other a thickness of 2 feet.

Still farther south and near the mouth of Roaring Run a large amount of coal was mined twenty-five or thirty years ago. No reliable data has been preserved regarding it, but it seems probable that a bed of good workable thickness was found in this locality. The coal is exposed on the crest of a small anticlinal roll in the bottom of the basin, and according to report the coal lay in a pocket and soon was worked out.

Prospecting has been done along the southeastern limb of the syncline on a coal bed which appears to lie considerably below the main sandstone that forms Third Hill and Short mountains. A shaft was sunk to this bed on the extreme northern point of Short Mountain and some coal was obtained, but the thickness of the bed is unknown, as the shaft is full of water and the coal is not visible. A more promising opening was made on the east face of Third Hill Mountain about one mile north of the Meadows road. An entry was driven in and considerable coal was removed. The parties doing the work seem to have been satisfied with what they found, and the mouth of the drift was closed so that no information could be made public concerning it.

QUALITY OF THE COAL.

At only one place, the Chappelle shaft, could the quality of the coal of the Meadow Creek basin be determined. Here it is exposed for inspection in a shaft 60 to 70 feet deep, but at other places all that can be seen are heaps of fine coal that have lain exposed to the weather for an unknown length of time.

The fragments probably represent the better part of the coal, and, as indicated by one analysis, they show little evidence of disintegration. The coal fragments seem to be about the same in quality as the best grade from the Chappelle shaft.

The middle bench only of the coal in the Chappelle shaft is accessible at this mine. In order to determine its quality a cut was made across the upper part through a thickness of 49 inches, including everything except large fragments of three shale partings which, presumably, could be separated in commercial mining. About 40 pounds of coal was taken from this cut, crushed, well mixed, and quartered, until a quart sample was obtained. This sample was intended to represent the mine run from the middle bench, and it was sealed in a glass jar which was not opened until the sample was analyzed in the Geological Survey laboratory. The composition of this sample is shown in No. 1 of the following analyses:

Analyses of coal from Meadow Branch coal field, West Virginia.[a]

	No. 1. Chappelle shaft.	No. 2. Chappelle shaft.	No. 3. Meadow Branch.
	Per cent.	*Per cent.*	*Per cent.*
Fixed carbon	73.20	79.64	76.37
Volatile hydrocarbons	9.00	11.51	12.31
Moisture	1.94	1.04	1.78
Ash	15.86	7.81	9.54
	100.00	100.00	100.00
Sulphur	.91	.81	.54
Phosphoric oxide	.04	.02	.02
Specific gravity at 20° C	....	1.35	....
Fuel ratios $= \frac{\text{Fixed carbon}}{\text{Volatile hydrocarbons}}$	8.13	6.92	6.20

[a] Analysis No. 1 by Mr. E. T. Allen, analyses Nos. 2 and 3 by Mr. George Steiger.

To ascertain the true character of the coal aside from the shale impurities with which it is mechanically mixed, about 30 pounds of selected lump coal were taken from the middle bench, from which sample No. 2 was obtained. The variations in these two analyses in the percentage of fixed carbon, moisture, and volatile hydrocarbons are probably no greater than would appear in the analyses of two samples collected from the same bench at different times or by different parties. The 8 per cent decrease in the ash represents the absence of crushed slaty fragments mixed with the broken coal.

Fresh samples could not be obtained from the upper bench, but from the imperfect exposures in the mine the coal seems to carry more impurities than the middle bench, and it is doubtful whether it can be mined to advantage. The value of the bottom bench is hypothetical. It could not be examined, but it seems probable that the thickness given is approximately correct. No samples could be obtained from it, and consequently its chemical composition is not known. Samples could not be obtained from the old openings along Meadow Branch. Most of these prospect pits had not been driven to a sufficient depth to get beyond the zone of weathering, so it was impossible to obtain an adequate idea of the quality of the coal.

The most extensive old workings are those already mentioned south of the Meadows road and in the upper part of the basin of Meadow

Branch. The history of this development could not be obtained, but it has not been worked for at least eight years. Considerable coal is still present on the dump, and from these small fragments a sample was obtained, which yielded analysis No. 3.

It is interesting to note that weathering has had no appreciable effect upon this coal. The amount of moisture is no greater than that contained in the samples obtained from the Chappelle shaft, but the fuel value is somewhat less, presumably due to the increased percentage of volatile hydrocarbons. This increase is not due to weathering, but depends upon the original composition of the coal.

From the above analyses it is apparent that the coal of this field, so far as it is represented by the samples taken, is not an anthracite and, in fact, it is doubtful if it falls within the class of semianthracites. According to the classification proposed by Persifor Frazer, jr.,[a] and generally adopted by the geologists of the second geological survey of Pennsylvania, the fuel ratio (per cent of fixed carbon divided by per cent of volatile hydrocarbons) of hard, dry anthracite ranges from 100 to 12; semianthracite, from 12 to 8; semibituminous, from 8 to 5, and bituminous (disregarding lignites), from 5 to 0.

Fuel ratios of 6.92, 8.13, and 6.20, as shown by the analyses on page 341, indicate that the coal belongs close to the dividing line between the semibituminous and semianthracite classes and that it can not compare with Pennsylvania anthracite, the fuel ratio of which is always greater than 12.

Although this coal is not an anthracite, it may have considerable value as a fuel since its low percentage of volatile hydrocarbons probably renders it nearly smokeless. Its commercial value, however, will depend largely on the condition in which it reaches market and the amount of impurities that it carries. The crushed coal on the eastern limb of the syncline is in poor condition for shipment, but it seems possible that in the center of the basin the coal may be less badly crushed and that it may be mined in sizes that will command good market prices.

Where the coal bed is undisturbed the shale partings are easily removed during the process of mining, but where it is crushed so badly as it is on the eastern limb of the syncline the separation of the shale fragment from the coal is a difficult matter. Owing to the low specific gravity of the coal, separation may be affected by washing, as suggested by Mr. Griffith.[b]

DEVELOPMENT OF THE FIELD.

With the exception of the mines that were formerly worked in the bottom of the syncline south of the Meadows road all the develop-

[a] Frazer, Persifor, jr., Classification of coals: Second Geological Survey of Pennsylvania, Report M M, 1879, p. 144.

[b] Jour. Franklin Inst., vol. 154, 1902, p. 438.

ment of the field has been along the eastern or overturned limb of the syncline. The selection of this part of the territory for development apparently has been determined by the unusual thickness of the beds of coal and also by the fact that they are more apt to be exposed where the beds of rock stand nearly vertical than they are on the western limb of the syncline or in the bottom where the rocks are approximately flat. In fact this condition has controlled the prospecting south of the Meadows road, for, as previously noted, the mines are located on a small anticlinal which traverses the floor of the basin in a line parallel with the general structural features of the region.

As previously stated, the search for thick beds of coal on the western limb of the syncline has not been successful and the impression seems to be general that the thick deposits are limited entirely to the overturned limb of the fold.

Even a very casual examination of the Meadow Branch field will show that the rocks constituting the eastern or overturned limb are much more disturbed and fractured than those in the center of the basin. The coal, being the softest member involved, has suffered the greatest amount of disturbance, and consequently it is reduced to the crushed condition shown in the Chappelle shaft.

The commercial development of this field should be undertaken as near the center of the basin as it is possible to locate; but before such operations are begun it should be determined positively whether the common idea that the thick coal is limited entirely to the eastern side of the fold is correct. Surface prospecting along Meadow Branch would probably determine this question, but it is preferable to test the basin with a diamond drill. As stated on a previous page, the coal-bearing rocks appear to have a thickness of about 300 feet. Hence, if a diamond drill were started at the base of the red shale which overlies the coal-bearing rocks and the drilling continued until the massive sandstone forming the crest of Sleepy Creek Mountain were reached, it would reveal the presence of all the coal beds in the basin, except possibly the one which is supposed to lie below the mountain-making sandstone. Since, in a basin of this character, faults are liable to occur, and movement may have taken place between the various beds of rock composing the coal-bearing series, it is possible that the coal may be faulted out at certain places. In order to guard against such contingencies, it is desirable to drill several holes in the basin in order to be certain of the sequence of the rocks and the thickness of the coal beds. The writer would suggest that a favorable place for testing the coals with a diamond drill is on the north-sloping hillside at the end of Third Mountain, overlooking Devils Nose. A test might be made to advantage directly east of Whites Gap, in the vicinity of Meadow Branch, and a hole might also be drilled near Tom Myer's place, where the Meadows road crosses the basin.

If three such tests show the coal to be thin and badly crushed, it is probable that the basin as a whole has little or no commercial value at the present time. If, on the other hand, the test holes show a good body of coal with little or no disturbance, then mines could readily be established near the axial line of the basin, presumably at its northern extremity, and the coal could reach the Baltimore and Ohio Railway over a short road down Meadow Branch and Sleepy Creek. An inspection of the topographic map leads to the conclusion that such a road could be constructed down Meadow Branch to the northern extremity of the mountain, where the grade could be kept well above creek level, and, passing over the low summit at the right of Meadow Branch, it could descend the next small stream to the east, reaching Sleepy Creek at a point about 3 miles above the river.

The coal field also can be reached by a branch road up Cherry Run, but in this case the development would necessarily take place along the overturned limb of the syncline, and mining would have to be carried on by means of shafts. This would necessitate the raising, not only of the coal, but also of the water, which necessarily would be a considerable item. The plan for development in the interior of the syncline is much more feasible, so far as the lay of the coal is concerned, and, presumably, the cost of a branch road into the field would be no greater than it would be along Cherry Run.

COAL OF THE BIGHORN BASIN, IN NORTHWEST WYOMING.

By Cassius A. Fisher.

GEOLOGIC RELATIONS.

The coal of the Bighorn Basin is confined mainly to the Laramie formation, but it occurs also in the basal sandstone of the Dakota on No Wood Creek, near Tensleep, and in the Benton in the vicinity of Clarks Fork Canyon. The Laramie coal beds are distributed through the formation from base to summit. Those of workable character, however, are confined principally to the basal sandy series, where coal is characteristic of one horizon throughout a considerable area.

In the Bighorn Basin the Laramie formation consists of a series of alternations of sandstones, shales, and clays, with beds of coal and coaly shale of variable thickness. The shales are chiefly gray or drab in color, and often contain a sufficient amount of carbonized wood particles to impart a lignitic character. The shales vary greatly in composition, often becoming very sandy, and occur in irregular bodies at various horizons. Concretionary inclusions are common, consisting of sand locally silicified to increased hardness, and darkened by oxidation of iron. In the vicinity of Red Lodge, Mont., limestone concretions are reported as occurring in the shale.

The sandstones are principally gray, but a variable amount of iron gives rise to local coloring. They occur in massive beds from 1 to 75 feet thick, those of 25 to 30 feet being most common. The sandstones exhibit considerable variation in character, particularly where shale intercalations predominate. At the base of the formation, however, they show a fair degree of persistence. Sandstone concretions are not uncommon, varying in size from 1 to 10 feet. The form is usually elongated, with rounded edges, although spherical and lens-shaped concretions abound.

The thickness of the Laramie formation in the Bighorn Basin varies, by estimate, from 1,000 to 1,500 feet, but the maximum probably was greater originally, the thickness having been greatly reduced by denudation of the upper members prior to the deposition of the Wasatch.

The exposed area of the Laramie formation is extensive, comprising approximately 1,500 square miles. It outcrops as a continuous zone encircling the basin, the maximum width being found along Gooseberry Creek and the minimum in the vicinity of Clarks Fork Canyon. Along the eastern edge of the basin a uniform width of 4 to 5 miles is maintained. The dips vary from 1° to 60°, the strike circling around parallel to the periphery of the basin syncline, the average inclination of the beds rarely exceeding 25°. The base of the formation is distinctly marked by an escarpment of sandstone overlooking the soft shales of the underlying formation.

Owing to the changeable character of the Laramie beds no distinguishing stratigraphic subdivisions exist, so there is no means for determining the horizon of a particular coal bed except by direct measurement from the base, or by reference to some of the broad general divisions of the formation. Accordingly it has been practicable in the present reconnaissance to ascertain only the approximate position of the various beds. The entire series of the Laramie beds in the Bighorn Basin is segregated for reference into three general divisions, the lower 300 to 400 feet, chiefly sandstones; the middle 300 to 700 feet, shales and clays, and an overlying series of sandstone and shale of undetermined thickness.

The coal deposits of the Laramie formation within the Bighorn Basin exhibit the usual variation in character encountered in the coal measures of this formation elsewhere. The most common variation is due to the presence of shale and sandstone partings, separating the beds into "benches." Sometimes these partings so increase in number and extent over a limited area as to render a part of the deposit worthless. Not infrequently numerous slaty layers contained in the coal bed at the outcrop will be seen to disappear entirely within a few hundred feet of the entrance to the tunnel. In one locality examined the lower layer of a coal horizon was represented at the outcrop by brown carbonaceous shale, with minute streaks or threads of coal. At a distance of 100 feet down the main entry the proportion of shale to coal changed to such an extent as to render the deposit workable. While the coal deposits of the Laramie formation in the Bighorn Basin are usually of a variable nature, there are exceptions. Thus, the lower coal deposit of the basal sandy series, with a characteristic bluish-gray, slaty parting near the middle, presents considerable uniformity all along the west side of the basin. Many of the smaller beds in the middle shaly division also exhibit a marked degree of persistence, but are too thin to be worked separately.

In the following discussion reference will be made to the above divisions as the "basal sandy series," the "middle shaly series," and the "upper sandy series."

The basal sandy series contains two workable beds, the lower and more important occurring about 100 feet above the base of the formation and the upper about 75 feet higher in the series. There are other coal horizons in the basal Laramie, but so far as observed they are thin and unimportant, except at the McDonald and Cottle mine, on Bighorn River, near the mouth of Kirby Creek, where they locally attain a thickness of 3 to 5 feet. The principal bed of this division has a variable thickness of 3 to 8 feet; that of 5 to 6 feet, however, is most frequently observed. It consists of two "benches" of about equal thickness, separated by a 3-inch layer of brown carbonaceous shale, which weathers to a bluish-gray color. This shale parting is characteristic of the horizon over a considerable area. The coal of the lower bench is sometimes superior in quality to that of the upper bench. This is illustrated in the Sunshine area, where the coals of the two benches present a marked difference in physical properties. That below the usual shale parting is a hard, black, oily variety, while that above is fibrous, brown, and dull in appearance. Shale partings 1 to 2 inches thick frequently appear in both benches of the bed, but they are few in number and of local nature.

In the middle shaly series coal beds occur at frequent intervals, but they are usually too thin and shaly for profitable working. In a few localities, however, a number of seams have been found sufficiently close together to constitute a workable bed. The Conie mine, on Meeteetse Run, and the Rogers & Gapen mine, near Basin, are of this character, as shown in their respective sections. The coal is usually inferior in quality to that found in the basal sandy series, and the contained shale and sandstone intercalations vary considerably in thickness.

So far as observed the upper sandy division contains few workable coal seams in the basin proper. The exceptions are the outcrops near the Meryl ranch, on Gray Bull River, 4 miles below Meeteetse, and the Silver Tip mine, at the extreme north end of the basin. To the north this division contains the extensive Red Lodge and Bear Creek coal deposits and probably corresponds in stratigraphic position to the coal measures of the Sheridan district, on the opposite side of the Bighorn uplift.

DISTRIBUTION OF COAL.

The distribution of coal within the confines of the Laramie area is very general. Openings might be made at frequent intervals around the entire basin. The greatest development, however, is where the larger streams have cut and exposed the coal-bearing measures. Here the most favorable conditions exist for locating mines, and the increased settlement of the irrigated valleys along the streams furnishes a local market. These districts of greatest development are limited to five: The Cody district, on Shoshone River; the Meeteetse district, on Gray Bull River; the Thermopolis district, on Bighorn River; the Basin area, on Bighorn River, near the mouth of No Wood Creek; and the newly opened Garland district, near Garland, Wyo.

Cody district.—This district embraces an area of 5 to 20 miles, with its greater dimension extending along the strike of the formation, from Heart Mountain southward to a point on Sage Creek 12 miles above its mouth. The dips are generally steep, ranging from 30° to 50°. Operations in this district are confined to two localities. The larger, known as the Burns & Roger mine, is situated 5 miles south-southeast of Cody, on the west rim of a shallow syncline through which Sage Creek flows. Coal occurs here in the lower sandstone division, 100 feet from the base of the formation. The deposit consists of three benches, separated by two shale partings. It has an eastward dip of 47°, and is included in beds of massive gray sandstone. An incline 90 feet long has been driven on the seam, with a large room on either side. The coal is hard and black, with a bright luster and uneven fracture. It does not yield readily to atmospheric agencies, and as a domestic coal is said to afford considerable satisfaction. The product of this mine will probably never be large, for the bed is thin and the pitch so steep that the limit of economic working will soon be reached. This mine furnishes a part of the fuel supply for the residents of Cody and the Shoshone River Valley. The Nevins mine, 3½ miles northeast of Cody, on the opposite side of Shoshone River, produces a small amount of coal from a 2-foot bed in the middle shaly division. The product is a good lignitic variety, but weathers easily. The following section was measured at the Burns & Roger mine:

Section at Burns & Roger mine, near Cody, Wyo.

	Ft.	In.
Coal	0	10
Bony coal	0	6
Coal	1	2
Gray slate	0	3
Coal	1	0

Considerable prospecting has been done on Sage Creek and its tributaries, in the vicinity of the Frost ranch. The principal openings are known as the Frost mine and the Mondell property. The former has been worked to some extent, but at present is abandoned. The analysis of the coal in the Mondell opening is given on page 362. It contains a small per cent of ash, but the remaining constituents show little variation from those of the average sample collected along the west edge of the Bighorn Basin.

Meeteetse district.—This, the largest coal area in the Bighorn Basin, comprises several well-developed mines located around the town of

Meeteetse, and embraces a region of about 20 square miles. The region is one of considerable structural complexity. A series of anticlinal folds with intervening synclinal troughs crosses the region with a south-southeast trend from the eastern extension of the Wasatch formation, about 3 miles below Meeteetse, to the base of the Shoshone Mountains. This folding has greatly increased the surface area of the Laramie formation, bringing the productive beds of the basal sandy series near the surface over a considerable area in the west half of the district.

Beginning at the base of the Shoshone Range, the first fold, which is small and unimportant in the present consideration, crosses Gray Bull River about 2 miles above the mouth of Rock Creek. This fold is exposed in the Benton shale. To the eastward, along Gray Bull River for a distance of 6 to 8 miles, the surface is occupied by Pierre shale. The Laramie formation is first encountered below the Frank ranch, where a bold escarpment of the basal sandy series faces the west. From here the Laramie extends eastward for about 3 miles in a synclinal trough, followed to the eastward by an eroded anticline exposing Pierre and Benton beds. These flexures have a northern extension of 4 to 5 miles, and to the southward continue to Gooseberry Creek. Still farther east, near the mouth of Rawhide Creek, are a low syncline and anticline, and to the south, toward Gooseberry Creek, a number of prominent folds occur. From the east slope of the low anticline at the mouth of Rawhide Creek the beds extend eastward with a low, uniform dip, passing beneath the Wasatch beds toward the center of the Bighorn Basin. These successive folds, with their greater lengths extending across the Meeteetse district at right angles to Gray Bull River, cause the lower coal horizon of the basal sandy series to reoccur at intervals along the banks of this stream from a point about 3 miles above Meeteetse to the vicinity of the Frank ranch.

The Conie mine, on the Meeteetse rim, 12 miles northwest of Meeteetse, has recently been reopened, after lying idle for several years. The coal is in a series of relatively thin beds, lying nearly horizontal. Its stratigraphic position is difficult to ascertain, but it is probably near the middle of the shaly division. The coal is black, with an unusually bright luster, brown streak, and subconchoidal fracture. The woody structure is maintained to a marked degree, and its resistance to weathering is slight. Its occurrence in a soft-clay formation renders it difficult to mine, and the absence of a solid roof necessitates elaborate timbering, greatly increasing the cost of operation. The mine is located in an inaccessible place, and will probably never be extensively developed. The character of this bed is illustrated in the following section:

Section of Conie mine, near Meeteetse, Wyo.

	Ft.	In.
Coal	1	2
Bony coal	0	7
Coal	0	11
Dark-gray slate	0	4
Coal	1	6
Dark-gray slate	1	8
Coal	1	6
Slate	0	4
Coal	0	8

The Orr mine is situated on a branch of Meeteetse Creek, about 3 miles northwest of Wise post-office.. This mine is well opened with a double, well-timbered tunnel, extending 100 feet from the outcrop. The deposit consists of two benches, each 3 feet thick, separated by a layer of light bluish-gray slate which is characteristic of this horizon. The coal occurs in the basal sandy series, and in appearance is black, with a bright luster, brown streak, and uneven fracture. It has a rather high per cent of fixed carbon, a moderate amount of volatile matter, and a low moisture content. This mine is worked during the winter months with a seasonal output of 300 to 400 tons. Considerable prospecting has been done near the Orr mine, and one opening has been made about a mile south which exposes a 6-foot bed of excellent coal.

The Blake mine is located about 3 miles above Meeteetse, on the north bank of Gray Bull River. Here a vein 5 feet 9 inches thick has been extensively operated, and is one of the oldest openings in the district. The dip of the beds is 9° northeast. The main tunnel is about 150 feet in length, with several side entries. The workings are too low in the river bank for perfect drainage to be effected, and some little difficulty has resulted from this condition. Operations were first begun at this place in 1892, but there was only a small output until 1898, when the property was purchased by the present owners. The total production during the past four years has exceeded 2,000 tons. In 1902 the product amounted to 900 tons with a market value of $2 per ton at the mine. There is another opening on the same horizon, a short distance up the river, owned by McDonald & Cottle, of Thermopolis. The dip in this region is low and the conditions are generally favorable for more extensive development of these properties.

Section of the Blake mine, near Meeteetse, Wyo.

	Ft.	In.
Bony coal	0	6
Clay and sandstone	6	0
Coal	3	3
Bluish-gray slate	0	3
Coal	2	6
Impure coal	0	6

That portion of the Meeteetse district lying south of Gray Bull River is separated into two parts by erosion along an anticlinal fold. The main body of coal-bearing measures lies east of Wood River, between Gray Bull River and Gooseberry Creek, and a detached portion occurs west of Wood River. The two anticlinal folds crossing the main body bring the lower coal-bearing measures of the Laramie to the surface in a number of places along Gooseberry Creek. These anticlines are roughly parallel, and extend southeastward, the lower and larger one crossing Gooseberry Creek 2 miles below the mouth of Enos Creek. On the divide about 6 or 7 miles south of Meeteetse this fold presents a deep topographic depression, known as the Upper Buffalo Basin, the center of which is occupied by Pierre shale encircled by a high wall of the coal-bearing Laramie sandstone. The upper and smaller fold crosses Gooseberry Creek about a mile above the mouth of Mud Springs Creek. This is also a topographic depression similar in structure to the Upper Buffalo Basin. Its central portion is composed of Pierre shale surrounded by a rim of basal Laramie sandstone. The greater dimension of this anticline extends from northwest to southeast and is about 6 or 7 miles long, while its greatest width will not exceed 2 miles. At the north end it is cut transversely by Gooseberry Creek, exposing the lower coal horizon of the basal sandy series. About 5 miles down Gooseberry Creek, near the mouth of Middle Fork, there is another small showing of coal which probably belongs to the same horizon. In a small ravine entering Gooseberry Creek from the south, and on the east rim of the southern extension of the Upper Buffalo Basin anticline, there is a coal opening known as the Dickie mine No. 1. This mine exposes a bed of bright, clean-looking coal 4½ feet thick, without parting. The coal is immediately overlain by a 2-foot layer of gray clay, fine grained and compact, containing carbonized plant fragments. The coal is at the lower horizon of the basal sandy series and dips at an angle of 17° east-northeast. The mine has never been worked extensively and the main entry extends but a few feet. The coal, however, is an excellent quality and the general conditions are favorable for development. There is another bed about 12 feet lower, the general character of which could not be ascertained owing to talus. The accompanying section shows the relative position of the two beds:

Section of the Dickie mine, No 1, on Gooseberry Creek, Wyoming.

	Ft.	In.
Gray, compact clay	2	0
Coal	4	6
Gray clay	3	0
Buff sandstone	6	0
Brown sandstone	2	0
Impure coal	6	0

About 3 miles southeast of Dickie mine No. 1, and 1 mile north of Grass Creek, Mr. Dickie has opened a coal bed 8 feet 3 inches thick, which is locally known as Dickie mine No. 2. The coal occurs in the basal Laramie sandstone, which here comprises the west rim of a large eroded anticline extending from the vicinity of Gooseberry Creek southeastward to Grass Creek and intersecting the latter at a point 3 miles above the mouth of Prospect Creek. The longitudinal axis of this anticline is 12 to 15 miles long and the transverse axis is considerably shorter. The central body of the basin is composed of Pierre shale, surrounded by coal-bearing Laramie sandstone. The only coal openings observed on this sandstone rim were the Dickie mine No. 2, and a small showing on the south side of Grass Creek about a mile distant. Coal of this horizon is said to outcrop, however, at frequent intervals along the southern rim of the anticline for some distance. The coal seam in Dickie mine No. 2 consists of two benches, separated by the usual bluish-white shaly parting near the middle. A 2-inch layer of light-gray shale also occurs near the top of the upper bench, but neither of these partings are sufficiently thick to affect materially the productive capacity of the seam. The coals of the upper and lower benches exhibit no essential points of difference in quality. The product is rather hard and compact, with an unusually bright luster, and the chemical analysis shows it to be a good variety of lignite. The mine is not operated at present, but the quality of the material, combined with the size and character of the seam, render it a desirable property. A section of the bed is given below:

Section of Dickie mine No. 2, near Grass Creek, Wyoming.

	Ft.	In.
Coal	4	6
Light bluish-gray slate	0	3
Coal	0	9
Light-gray slate	0	2
Coal	3	0

The small detached Laramie area lying west of Wood River is structurally a synclinal trough comprising about 20 square miles and extends from a point 3 miles north of Gray Bull River southeastward to Wood River. This area is about 10 miles long and 2 to 3 miles wide. Its axis trends N. 5° W. The formation is the basal sandy series, the overlying shaly division being absent. The sandstones of the Laramie in this region are heavily developed, and there occur immediately above and below the coal horizon massive sandstone layers 20 to 30 feet thick, the upper having a white and the lower a yellowish tint. The color and thickness of these two sandstone layers are very persistent throughout the Meeteetse district and serve as an indicator of the position of the coal. The dips vary from 20° to 40°

from rim to center, with a direction according to their position on the periphery of the syncline. They are very steep along the east and north sides, but to the west and south they decrease materially. The area is encircled by a continuous coal outcrop. The lower coal bed of the basal sandy division probably underlies the entire district, and the upper seam, 75 feet higher in the series, here locally attains a workable thickness. Development has been chiefly confined to Sunshine Gulch and its tributaries, about 3 miles north-northwest of Sunshine post-office, although openings have been made at other points within the area. None of these localities are operated at present, but the coal is said to be of excellent quality. The average thickness of the lower coal bed in Sunshine Gulch is 6 feet, while the upper seam is only 2 feet 8 inches.

A coal bed averaging 6 feet in thickness contains about 3,000,000 tons of coal per square mile, but of course there is considerable loss in working. There are now in this field about 18 square miles underlain by coal that would doubtless average 4 or more feet in thickness. On this estimate the field has a productive capacity of 36,000,000 tons. A trial pit near the north end of this area, in the sandstone bluffs on the south side of Gray Bull River, exhibits the following section:

Section of Vetter's coal opening near Meeteetse, Wyo.

	Ft	In.
Bony coal	0	3
Coal	0	10
Bony coal	0	2
Coal	1	6
Light bluish-gray slate	0	3
Coal	1	0
Dull-gray slate	1	0
Coal	0	4
Bluish-gray clay	2	6

About 4 miles northeast of Embar there is a small opening known as the Smith mine, which was formerly operated to some extent but at present is abandoned. Some of the earlier analyses of this coal show a high fuel ratio, but an unusually large amount of moisture. There is another small mine in the Laramie formation, about 2½ miles northeast of Middleton post-office, known as the Eades mine. The bed is 4 feet thick without parting, and occurs in the massive, gray sandstones of the basal Laramie. The beds dip 9° to the north. From an incline about 60 feet in length that has been driven on the dip a small amount of coal is taken out during the winter season. The coal in appearance is black, with a bright luster and uneven fracture. It does not weather easily. The following section was measured:

Section of Eades mine near Middleton, Wyo.

	Ft.	In.
Dark-gray, compact clay	2	0
Impure, coaly shale	1	0
Coal	4	0

Thermopolis district.—This district is located on the west side of the Bighorn Basin, about 12 miles north-northeast of Thermopolis, and a few miles below the mouth of Kirby Creek. The formation consists of alternating layers of massive, gray sandstone, sandy shale, and clays belonging to the basal sandy series, with an increased amount of shale, and a locally developed clinker bed occurring immediately below the principal coal seam of the district. This is the only clinker bed thus far observed. The dip of the beds is 17° north-northeast. The Jones mine was opened in this district in the summer of 1889, but the output was small for the three following years, scarcely exceeding 200 tons a year. Since 1900 the annual output has increased to 1,000 tons, but as yet only a small part of the field has been worked and the present production of this locality could be increased many times. Operations have now ceased at the Jones mine and a new opening has recently been made by McDonald & Cottle. The principal bed is 9 feet thick, overlain by a bed of sandy clay of variable thickness. Above this is another coal bed 5 feet thick. In the McDonald & Cottle mine the sandy clay reaches a minimum thickness of 2 inches, which practically unites the 2 seams, giving a total thickness of 14 feet. This is the thickest coal deposit thus far observed in the Bighorn Basin. Five other closely adjacent beds occur, 4 below and 1 above the 14-foot bed; 3 of the lower beds are said to be workable. The uppermost, outcropping 25 feet below the McDonald & Cottle vein, is 3 feet thick and apparently of good quality. The total thickness of the various beds exposed within close vertical range is approximately 30 feet. The material is a bright, firm, free-burning variety of lump coal. It gives a brown streak, breaks in blocks, and does not crumble easily on exposure. The analysis shows a rather high per cent of fixed carbon and moisture, and only a small amount of ash. At the McDonald & Cottle mine the following section was taken:

Section of the McDonald & Cottle mine near Thermopolis, Wyo.

	Ft.	In.
Coal	5	0
Dark-gray, sandy clay	0	2
Coal	9	0

An area of 1 square mile underlain by a coal bed 14 feet thick would contain 7,000,000 tons of coal, an amount far exceeding the total product of the Red Lodge mines during the past fourteen years. Of course there is always a loss in working, and in an area of broadly lenticular coal deposits allowance must be made for a certain amount of variation in thickness. In an area underlain by 30 feet of coal, 1 square mile would contain 15,000,000 tons, or, supposing that on an average only one-half that thickness were found, there would be 7,500,000 tons of coal. A determination of the productive capacity of the entire Thermopolis district was not undertaken in the present reconnaissance. The total coal acreage of this region can be only rudely estimated, for no systematic prospecting has ever been conducted, but coal outcrops may be seen along the strike of the beds for several miles, and, as the dip is uniform and moderately low, the field is undoubtedly large.

Coal is reported to occur in beds of a thickness sufficient for economic working 6 miles southwest of Tensleep post-office, near the head of some small tributaries of No Wood Creek. Here a few prospects have been made from which a small amount of coal is taken. The coal is said to be of good quality and in a favorable condition for mining on a more extended scale. Reports are also current of good outcrops on No Wood Creek, about 12 miles above its mouth, and at the head of other streams near by that rise within the confines of the Laramie formation. This part of the Bighorn Basin is thinly populated and the demand for coal is slight, therefore little prospecting has been done. An examination of this district was not undertaken, but as it is situated in a region of such general distribution of coal deposits it is probable that this area will be found to be productive.

On No Wood Creek, about 25 miles above its mouth, there is a small coal district. The principal interest attached to this locality is the fact that the deposits are contained in the basal sandstones of the so-called Dakota series, less than 50 feet above the Morrison formation. The coal has been prospected at frequent intervals for 2 or 3 miles along the strike, which here trends east-southeast, but at present operations are confined to one opening known as the Diehl & Bell mine. The deposit consists of two benches each of 4 feet, separated by a 2-inch layer of dark-colored shale. In appearance the coal is dark, with dull, earthy luster, conchoidal fracture, and resembles closely a carbonaceous shale. The analysis shows a moderately high percentage of fixed carbon and volatile matter, a low per cent of moisture, but an unusually high amount of ash. It weathers slowly, but as a domestic fuel it does not give general satisfaction. The bed thins rapidly to either side of the opening, strongly suggesting the lenticular character of the deposit. The product will not coke, but it is said to be suitable for welding purposes. The accompanying section will show the character of this deposit.

Section at Diehl & Bell mine, near Tensleep, Wyo.

	Ft.	In.
Coal	4	0
Dark-gray slate	0	2
Coal	4	0

Basin district.—The next locality of coal outcrops to the northwest is locally known as the Basin district, because of its nearness to Basin, the county seat of Bighorn County. There are two mines in this district; the larger one, located near the mouth of No Wood Creek, about 5 miles southeast of Basin, is owned by Rogers & Gapen. It has been worked continuously for about three years, although coal has been taken from this opening for more than a decade. The deposit has a measured thickness of 5 feet and contains many thin, slaty partings which, although numerous, are in total thickness insufficient to render the deposit unfit for economic development. Since 1900 the product has averaged about 400 tons a year with a market value of $2 per ton at the mine. The coal is in the shaly division, probably near the middle, but in this locality there appears to be a change in the sequence of the Laramie beds, rendering the broad divisions of the formation difficult to recognize. The character of the seam is illustrated in the following section:

Section of the Rogers & Gapen mine, near Basin, Wyo.

	Ft.	In.
Coal	1	1
Impure, coaly shale	0	1
Coal	0	8
Black shale	0	2
Coal	0	7
Dark-gray clay	0	6
Coal	0	5
Coaly shale	0	2
Coal	0	11
Dark-gray clay	0	2
Coal	1	3

There is another mine in this district, located about 1 mile southwest of Basin, owned by G. N. Mecklen. The bed is 2½ feet thick, with a 6-inch shaly parting near the base. The coal is contained in the basal sandy series, which here dips to the southward at such a steep angle that the limit of economic mining will soon be reached. This mine produces about 600 tons a year, which is consumed by the residents of Basin and the Bighorn River Valley. The mine is poorly improved and the bed is too thin to warrant any considerable development, as is shown by the following section:

Section of Mecklen mine, near Basin, Wyo.

	Ft.	In.
Coal	2	0
Dark-gray slate	0	6
Coal	0	6

Along the exposed area of the Laramie formation, between Gray Bull and Shoshone rivers, some prospecting has been done, resulting in the location of a few thin coal deposits, all of which are under the limit of a profitable working thickness.

Garland district.—About 3 miles northwest of Garland a small coal district has recently been explored. The coal is in the basal sandy division, which is here represented by a series of low sandstone ridges dipping gently southwestward, and soon passing under the Wasatch toward the center of the basin. There are two mines doing development work at present—the Wyoming Coal and Fuel Company and the Garland Coal Company. The mines are located within a few yards of each other, and both are working the same coal deposit, although a comparison of the beds at the two openings shows considerable local variation. At the former the deposit is composed of an upper and lower bench, containing two distinct varieties of coal. In the upper bench, which is 2 feet 2 inches thick, the coal is a black variety of lignite, with a bright, shiny luster. It occurs in layers and breaks in blocks. The lower bench, having a thickness of 1 foot 4 inches, consists chiefly of a brown carbonaceous shale with numerous thin layers of coal. The proportion of shale to coal varies, the former sometimes disappearing entirely. The two benches are not separated by a layer of shale, as is usually the case at this horizon, but the sudden change in the character of the material indicates the dividing line.

At the Garland Coal Company's mine a slightly different section is observed. Here there is an increase in the thickness of the upper bench, but in quality no essential points of difference can be noted. In the lower bench of this mine the coal predominates over the carbonaceous shale, the change having been affected by the rapid thickening and uniting of the thin coal layers. The product of both benches resists weathering fairly well for a lignite variety, and that of the upper bench is said to be suitable for metallurgical purposes. Midway between the two mines the Wyoming Coal and Fuel Company has opened at this horizon a trial pit which exhibits 4 feet 3 inches of coal without parting. The coal of the lower bench is entirely free from carbonaceous shale, and in its physical properties has the appearance of being superior to that of the upper bench. The region is one of low, uniform dips, and the contained coal could easily be mined. No other coal beds were observed above or below this horizon. The mines are less than a quarter of a mile from the Toluca-Cody branch of the Burlington and Missouri River Railroad, so that a sidetrack might be constructed at a nominal cost, which would enable the companies to ship this product. The following measurements were taken at the three different openings along the strike:

Section at Wyoming Coal and Fuel Company's mine, Garland, Wyo.

	Ft.	In.
Coal	2	2
Brown carbonaceous shale with streaks of coal	1	4

Section of trial pit at Wyoming Coal and Fuel Company, Garland, Wyo.

	Ft.	In.
Dark-gray, compact clay	4	0
Coal	4	3

Section at Garland Coal Company's mine, Garland, Wyo.

	Ft.	In.
Dark-gray clay	2	0
Coal	3	6
Coal with streaks of carbonaceous shale	2	6

Silver Tip district.—This district is located on the divide between Clark Fork and Gray Bull River, near the head of Cottonwood Creek. In the vicinity there are several small openings, of which the Silver Tip mine is the most important. The work at this place so far can be regarded only as development, although about 500 tons of coal of a good quality have been taken out. The total thickness of the deposit is 5 feet, with two partings of impure coal and a thin layer of soft, light-colored clay. The tunnel extends 60 feet from the outcrop at present, but plans for more extensive development have been consummated. The analysis of this coal shows a rather high percentage of fixed carbon and volatile, combustible matter, with a low per cent of water and ash. Of principal interest is the fact that the coal occurs in the upper sandy division, which is the highest member of the Laramie in the Bighorn Basin. It is in the same formation as the Red Lodge coal measures, and as these deposits have been traced more than 150 miles to the northwest, showing marked continuity, it seems reasonable to expect their southeastern extension to be found in the high divide south of Clark Fork, the vicinity of the Silver Tip mine. Some prospecting has been done in this region, but, judging from the productivity of these measures elsewhere, it is believed that a careful, systematic investigation would probably result in the location of other valuable coal beds. A section of the deposits at the Silver Tip mine is here given:

Section at Silver Tip mine, Wyoming.

	Ft.	In.
Coal	1	10
Bony coal	0	2
Coal	0	6
Light-gray clay	0	1
Coal	0	5
Impure coal	0	2
Coal	3	3

The data obtained in the present reconnaissance, concerning the occurrence of coal in the Bighorn Basin, is on the whole encouraging. While the region can probably not be regarded as one of general promise for large production or shipment, yet there are two or more localities within the basin where the quality of the coal, combined with the number, size, and character of the seams, warrants extensive development. There are other localities in which a careful, detailed investigation, both by prospecting and drilling, is to be recommended. The general distribution of coal in large or small quantities throughout the entire exposed area of the Laramie formation encircling the basin is most important, in that it will always furnish an inexpensive fuel supply to settlers living along the local irrigated valleys. Comparison of the chemical analysis of a representative sample of coal from the Bighorn Basin with that of similar products elsewhere, shows it to be a good, average variety of lignite, fully capable of competing with some of the standard lignite coals now on the western market. Coal enterprises in the Bighorn Basin hitherto have been and still are comparatively small and unimportant, and much of the work can be regarded only as development. This is not due, however, to a limited supply of coal, but rather to the smallness of the demand, which is necessarily limited by the remoteness of the district from large industrial enterprises and the absence of rapid transit. From 1889 to 1900 the total coal production of the Bighorn Basin was 3,000 tons, taken from 6 or 8 small and poorly improved mines. In 1903, 12 of the larger openings produced over 5,000 tons. At present the Wyoming Coal and Fuel Company, of the Garland district, is making preparations to place its coal on the market, and in other districts, particularly the Thermopolis and Meeteetse, the present output would doubtless be increased many times if shipping facilities were available.

Rocky Fork district.—While the Rocky Fork district, comprising among others the Red Lodge and Bear Creek mines, is outside the area to which this report relates, it has such an important bearing on the possibilities of the coal deposits in the north end of the Bighorn Basin, especially those of the Silver Tip district, that a brief description is here given.

For a more extended account of this field the reader is referred to a report by Mr. J. E. Wolff of the Northern Transcontinental Survey.[a] Mr. W. H. Weed, of the United States Geological Survey,[b] has since described these beds in connection with other coal deposits in Montana. A brief statement of the nature of the deposits has also been published by Mr. G. H. Eldridge.[c]

The Red Lodge coal deposits are contained in a series of massive, gray sandstones and shales, the latter predominating, which overlie the middle shaly division. This series occurs near the middle of the

[a] Wolff, J. E., Report on the Rock Creek coal field, Montana: Tenth Census of the United States, 1886, pp. 755 and plates.

[b] Weed, W. H., The coal fields of Montana: Eng. and Min. Jour., vol. 53, No. 20, 1892, pp. 520-522.

[c] Eldridge, G. H., A geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No. 119, 1894, p. 53.

Laramie formation as represented in central Wyoming. The coal measures occur within a series about 1,000 feet thick. There are seven workable beds in the Red Lodge mine, varying in widths from 5 to 14 feet, and comprising a total thickness of approximately 54 feet. These different deposits are designated as Nos. 1, 2, 3, 4, 4½, 5, and 6. Beginning at the top, No. 1 has a thickness of 5 feet, with a 2-inch layer of bony coal near the middle. It is overlain by massive sandstones and underlain by so-called fire clay. No. 2 is 7 feet thick, overlain by an impure, coaly shale, varying in thickness from a few inches to 2 feet. No. 3 has a total thickness of 14 feet, with many shale intercalations. Seam No. 4 is 8 feet 2 inches thick and contains several small partings. No. 4½, a horizon recently developed in the Red Lodge mine, has a thickness of 4½ feet with one 2-inch parting of bony coal. The roof is composed of massive, gray sandstone, the floor of a gray, compact clay. Seam No. 5 has a total thickness of 11 feet, but contains numerous shale intercalations which will aggregate 4 feet. A 2-foot layer of soft, gray, sandy shale immediately overlies the coal, merging upward into massive, gray sandstone. Bed No. 6, the lowest in the series, is 5 feet thick. It has a roof of hard, gray shale, varying in width from 6 inches to 3 feet. The product of these different beds shows some variation in quality. That of Nos. 2 and 4 is preferred as a domestic and steam coal, while No. 6 is best suited for metallurgical purposes. In addition, 13 coal horizons are reported to occur below, 5 of which are said to be of workable character. The coal measures outcrop along the east bluff of Rocky Fork, with a varying southerly dip of 17° at the Red Lodge mine, but this dip rapidly decreases to the southeast and south.

Development was first begun in this district at Red Lodge, Mont., in 1887, but the output was small for the two succeeding years. The first shipments were made in 1889, and since that time there has been an annual production of 600,000 tons, with a shipping value of about $2 per ton. The product in 1902 was over a half million tons, valued at $1,200,000. The mine was formerly operated by the Rocky Fork Coal Company, but in 1899 was purchased by the Northwestern Improvement Company. A large portion of the product is shipped northwest.

About 4 miles southeast of Red Lodge, Mont., at the head of Bear Creek, several openings have been made. This area is locally known as the Bear Creek coal district. The coal is found in the upper sandy division of the Laramie and belongs to the same general horizon as the Red Lodge mines. The dip of the beds is 4° southwest. Five different beds have been located at this place; commencing at the top they are designated as Nos. 1, 2, 3, 4, and 5, and are 5½, 6, 8, 4, and 4 feet thick, respectively. No. 2 is the only horizon worked at present. It consists of 2 benches, each of 3 feet, separated by a 1-inch layer of dark-brown carbonaceous shale. The first opening was made at this place in 1894, but for six years following all operations were in the nature of development. In 1900 the Montana Coal and Iron Company made the first shipment, and during the past two years the total product has exceeded 4,000 tons, having a market value of $3.30 per ton. All material is shipped from Red Lodge, Mont. The coal is a superior quality of lignite and commands a good price on the market. Some of the earlier analyses of this product, taken from the surface where it had been subjected to atmospheric agencies for years, show it to be an excellent variety of lignite coal with an unusually high fuel ratio.

Chemical analyses of coals from the Bighorn Basin, Montana.

District.	Mine or prospect.	Owner of mine.	Thickness of bed.		Percentages.				Fuel ratio $\frac{C}{V\ H\text{-}C}$.	Analyst.
			Ft.	In.	Moisture.	Volatile matter.	Fixed carbon.	Ash.		
Meeteetse	12 miles northeast of town	J. B. Orr	6	0	7.07	36.03	48.03	7.07	1.33	Laboratory of Calusa-Parrot Mining and Smelting Co.
Do	3 miles west of town	Edward Blake	5	9	11.95	33.55	46.37	8.12	1.38	F. W. Traphagen, Montana Agricultural Experiment Station, Bozeman, Mont,
Do	13 miles southeast of town	David Dickie	8	3	8.85	34.15	47.90	9.10	1.40	A. B. Bombauer, Butte, Mont.
Do	3 miles below mouth of Enos Creek.	do	4	6	9.75	32.75	53.15	4.35	1.62	Do.
Thermopolis	12 miles northeast of town	McDonald & Cottle	14	0	14.86	37.54	43.94	3.66	1.17	F. J. Augier, Edgemont, S. Dak.
Tensleep	9 miles northwest of town	Diehl & Bell	8	0	3.00	35.00	44.02	11.05	1.26	Laboratory of W. A. Clark, Butte, Mont.
Basin	Mouth of No Wood Creek	Rogers & Gapen	4	11	9.75	43.52	38.17	8.56	0.88	
Silver Tip	12 miles northwest of Garland.	Silver Tip Coal Co.	5	0	8.40	34.15	49.35	8.10	1.44	Do.
Cody	3 miles northeast of town	Fred Nevins	2	6	8.82	28.37	46.87	15.92	1.65	Do.
Do	14 miles southeast of town	Mr. Mondell	5	8	12.87	42.20	40.10	4.83	0.95	M. H. Wickhorst, Aurora, Ill.

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PETROLEUM, NATURAL GAS, AND ASPHALT.

PETROLEUM FIELDS OF ALASKA AND THE BERING[a] RIVER COAL FIELDS.[b]

By G. C. Martin.

INTRODUCTION.

For several years indications of petroleum have been observed at Cape Yaktag,[c] near Controller Bay, on the western shore of Cook Inlet, and at many points on the Alaska Peninsula; and high-grade coal has been known on Bering River. A large amount of capital has been invested in these fields, several wells having been drilled, many coal openings made, and other improvements undertaken and projected. The verbal and newspaper reports from the region have been varied and conflicting, while such statements as have been published by geologists have not been based upon their own observations. Some of the petroleum and coal properties have been carefully examined by geologists or mining engineers in the interests of the owners, but their reports have not been made public.

In response to the general demand for information, a reconnaissance of the petroleum and coal fields in the vicinity of Controller Bay and Bering River and of the petroleum fields on the west shore of Cook Inlet and at Cold Bay was made by the writer during the months of June, July, and August, 1903. The following is a brief statement of the results of the investigation; a more complete discussion, together with maps of the regions, is in preparation and will shortly be published:

These fields, though widely separated, are all on the southern coast of Alaska and, except the Bering River coal field, on tide water. The Controller Bay petroleum fields are near the mouth of Copper River, and the Cape Yaktag fields are 75 miles farther east. The Cook Inlet fields are about 320 miles west of Controller Bay, in the middle part of the western shore of Cook Inlet, and the Cold Bay field is about 160

[a] On some maps called Chilkat River. [b] Abstract of report in preparation.
[c] Commonly spelled Yakatag or Yakataga.

miles to the southwest, on the southern shore of the Alaska Peninsula. The Bering River coal fields are from 20 to 40 miles from the coast, in the valley of Bering River, which flows into Controller Bay.

All these regions may be reached directly from Seattle by steamer, except the Cape Yaktag field, where there is no steamer landing. Controller Bay is from seven to nine days' sail from Seattle; Cook Inlet is about three days farther, while Cold Bay is two days beyond this. In order to reach the Cape Yaktag fields it is necessary to secure a small boat for the trip from Controller Bay.

CONTROLLER BAY PETROLEUM FIELD.

GEOGRAPHY.

Controller Bay is an indentation of the coast about 100 miles west of Mount St. Elias, sheltered on the southeast by Cape Suckling and on the southwest by a group of islands of which the largest is Kayak. The area here to be discussed includes the shores of Controller Bay and the adjacent region, with an irregular group of low peaks having no uniform elevation or trend, which form the foothills of the Chugach Mountains to the north. These foothills are highest near the mountains and fall away irregularly toward the sea, where few points are more than 2,000 feet high. The eastern shore of Controller Bay and of Bering River is low and almost flat.

Bering River, with its tributaries, drains the central part of this region and flows through Bering Lake, which is about 10 miles from the sea. Above the lake it receives as tributaries Canyon Creek and Stillwater Creek, which drains Lake Kushtahkah. Shepherd Creek enters Bering Lake from the north at its northeast corner. Nitchawak River enters Bering River from the east between the lower end of the lake and Controller Bay. Katalla River and a number of small streams drain the peninsula between Bering Lake and Controller Bay. The region northwest of the valley of Katalla River drains into the Copper River delta.

Most of the lowlands about Controller Bay are covered with a dense forest. Spruce, fir, and hemlock predominate among the larger trees and are of good size and fair quality. This heavy growth extends up the hillsides to an elevation of about 1,000 feet, where it gives way to less dense timber of the same species, and grades into a zone in which scrub alders are far in excess of the other trees. In the lower part of the valley of Shepherd Creek and in the valley of Katalla River there are meadows covered with a luxuriant growth of grass.

The various companies interested in the development of this region have built trails from cabin to cabin, and land travel is confined to these. The network of rivers, however, makes it very easy to get about in small boats, so almost all travel is done in this way.

The most important settlements are Kayak, on Little Kayak Island, which is the steamer landing and post-office for the entire region, and the town of Katalla, at the mouth of Katalla River. There are no other settlements, except the camps of the various operating companies and several small Indian villages.

GEOLOGY.

The rocks include a complex semimetamorphosed series, a series of oil-bearing shales, a series of coal measures, and a few igneous rocks.

The semimetamorphosed beds consist of sandstone, limestone, and shales, which are well exposed on the coast west of Katalla. Fox Islands and apparently the extreme southwestern point of Little Kayak Island are also composed of these rocks. They vary in color from dark gray to dull tones of red and green, and frequently have a mottled appearance. They are usually somewhat crumpled, and do not carry any evidence of their age or of their relation to the other rocks of the region.

The oil-bearing shales consist of a series of dark argillaceous and carbonaceous shales, with occasional bands of sandstone, limestone, conglomerate, and glauconitic rock. They occupy the peninsula between Controller Bay and Bering Lake and extend beyond Bering River to the east. No estimate could be made of the thickness of these shales. The few fossils which have been obtained indicate that they are of Tertiary age.

The Coal Measures, which apparently overlie the oil-bearing shales, consist of many hundred and perhaps several thousand feet of sandstone and shale, with many coal seams. The sandstones are usually coarse and are frequently feldspathic. There is no evidence as to the age of the formation, except that the general structure of the region is such as to indicate very strongly that the Coal Measures overlie the oil-bearing sands, which are of an indefinite horizon in the Tertiary.

There are several masses of igneous rock in various parts of this region.

Structure.—The structure is very complex, at least so far as the minor details are concerned. There appears to be a larger folding, modified by a minor folding, that often reveals itself merely as a crumpling in the softer shales, but which is locally so strongly developed as to obscure the major folding. There are thus two sets of structural features, one of which reveals itself in an east-west, the other in a northeast-southwest strike. The first is well shown in the great anticline which is described below as extending along the coast at Cape Yaktag, and again appears in many of the exposures of this region, especially along the coast near Katalla. Of the second series of folds, those extending in a direction from northeast to southwest, one of the most illustrative is the anticline which apparently extends along the center of the Katalla Valley. This is paralleled by a number of other folds east of it in the peninsula between Bering Lake and Controller Bay, one of the most distinct being the anticline in the little valley nearest Bering River. The central part of the peninsula appears to consist of a succession of folds, several of which are exposed in the valley of Burls Creek.

OCCURRENCE OF PETROLEUM.

Petroleum seepages.—Petroleum seepages are very abundant in the Controller Bay region. Those which are best known are situated about 4 miles east of Katalla. The flow of oil is here very large, and good-sized pools have collected on the surface. Another group of seepages is on the headwaters of Burls Creek, where the petroleum may be seen oozing from the joints and bedding planes of the carbonaceous and glauconitic shales which are exposed in the deep ravines. The quantity of petroleum here exposed is not as large as at the seepages east of Katalla, but is more widespread. The small stream between Burls Creek and Bering River has several seepages along its east bank. Seepages occur, too, in other parts of the peninsula between Bering Lake and Controller Bay and in the region west of Katalla. The so-called Nitchawak region, which is situated on the banks of the various branches of Nitchawak River and in the vicinity of Mount Nitchawak, also presents a number of seepages. Some of these are located on the banks of a small lake, which is reported to be at times covered with petroleum. The small creeks which enter Little Nitchawak River from the north have a number of seepages on their banks, in some of which oil issues directly from the rock, which is here a shale.

A strong flow of gas bubbles to the surface of the water at a number of places along the lower course of Katalla River. In places this flow is so strong that it can be heard for a distance of several hundred feet. The composition of the gas is not known.

Several large sulphur springs issue from the northern bank of Bering River within a mile on either side of the Indian village.

Petroleum wells.—The first well in the Controller Bay region was drilled in the summer of 1901. Work upon it was stopped owing to the loss of tools.

The same company drilled another well in the summer of 1902, which at a depth of about 250 feet yielded petroleum. At a depth of 350 feet the tools appeared to break through into a cavity of the rock and a large flow of oil began, spouting, it is reported, many feet above the top of the derrick. No estimate of the amount of the flow has been made. This well was immediately capped, to be reopened in July, 1903, and drilled deeper. In September of this year the depth attained was between 400 and 500 feet, drilling still continuing.

Encouraged by such success, another company in the spring of 1903 began work on a well about 4,000 feet south of the first one. In July this well was abandoned at a depth of 1,700 feet, that being as far as it was possible to drill with the light rig which was used. No flow of oil was encountered in this well, but a little was brought up in the bailer from time to time.

It should be noted, in comparing the results obtained in these two wells, that the location of the second with reference to the first is in the direction of the dip. The dip is very steep in the interval of 4,000 feet between the wells, and while the exact amount is undetermined, it is surely enough to carry the oil sand which was tapped in the first well to a depth considerably exceeding 3,000 feet at the location of the second.

A third company began drilling in July, 1903, on one of the islands of Bering River, about 7 miles above the mouth. In September they had reached a depth of over 500 feet, with no indication of oil.

Another well, also begun during July, 1903, is on the north bank of Katalla River, about 2 miles above the town of Katalla. No information has since been obtained concerning it. At the time the writer left Alaska, in September, a number of other wells were about to be drilled, but no account of their progress has been received.

Structural relations of the petroleum.—The conditions believed by the majority of observers to be necessary to the occurrence of petroleum in commercial quantities are, first, the presence, originally, of a large amount of organic matter in the sediments from which the oil was derived; second, the existence of a porous rock, in the aggregate very considerable, in which the oil could accumulate; and, third, the protection of this rock in such a manner that the oil can not escape. The condition generally regarded as affording the most efficient protection is the presence of an overlying stratum of fine, compact rock, which the oil can not penetrate, and the flexure of the strata into a gentle anticline, so that escape of the oil is cut off, both in an upward direction and laterally, in the latter case, it may be, by the body of water behind it. Other conditions which govern the accumulation and distribution of oil are changes in the porosity of the containing bed, either from variation in the coarseness of sediment, or from the filling of the interstices with mineral deposits; for example, carbonate of lime. Underground water, also, doubtless plays a part in the accumulation and distribution of oil.

From the size and distribution of the seepages it may be reasonably inferred that a vast amount of organic matter which was subsequently converted into petroleum was incorporated with the sediments now constituting the oil-bearing shales of the Controller Bay region. The appearance of the rocks is evidence that there are numerous horizons in the series sufficiently porous to afford reservoirs for the accumulation of oil, and the successful well shows that the conditions are favorable for at least one productive field. It is, however, frequently very difficult to ascertain conditions below the surface, and the aid ordinarily derived from well records is not yet sufficient in this field to show conclusively the relation in depth between the occurrence of the oil and the structure and stratigraphy of the containing series. The structure of the field is complex, but if drillings are made after a careful consideration of all geologic details, the existence of valuable oil areas may perhaps soon be proved and their definition safely suggested.

Properties of the petroleum.—A sample of the petroleum from the well near Katalla has been tested by Penniman and Browne, of Baltimore, with the following results:

Test of petroleum from Katalla, Alaska.

Specific gravity	39.1° B. (0.828 at 15.5° C.).
Distillation by Engler's method:	
Benzine (80°–150° C.)	21 per cent, 54.9° B. (0.7573)
Burning oil (150°–300° C.)	51 per cent, 40.6° B. (0.8204)
Residuum (paraffin base)	28 per cent, 23.9° B. (0.9096)
Sulphur	Trace.

The burning oil was purified by concentrated sulphuric acid and soda, the volume of acid used up being too small to measure. The purified burning oil was put into a small lamp, where it burned dry without incrusting the wick or corroding the burner, and without any marked diminution of flame. The burning oil compares very favorably in these respects with Pennsylvania oil prepared in the same way.

The results of the tests may be compared with those of other petroleums in the following table:

Tests of petroleum from Alaska and other fields.

	1. Alaska.	2. Pennsylvania.	3. Ohio.	4. Colorado.	5. Mexico.	6. Beaumont.
Benzine (80°–150° C.)	21	16½	10	16	10	2½
Burning oil (150°–300° C.)	51	54	50	40	60	40
Residuum	28	29	40	44	30	57½
Sulphur	Tr.					1.7
Specific gravity	39.1°B.			43°B.		22°B.

1. Penniman and Browne for this report.
2. S. F. Peckham, Report on Petroleum, p. 365.
3. Durand Woodman, Jour. Am. Chem. Soc., vol. 13; p. 168.
4. F. H. Oliphant, Mineral Resources U. S., 1901, Petroleum, p. 560.
5. T. B. Stillman, Engineering Chemistry, p. 364.
6. Hayes and Kennedy, Oil fields of Texas-Louisiana coastal plain: Bull. U. S. Geol. Survey No. 212, pp. 146–151.

The petroleum is clearly a refining oil of the same general nature as the Pennsylvania petroleum. It resembles the latter in having a high proportion of the more volatile compounds and a paraffin base, and in containing almost no sulphur.

The proportions of the several constituents given in the table above do not necessarily represent the full amounts that could be obtained in practice by different treatment.

CAPE YAKTAG PETROLEUM FIELD.

Cape Yaktag is situated about 75 miles east of Controller Bay. The shore line is here straight and there is no harbor which affords shelter for any kind of boat. A strip of land from 5 to 10 miles in width lies between the coast and Bering Glacier. The ice front is marked by a line of hills which are parallel to the coast and from which a steep slope descends to the sea. This slope is drained by many short parallel streams, some of which head in the ice. The Cape Yaktag oil field extends eastward for about 25 miles from the mouth of Yaktag River, which is the easternmost of the longer streams reaching the ocean near Cape Yaktag.

GEOLOGY.

The writer was not able to visit this region, so that the following observations are based upon the statement of others. The structure, it is said, is anticlinal, with the axis parallel to and very near the shore line. The dip on the southern flank of the fold is very steep, the rocks standing vertically along the beach. The dip on the northern side is much gentler, seldom exceeding 20°. The rocks consist of shales with interbedded sandstone and limestone, the whole resembling very closely in lithologic character the rocks of the Controller Bay oil field. The northward dip continues inland as far as the region has been explored. The structure is very uniform, no marked variations from the strike and dip recorded above having been noticed.

BERING RIVER COAL FIELD.

Bering River coal field is situated from 12 to 25 miles inland from Controller Bay. The coal area, as far as known, is restricted to the region north of Bering Lake and upper Bering River. Its southern boundary appears to coincide approximately with the position of the lake and with Bering River above the lake. The western boundary, although not definitely known, is assumed to lie along a north-south line extending through the north arm of Bering Lake parallel to its western shore. The northern and eastern boundaries are also uncertain, but are probably at a considerable distance beyond the region as now known. The coal area as at present recognized includes about 85 square miles.

The following sections of the coal seams have been measured:

Section in tunnel on east bank of Carbon Creek.

	Ft.	In.
Dark shale	2	0
Coal	20	0
Massive, arkosic, cross-bedded sandstone with many thin carbonaceous streaks	10	0

The strike at this point is N. 65° E. The roof of the seam dips 60° NW., the floor 78° NW.

About 100 yards northwest of this point a seam containing about 3 feet of clean coal has been exposed. One mile northwest, at what is known as Doyle Camp, a coal seam 20½ feet thick is exposed. The strike of the roof is N. 10° E., of the floor N. 30° W.; the dip is from 75° to 85° E. Both roof and floor are very irregular.

Section 1 mile northwest of canoe landing on Shepherd Creek.

	Ft.	in.
Coal	3	0
Shale	0	2
Coal	4	4

The strike at this point is N. 20° E., the dip 65° NW. This opening is on the west side of the valley of Shepherd Creek, at an elevation of about 200 feet above the lake.

Four seams are exposed on the east bank of Canyon Creek. Three miles above the mouth of Canyon Creek the coal has a thickness of 2 feet, 9 inches. It is overlain by sandstone and has a shale floor. The strike is N. 80° E., the dip 35° W. The section was measured at the level of the valley floor. This seam is variable in thickness, pinching out somewhat higher in the bluff.

Four miles above the mouth of Canyon Creek the coal has a thickness of 4 feet, 2 inches; it strikes N. 10° E., and dips 60° W. It has a shale roof and shale floor.

At the south end of Carbon Mountain there is a high bluff where Bering River has been pushed against the end of the mountain by the Bering Glacier. In this bluff the following section was measured:

Section at south end of Carbon Mountain.

	Feet.
Sandstone	30
Coke	1
Sandstone	20
Coke	2
Sandstone	2 to 5
Coke	1 to 5
Sandstone	3
Coke	1
Sandstone	8
Coke	1¾ to 2¼

The strike at this point is N. 80° W., the dip from 20° to 25° N.

The following section is exposed in the west bank of Trout Creek, 2 miles above its juncture with Stillwater Creek, and 6 miles above the mouth of the latter:

Section on Trout Creek.

	Feet.
Shale	4
Coal	6½
Sandstone	5

The strike is N. 40° E., the dip 38° W.

At a point on the north shore of Bering Lake a coal seam has been exposed which has a thickness of about 2 feet. The roof was not seen; the floor is massive sandstone.

The preceding include all the coal sections which were accessible at the time the region was studied; it is reported, however, that there are many other seams, some of them exceeding in thickness any which the writer saw. Two of these, said to be 35 and 40 feet thick, have been opened on the headwaters of Carbon Creek, and it is rumored that a still thicker seam had been discovered in the Stillwater Valley during the latter part of the summer of 1903. Smaller seams have been opened on the shores of Lake Kushakah and on the north shore of Bering Lake.

It is the opinion of the writer that the foregoing sections represent distinct coals, and that furthermore, from the smut observed by him in the development of the country, many additional ones will be discovered which are now concealed beneath the soil and the dense vegetation.

Owing to the general northerly dip throughout the coal field, the northern portion of it, as at present recognized, is underlain by a far greater number of seams than the southern. The northward extent of the field, however, the nature of its structure, and the manner of its termination, remain unknown.

The features to be considered by the mining engineer embrace faults and their attendant problems; steep dips; the physical properties of the coal as affecting its shipment and market value, a tendency to crush being especially noticeable; the proportion of the seams above water level, and their accessibility.

CHARACTER OF THE COAL.

The physical properties of the coal are very much alike in all seams and in all parts of the field seen by the writer. The coal resembles the harder bituminous coals of the East more than it does anthracite. It is doubtful if much of the coal could be sized so as to compete with anthracite coal for domestic use. Under ordinary handling it will probably crush to almost the same extent as the harder grades of semi-bituminous coal. This will not, of course, impair its value as a steam fuel, but it will necessitate careful handling if the coal is to compete with Pennsylvania or Welsh anthracite as a domestic fuel.

The following table includes all the analyses and calorimetric tests which have been made upon the Bering River coal. The first five samples were collected by the author and represent the composition of the entire seam; that is, coal was cut evenly from the seam from roof to floor.

Analyses and tests of Bering River coals.

Locality.	Thickness of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Color of ash.	Calories.	Recalculated. Fuel elements. Volatile matter.	Recalculated. Fuel elements. Fixed carbon.	Recalculated. Fuel ratio.
	Feet.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*			*Per cent.*	*Per cent.*	
1. Carbon Creek[a]	20	2.41	15.03	79.24	3.32	0.51	Reddish	8,345	15.94	84.06	5.27
2. Shepherd Creek[a]	$7\frac{1}{3}$	1.54	14.58	72.99	10.89	.69	Yellow	7,664	16.65	83.35	5.01
3. Trout Creek[a]	$6\frac{1}{2}$	2.36	18.12	71.87	7.65	.73	Reddish	7,819	20.14	79.86	3.97
4. Canyon Creek[a]	$4\frac{1}{6}$	3.24	9.79	62.97	24.00	1.94	Yellow	6,502	13.45	86.55	6.43
5. South end of Carbon Mountain (coke)[a]	5	1.34	6.30	84.57	7.79	.77	Very red	7,776	6.93	93.07	13.43
6. Controller Bay[b]	......	.75	13.25	82.40	3.60	.69	....	......	13.85	86.15	6.22
7. Icy Bay[b]	......	.78	13.22	80.30	5.70	2.90	....	......	14.13	85.86	6.07
8. Bering River[c]	......	.77	13.79	82.36	3.08	2.68	....	......	14.34	85.66	5.97

[a] Sample collected by G. C. Martin. Analysis and calorimeter test by Penniman and Browne.

[b] Analysis furnished by F. H. Shepard. Published by J. E. Spurr: Reconnaissance in Southwest Alaska. Twentieth Annual Rept. U. S. Geol. Survey, pt. 7, p. 263.

[c] Sample collected by W. M. Carless. Analysis by W. F. Hillebrand. Published by Schrader and Spencer. Geology and Mineral Resources of a Portion of the Copper River District, Alaska, p. 91.

These coals vary greatly in composition and in heating power, and it seems likely that in this field, as everywhere, each seam will be found to have a characteristic composition. The source of Nos. 6, 7, and 8 is not known, but possibly Nos. 6 and 8 are from the opening on Carbon Creek, from which No. 1 was obtained. The difference in the amount of moisture in these samples and in those collected by the author is probably due to the fact that the latter were placed in sealed cans as soon as taken and no opportunity was given for the coal to dry out. The very high percentage of sulphur in Nos. 7 and 8 is probably due to their having been taken, not from the entire thickness of the seam, but from pieces of coal which were picked for their hardness and apparent cleanness. The one who took the samples evidently overlooked the fact that their exceptional hardness was not due to the coal being a higher grade of anthracite, but to its containing a large amount of pyrite (sulphide of iron).

The 20-foot seam now exposed in the tunnel on Carbon Creek is the most promising coal seen by the writer. It not only possesses the greatest thickness and is entirely free from bands of shale and other impurities, but, as the above table shows, it is the purest coal and has the highest heating power. Its composition shows it to be semianthracite of somewhat the same composition as the coal of the Bernice Basin (Loyalsock) in Pennsylvania,[a] although it is purer and has a higher heating power than that coal. It differs from the anthracite of Pennsylvania and Wales in having more volatile matter in proportion to the amount of fixed carbon. In the ratio of fixed carbon to volatile matter it is nearer to the Bernice Basin coal than to any other coal that reaches the general market. In heating power as well as in the low amount of impurities it is almost identical with the Pocahontas steam coal of West Virginia, but excels this coal by having a higher proportion of fixed carbon. There is no other coal with which it is likely to come into general competition with which it is to be compared, for it is far higher in heating power and in purity than any coal that is mined upon the Pacific coast, either in the United States, Canada, or Australia.

The seams opened on Shepherd Creek 1 mile northwest of Canoe Landing, and also near the headwaters of Trout Creek, are probably representative of the thinner seams of this region. These coals differ from the coal of the 20-foot seam in having a less amount of fixed carbon in proportion to the volatile matter and in having a higher percentage of ash and sulphur. The heating power is consequently less. They resemble coals of the semibituminous type that enter the market as high-grade steam coals. They correspond in texture, composition, and heating power to the high-grade Pocahontas (West Virginia) and Georges Creek (Maryland) steam coals, and also to some of the semibituminous coals of Wales.

The coke exposed in the southern end of Carbon Mountain is an interesting deposit, which may prove to be of considerable value. The analysis shows it to be of great purity and high heating power. It will be seen from the section given on page 372 that it is broken up by partings into a number of thin seams which vary considerably in thickness within short distances. It may be that some of these will be found sufficiently thick and persistent to be of economic importance. Part of the coke is dense and hard and shows a well-marked columnar structure. The latter will break into fine fragments on handling, and will thus be at a disadvantage from the market standpoint. The product should be carefully screened, when the lump will make a high grade of domestic fuel.

[a] The following is an average of several analyses of Loyalsock coal:

	Per cent.
Moisture	1.49
Volatile material	11.07
Fixed carbon	78.88
Ash	7.70
Sulphur	.86

COOK INLET PETROLEUM FIELD.

GEOGRAPHY.

The region under discussion occupies the western shore of Cook Inlet from the foreland on the north side of the entrance of Chinitua Bay southwestward for about 40 miles to the mouths of Enochkin[a] and Iliamna bays, and extends inland, with a maximum width of about 10 miles, to the crystalline rocks at the eastern front of the Chigmit Mountains. Its coast includes the deep indentations of Chinitua, Enochkin, and Iliamna bays and the lesser ones of Oil and Dry bays.

The region includes a high mountain range, a range of lower hills, and an intervening valley region. The rugged Chigmit Mountains have an average elevation of about 5,000 feet and are parallel to the general shore of the inlet. The range of lower hills, unnamed, extends from the mouth of Enochkin Bay northeastward to Snug Harbor, paralleling the coast at the distance of a mile. The general height of these hills is about 2,500 feet. A general area of depression occupies the position between these two ranges. This consists of many valleys drained by streams flowing into the bays named above, and of irregular, low, rounded hills. The divides between the drainage systems are low and permit easy portages. The streams are all small, for the most part unnamed, and entirely unnavigable.

The lowlands are covered with dense vegetation and consist of about half meadow and half forest. The meadows are deeply grassed and are dotted with groves of cottonwood and thickets of alder and willow. The forests consist of a fair growth of spruce and hemlock. The tree are not large, but are straight and sound.

A wagon road has been built from the lower landing point of Enochkin Bay to the head of Oil Bay, and there are cleared trails from the head of Oil Bay to Dry Bay, to the head of the eastern arm of Enochkin Bay, and to a point on the shore of Enochkin Bay 2 miles above the lower landing. There are also two trails from Dry Bay to the shores of Chinitua Bay, and a portage trail from the head of Enochkin Bay to the head of Chinitua Bay.

GEOLOGY.

The rocks of this region consist of a zone of a massive crystalline series exposed in the Chigmit Mountains, a sedimentary formation of Jurassic age in a belt east of them, and a series of overlying agglomerates, shales, and bedded volcanic flows, which are exposed in the coastal range of hills. The formations lie in belts parallel to the coast. The relation of the sedimentaries to the crystallines is complex and obscure,

[a] This has been variously spelled as Inerskin, Innerskin, Inischen, and Innisken, but as here given is said to be the correct spelling of the Russian name.

but the remainder of the series is conformable throughout and is gently and simply folded. The general section is as follows:

General section of Chigmit Mountains.

	Feet.
1. Sandstone, shale, and conglomerate with fossil trees	100 ?
2. Volcanic rocks (andesite, etc.) with some interbedded shale	2,000 ?
3. Shale	580
4. Volcanic rocks (andesite or agglomerate)	300
5. Shale	1,650+
6. Coarse crystalline rocks.	

The crystalline rocks of the Chigmit Mountains extend along the entire western shore of Enochkin Bay, and both shores of the northern arm of that bay. There is considerable variety to the series, but granite and rocks similar in texture and general appearance predominate.

Jurassic shales.—The rocks overlying the crystallines consist of a thin conglomerate at the base, followed by more than 1,600 feet of dark sandy shales with occasional bands of sandstone, conglomerate, and limestone and many fossil beds; they are well exposed in the cliffs on the east shore of Enochkin Bay. Rocks of the same lithologic character extend along the strike northeastward from these exposures, passing the heads of Oil and Dry bays to Chinitua Bay. They have not been followed beyond the north shore of Chinitua Bay by the writer, but from the great thickness exposed it is evident that they must extend a considerable distance. Rocks of similar lithologic character have also been reported from the vicinity of Snug Harbor. Fossils are distributed throughout the formation and show the age to be middle Jurassic.

Volcanic flows and agglomerate.—The Jurassic shales are overlain by a series of volcanic flows, probably of andesite, and by coarse agglomerate. There is some interbedded shale. The agglomerate seems to be confined to the shore of Enochkin Bay. These rocks form the high coastal ridge which extends from Enochkin Bay to and beyond Chinitua Bay, their total thickness being probably more than 2,000 feet.

Structure.—The structure of this region consists of a broad, low, somewhat undulated anticline parallel to the shore of Cook Inlet and to the general line of the eastern front of the Chigmit Mountains, followed on the west by a narrow syncline, beyond which is a second, very closely folded and probably faulted anticline. The dip in the broad, easternmost anticline is moderate in amount and very regular, except on the crest of the fold, where it is undulating, but is not in excess of 10°. On the eastern limb the dip varies from 20° to 28°, diminishing as the shore is approached, and on some of the long points and islands becoming almost or quite horizontal. The steepest dip in the southwestern part of the field was observed on the shore of

Enochkin Bay, where the rocks are inclined southeastward at an angle of 28°. The greatest dip at the northern end of the field is between half a mile and a mile southeast of the entrance to Chinitua Bay, where it is from 25° to 45° SE. On the western flanks of this anticline the dip is about 17°.

The nature of the undulations at the crest can be seen in the cliffs on the eastern side of Enochkin Bay.

The syncline which adjoins this anticline on the west is a much narrower and simpler fold. It is characterized by a steeper dip on the western than on the eastern flank. It appears to die out toward the northeast and was not recognized on Chinitua Bay.

West of this syncline is an anticline in which the rocks are badly crumpled and faulted. The crystalline rocks are exposed on its western side and at places within it. The contact of the westernmost outcrops of the shales with the crystalline rocks appears to be along the line of a great fault. The amount of pitch of the axes of these folds is not known.

OCCURRENCE OF PETROLEUM.

Surface indications.—The surface indications of petroleum in this region consist of seepages or oil springs, and the so-called gas springs. In the first, the petroleum may be seen oozing from the cracks in the rock or coming out of the soil. On the east shore of Enochkin Bay a good seepage was seen about 1,000 feet below the lower cabin, although the spring is covered at high tide. The flow is often so strong that the petroleum collects in large blotches on the pool, or even covers its entire surface. At one point it issues from a crevice in the rock, which is Jurassic shale.

In the vicinity of the cabin at Oil Bay are a number of large springs. From the bottom of one the petroleum is almost continually rising, the flow varying, however, from time to time, now almost ceasing, now becoming very strong. It is frequently possible to skim several quarts of petroleum from the surface of the pool.

About 2 miles west of the beach at Dry Bay is a so-called gas spring, gas of unknown composition rising in a continuous stream of bubbles to the surface of the water. From the north shore of Chinitua Bay both oil and gas springs have been reported, but they were not seen by the writer.

The geologic structure of this region has already been outlined. It consists of a long anticline, parallel to the coast, with an axis having a N. 80° E. trend. The dip on each flank is regular and comparatively moderate, seldom exceeding 20°. Although in the axial region of the fold the strata are faintly undulating, the crown of the arch is almost flat. Other things being equal, the fold is such, indeed, as should yield a good flow over a considerable area, granting the existence below of a porous reservoir capped by impervious beds and filled with oil. A line extending from about a mile above the lower cabin on the shore of Enochkin Bay to a point a half mile northwest of the beach at Oil Bay, thence through a point 2 miles above the beach at Dry Bay to the center of the high cliff on the north shore of Chinitua Bay, would lie at about the center of the zone which at the present seems to be the most promising. The oil sand would probably be found nearer the surface along this line than either to the southeast or northwest.

As in all cases, however, drilling is necessary to obtain a knowledge of the underground conditions, as well as to estimate the economic and commercial value of the field; thus far this has been insufficient. As regards the entire Enochkin Bay region, it is almost certain that the oil will be confined to the easternmost anticline.

Development.—Indications of petroleum were discovered in this region about fifty years ago. The first was taken out in 1882 by a Russian named Paveloff. A Mr. Edelman staked ground in 1892. His location was near the divide at the head of the creeks entering Oil and Dry bays, but the claims were subsequently abandoned. In 1896, Pomeroy and Griffen also staked property at Oil Bay, and during the next year organized the Alaska Petroleum Company. Work was begun in 1898. The Alaska Oil Company was organized in 1901, and in 1902 began drilling at Dry Bay.

The well at Oil Bay is reported to have struck a flow of 50 barrels of petroleum at a depth of about 500 feet. On drilling deeper a strong flow of water was encountered which shut off the flow of oil. The well is now over 1,000 feet in depth and affords a continuous flow of gas, which at times becomes very strong. Attempts have been made to shut off the flow of water and either recover the lost oil or drill deeper. No log could be obtained.

The well at Dry Bay was drilled to a depth of 320 feet, without encountering oil. The tools were then lost and the hole abandoned. In August, 1903, a new well was started in close proximity to the first.

The shipment of petroleum from this field would probably be from Enochkin and Chinitua bays, which are harbors affording safe anchorage to large vessels in all weather, as well as good wharf sites. Ships can, however, anchor in the mouth of Oil Bay and off Dry Bay except during very bad weather. If docks should be built either at Enochkin or Chinitua, it would be necessary to build pipe lines and pumping stations to transfer the product from the field to the shipping point. This would not, however, be a serious matter, as divides are low and construction and operation would be easy.

COLD BAY PETROLEUM FIELD.

GEOGRAPHY.

Cold Bay is situated on the south shore of the Alaska Peninsula at the southwest end of Shelikof Strait and opposite the west end of Kodiak Island. It may be reached by steamer from Seattle either direct or by transfer at Valdes or Kodiak, or from Dutch Harbor. From Seattle the time is about fifteen days; from Valdes, four. It may also be reached from Bristol Bay by a canoe and portage across the peninsula.

The southern shore of the Alaska Peninsula is very sinuous, with deep indentations and long, rugged forelands. Cold Bay is one of the best of the harbors. It is roughly triangular in shape, about 10 miles long by 7 wide at the mouth, and contains a very large area of deep water.

The surrounding country consists of an elevated upland with gently rounded or flat-topped hills rising above it. Its general level is about 750 feet above tide. Most of the higher peaks rise to an elevation of about 1,500 feet, while farther back from the coast, in the central part of the peninsula, are mountains 5,000 feet or more in height.

The streams emptying into Cold Bay and into the other bays in the vicinity are short and swift, but carry a large amount of water. The northern slope of the peninsula, on the other hand, is drained by a comparatively small number of fairly large rivers which empty either into shallow bays or directly into the sea. All of these rivers have lakes either at their headwaters or along their courses. Lake Becharof, the head of which is situated about 15 miles from the landing at Cold Bay, is one of the largest.

Timber is almost entirely lacking in this region, the only trees being a few small cottonwoods, willows, and scrub alders along the banks of the streams. This is characteristic of the greater part of the Alaska Peninsula.

GEOLOGY.

The rocks observed in the vicinity of Cold Bay consist of a few thin limestones and dark shales which break on the weathered surface with a conchoidal fracture. These alternate irregularly. Their age is Mesozoic, corresponding closely to that of the rocks of the Cook Inlet oil fields. They carry Jurassic fossils everywhere except at the promontory on the east side of the bay, where Triassic forms have been reported.

Structure.—The rocks either lie horizontal or with a dip that is very gentle, though somewhat irregular, both in amount and direction. In the forelands the general dip is northwestward. Several miles back this dies out and the rocks lie horizontal or dip slightly toward the east. Farther inland the northwestward dip is resumed and continues to the limit of the area examined by the writer. According to reports, the dip is reversed again near the center of the peninsula, so that Becharof Lake lies in a syncline, while near its northwestern shore a sharp anticline is said to rise, which brings to the surface not only the entire sedimentary series but also a mass of crystalline rocks that form the core of the peninsula throughout most of its length. It has been stated that there is a great anticline parallel to the southern coast that has its axis near the ends of the forelands. This view is sustained by the fact that on one of these promontories at least rocks older than the Jurassic are exposed, but the writer has not seen any evidence which would show how far seaward this northwestern dip may extend.

INDICATIONS OF PETROLEUM.

Petroleum seepages occur in or near the first zone of horizontal or southeastward dip described above. In this same position two wells were begun in the summer of 1903. They are located about 5 miles from the landing on the west shore of Cold Bay, and at an elevation of about 750 feet above tide. They are distant also about 9 miles in an air line from Becharof Lake.

If petroleum be stored within the series of rocks about Cold Bay, other things being equal, the very gentle folding which the strata have undergone should be favorable to the formation of large pools. The petroleum from this field has a paraffin base and is probably similar to the Controller Bay petroleum.

If petroleum should be discovered in commercial quantities in this region, it can be piped from the wells to Cold Bay by gravity and shipped from thence to San Francisco or to Puget Sound ports.

PETROLEUM RESIDUE.

On some of the hillsides several miles inland from Cold Bay are seepages of petroleum that are in some cases continuous, in others intermittent. The petroleum runs down the hillsides in the water-courses, and, in several instances, collects at the bottom of the hills in peat bogs. Losing enough of its volatile constituents by evaporation to render it immobile, it there remains, impregnating the peat and forming over its surface a thick coating of black paraffin wax.

These deposits have already been of considerable importance in the development of the region, for the peat impregnated with paraffin wax has proved a fuel of greatest value, replacing even coal from the mines of Puget Sound, imported in large amount for use under the boilers in drilling operations. The deposit which has furnished this fuel for the past season has an area of about 1½ acres, the material having been dug to a depth of about 3 feet without in some cases reaching bottom. This deposit alone contains enough of the residue to supply all local needs for fuel for some time to come. Another deposit has, however, been discovered in the vicinity which has an area of 3 acres and a thickness of at least 10 feet. Many more, also, will doubtless be brought to light.

Chemical and calorimetric tests of the petroleum residue have been made by Penniman & Browne, of Baltimore. The result of their tests follows:

Test of petroleum residue from Cold Bay.

Moisture:	
Volatile matter	85.40
Fixed carbon	7.76
Ash	6.84
Sulphur	0.36
Soluble in gasoline	68.20
Calories	8,193

The table shows a material that compares favorably with most of the coals sold on the Pacific coast. It is, indeed, their superior as regards calorific power, ash, and amount of sulphur. The amount indicated in the table as soluble in gasoline represents the petroleum residue present, the remaining 31.8 per cent consisting of peat and earthy material.

STRUCTURE OF THE BOULDER OIL FIELD, COLORADO, WITH RECORDS FOR THE YEAR 1903.

By N. M. Fenneman.

The field here referred to has be n producing petroleum in moderate quantities for the past two years. It comprises a small area centering about 3 miles northeast of Boulder, Colo., east of and within 3 miles of the foothills of the Front Range. Above 3,000 feet above sea level the entire zone traversed in drilling is within the Fort Pierre shales of the Cretaceous. Small quantities of oil have been found at various depths, from a few hundred to 3,400 feet. Sometimes the oil (or gas) has been in the sandier beds, which may occur at any and all depths, and sometimes in the shale itself. Neighboring wells find oil at very diverse depths. Further details of the occurrence of the oil and the work of obtaining it have been given in a former publication.[a]

From all observations made previous to the report just noted, there appeared to be no law governing the distribution of oils in the Fort Pierre shales. Oils are found in various parts of Colorado and neighboring States, but their structural relations, so far as known, gave vague explanations of their presence and left the prospector with the impression that oil might or might not be found at almost any place in the Fort Pierre shales.

The want of any evidence of anticlinal arches suggested the inference that such structures were unnecessary to form receptacles for oil and gas in so dense a rock as the Pierre shales. The idea that the occurrence of the oil had some connection with folds was, however, not given up, and renewed efforts were made to induce companies and drillers to preserve samples and careful records, with a view to determining the exact position of the strata.

During the last summer a detailed structural study has been made of an area of 150 square miles, of which the oil field occupies the center. The careful study of the borders of this area was made necessary by the fact that its broad central portion, containing the wells, is underlain by the Fort Pierre shales, which are in general so nonresistant and homogeneous that exposures of solid rock are extremely rare.

[a] Bull. U. S. Geol. Survey No. 213, 1903, p. 312.

Here and there among the fields or in the side of an irrigating ditch, the outcropping of a thin harder bed may be indicated by a few frag-

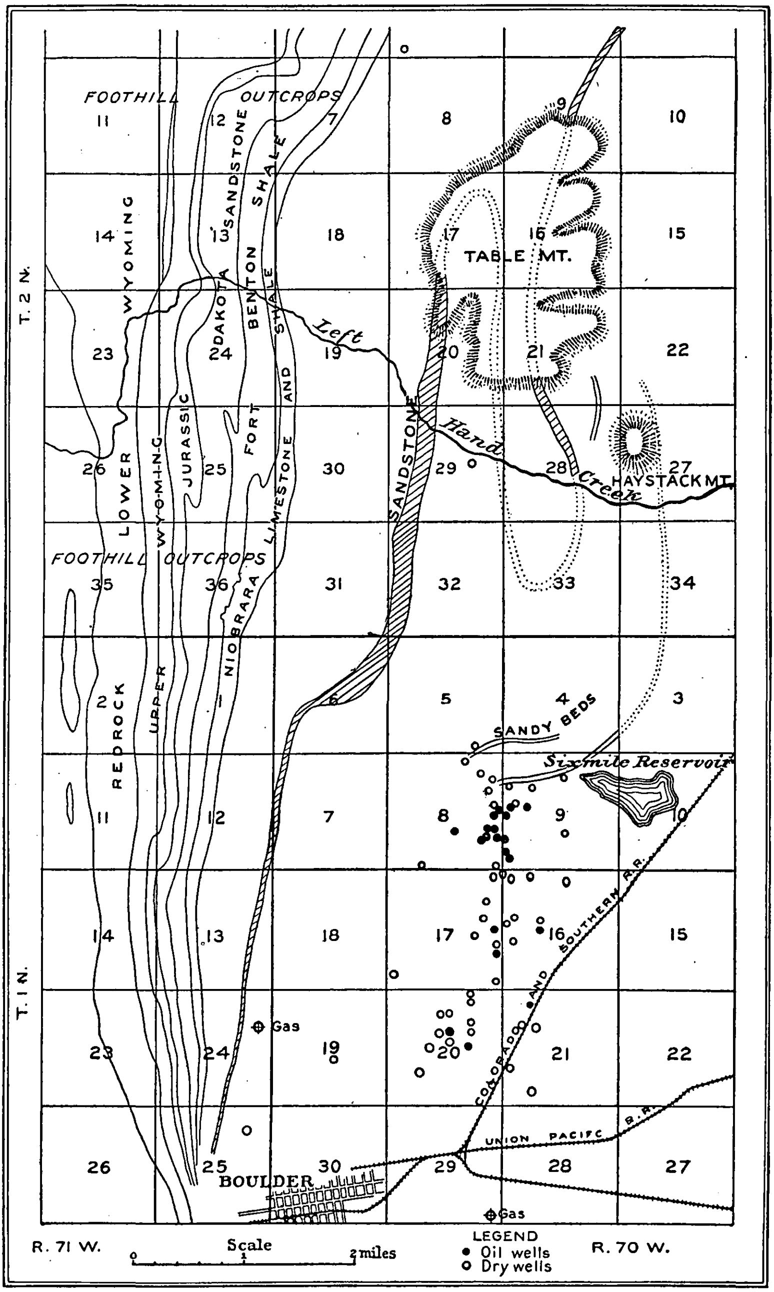

FIG. 10.—Sketch map of the Boulder oil field, Colorado.

ments and a sandier soil, but generally the bed is not strong enough to cause even a small ridge. A little excavation may sometimes reveal the position of the beds. Such indications and the still rather indefinite inferences from the comparison of well sections are the only direct means by which structure can be determined in the immediate vicinity of the oil wells.

It is otherwise with the borders of the area. On the west are the fine exposures of the firm rocks of the foothills. Their clearly revealed structure is now seen to show peculiarities corresponding to the essential structural features of the oil field. In the shales of the oil field these features can be made out only by wearisome search; their correlatives in the foothills are open to the light of day. The practical significance of this relation will be evident to any who may be prospecting for similar deposits of oil along the front of the range. On the south, east, and north are also good exposures, though only those of the north have structural significance comparing in importance with the western outcrops.

Folds.—The general dip of the Fort Pierre shales and lower strata is a little south of east. There is at the same time a tendency to folding along axes running north and south or northwest and southeast. Strong folding of this character causes actual anticlines whose direction is not quite parallel to the foothills, and the folds therefore run out in the foothill upturns. The folding may not be so strong and then there is no actual anticline, but only a check in the general eastward dip. When an actual anticline occurs the effect on an outcropping stratum is to cause its edge to make a long loop, nearly parallel with the general trend of its outcrop. When the folding does not succeed in making a true anticline but causes only an arrest in the prevailing dip the effect on its outcrop is to cause a jog, the northern part (in this case) being offset to the east of the southern portion. Both these conditions are clearly illustrated in the accompanying sketch map. Such structure is called echelon folding. It is the characteristic kind for a long distance north of Boulder.

It has been pointed out before that all the wells which have thus far produced oil are along a narrow north-south belt. It is now known that this line follows a monoclinal fold of the Fort Pierre shales, the wells being near its top and therefore in similar position to those of Ohio, described by Orton as occuring on "arrested anticlines." If extended northward, this monocline is almost in line with an incipient echelon fold, which affects the outcrop of the sandstone seen in sec. 6, by causing a strong offset to the east. The axis of this fold points south-southeast. About 5 miles farther northeast a more strongly developed fold of similar character is revealed by the outcrop of the same sandstone. The fold runs almost due south so far that an important part of it lies east of the smaller one mentioned above. Both these folds are described below. The monocline, which determines the present line of producing wells, is the southward continuation of the western and smaller of the two flexures, but is affected both in degree of flexure and in the direction of its axis by the stronger fold on the east.

It may therefore be confidently affirmed that whatever may be the nature of the occurrence of oils elsewhere in the Fort Pierre, there is nothing thus far known in the field at Boulder to offer encouragement to prospecting, except in intimate relation with folds. It should then be determined with care what are the essential features of this particular flexure. Such a study may afford a basis for inference as to the probable oil-bearing or barren character of other similar structures occurring for a distance of 50 miles along the front of the range.

The form and location of the folds with which we are here concerned can best be defined after a description of the sandstone stratum which made their discovery possible.

There is in the great mass of Fort Pierre shales, about one-third way up from their base or a little higher, a strong and persistent sandstone whose outcrop can be traced with little interruption from Boulder for many miles to the north. Beyond Fourmile Gulch it generally forms a strong ridge, except where it passes under the broad mesa known as Table Mountain. Just south of Table Mountain it has a thickness of 250 feet An isolated outcrop of similar sandstone at Bear Canyon, 3 miles south of Boulder, probably represents the same horizon. Its thickness here is 150 feet.

To the public this sandstone has become well known on the Culver ranch, 6 miles southwest of Berthoud, where it crosses Little Thompson Creek and where a seepage of oil has long been known.

The sandstone is in many places thick bedded and frequently cross bedded. Much of it has a dark-greenish color and a gritty texture. The remainder is of a lively gray color. The whole is calcareous where fresh. Much of its surface is weathered, having lost its lime, taken on a pale greenish tint, and become friable. It is fossiliferous and frequently contains carbonaceous matter, suggesting small sticks of wood turned to coal.

Near Boulder the stratum is thin and weak and is separated from the Niobrara limestone and shales on the west by not more than 1,000 feet of shales. Seven miles north of Boulder it is 250 feet thick and the Pierre shales below it have thickened to nearly 3,000 feet. As the dip has also greatly decreased within the same space, the sandstone outcrop bears strongly to the east.

Stated more definitely, the outcrop forms a prominent cuesta, a ridge of long and gentle dip slope and a steep scarp, running from the southwest corner to the northeast corner of sec. 6, T. 1 N., R. 70 W. This northeastward strike, an exception to the prevailing trend which is almost north, is the surface expression of the mild echelon folding mentioned above as belonging to the same flexure as the monocline of the oil field. Thence the outcrop goes north by east through the west side of sec. 32, T. 2 N. For nearly a mile north of this the ridge is lost, but it reappears in the west side of sec. 20, running almost north. On the north side of this section the outcrop disappears under the mesa.

Crossing Table Mountain in a northeasterly direction the observer comes to the northern side of the mesa, at the middle of sec. 9. At this point, emerging from the steep side of the plateau, the sharp crags of this same sandstone are seen, forming a bold, bare ridge running far away to the northeast (N. 27° E.).

If now the mantle rock were removed from the mesa top the outcropping sandstone ledge would be seen to describe a great loop, instead of cutting straight across from the point where it disappears under the southwest side to where it reappears on the northeast. The evidence of this will appear from the following: As noted above, the strike of the last mile or two on the south side is nearly north. Similarly on the northeast side the ledge, which approaches the plateau with a strike of S. 27° W., turns just before its disappearance to a direction differing only 8° from due south. Either line of outcrop if continued across the mesa would miss the position of the other by from 1 to 2 miles.

Southeast of Table Mountain, one-half mile west of Haystack Butte, the stratum appears again, striking N. 35° W., and dipping 10° NE. It forms a low ridge, ending, as in the other cases, against the steep mesa scarp. This ledge is doubtless directly continuous with that which abuts against the north edge at the middle of sec. 9.

The two outcrops which end against the south side of Table Mountain are more than a mile apart. They represent the same stratum which, if the soil cover could be removed, would be found outcropping again in an intermediate position, with a dip toward the west. This supposed middle outcrop and the eastern one, which is plainly seen, represent an anticline whose crest has been eroded away.

Wherever exposures permit the reading of dips, the latter are seen to accord with the structure above described. Although the sandstone does not outcrop on the western limb of the anticline, westward dips are plainly seen within the shales at the place where such dips should be expected. At the north end of the canoe-shaped synclinal trough southward dips are found, just as expected. The more detailed evidence of this echelon fold is reserved for the bulletin covering the general geology of the area. If, then, the continuous outcrop of the sandstone were laid bare, it would be seen to cross Table Mountain with a southerly trend from the middle of sec. 9, pass in a southeasterly course past Haystack Butte, looping perhaps a mile farther to the south, then turning back to the north for 3 miles or more, then turning sharply around once more to the south along the course first described.

Structure in the immediate vicinity of the wells.—Such an anticlinal fold must die out gradually at the end. If the axis be traced southward, the dip of the western limb should be found less and less steep. At a certain point the westward dip will become zero; there will be a structural bench, as it were, interrupting the general eastward dip. This bench will be horizontal, except for a southward inclination. Still farther south the whole will again dip toward the east, but in line with the axis of the anticline the dip will be smaller than will be found either east or west of that line.

In the north side of sec. 9, T. 1 N., northwest of the Sixmile reservoir, the only dip is one to the south. This is on the axis of the larger fold. At this place the axes of the two folds are in close proximity, and the effect of the eastern and stronger fold is to uplift the east side of the feebler western fold, thus making a horizontal bench out of what would otherwise be only a partial flattening of the general eastward dip. The result is seen on a line passing south through secs. 8, 17, and 20, along which the shales have no eastward dip. This belt is, however, narrow, a small fraction of a mile, and in short distances, both east and west of it, decided eastward dips appear.

It is immediately east of this bench, perhaps on an average one-fourth of a mile, that the producing wells are found. The linear distribution of the productive territory is more pronounced than might be inferred from the accompanying sketch map. Speaking generally, the wells farthest from the middle of this narrow belt have produced comparatively little. The continuity of the line becomes more striking if it be extended south to include the Buffalo gas well in the southeast corner of sec. 29. This position of the oil-producing strip is in exact accord with that of the Ohio oils, whose conditions of occurrence have been made so well known by the very complete discussion of Orton.[a] The possible finding of other pools remote from such a structure need not be discussed here. It can only be said that the example of this field offers no warrant for prospecting where these structural features are absent.

It may be safely assumed that the one essential element in the structure above described is the decided arrest of the general eastward dip. The peculiar relations of two folds, whose effects at this place unite to produce the result, are not believed to be necessary features which must be duplicated in the case of any new deposits to be discovered. Further, it must not be assumed that this or any similar flexure will necessarily be oil bearing throughout its whole length. Even very small transverse folds affecting the axis are sufficient to break up the

[a] The Trenton limestone as a source of petroleum and inflammable gas: Eighth Ann. Rept. U. S. Geol. Survey, pt. 2, 1889.

deposit into so-called "pools." The intermittence of good oil territory along the line thus far developed from secs. 8 and 9 on the north to the Buffalo gas well on the south is already known. It can not, therefore, be assumed that one or two dry holes indicate that a line marked by the above-described structure is entirely barren.

Possible finding of other similar deposits.—If, then, the promise of future developments in this oil field is limited to this relationship with interrupted dips, it is highly important that similar occurrences beyond the limits already developed be examined. At the outset the further extension of this immediate group of wells demands attention. It must always be taken into account in this field that the beds capable of containing deposits are of small and always uncertain lateral extent. This feature was fully stated in the former report,[a] and that statement needs no modification.

The axis of the fainter of the two folds whose combined effects produce the monocline in and south of sec. 8 runs north-northwest from the present developed field. The very few exposures along this northern portion have not shown dips which indicate a structure similar to that farther south in the vicinity of the successful wells.

The stronger fold to the east completely neutralizes the eastward dip as far south as sec. 4, while farther north it has a westward-dipping limb. The axis of this fold runs north by a little west through secs. 4, 33, 28, etc., and has not been tested by the drill.

Hayden's large-scale map shows a series of large echelon folds with considerable detail, but those described above are in general too small to appear on that map, though the salient curve in the Dakota north of Lefthand Creek must be correlated with the long loop in the sandstone bed above described. If that formation were drawn on the Hayden map, the loop in question would be three-fourths of an inch long; but a fair idea of relative size may be had by comparing the effects of each on the same formation, as, for example, the Dakota.

The question of stores of oil in these larger folds naturally suggests itself in view of the known relation of oil to the smaller folds. It is to be remembered, however, that in the Appalachian region it is not the great anticlines which have conserved the hydrocarbons. Here, as there, it may prove that the greater deformations have made poor reservoirs, probably by the opening of cracks. It has not yet been shown that the larger of the small folds in the Boulder field is an oil reservoir. If the future proves it otherwise there will be a strong presumption in favor of restricting the search to folds of the smaller order. If, then, the large folds shown on the Hayden map are to prove oil bearing it will probably be in their remote ends, where the fold is dying out on the plains.

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[a] Bull. U. S. Geol. Survey No. 213.

This hypothesis has been put to test in one instance. A fine fold of this kind north of Lyons flattens out in the vicinity of Hygiene. Here in a line transverse to the axis three wells were drilled to depths approximating 3,000 feet. They were not without showings of oil, but a better showing was obtained 4 miles farther down its axis to the southeast, where the fold was probably never considered a factor. Oil from a depth of about 600 feet has also accumulated in an abandoned water well a mile north of Hygiene. This is also on or near the axis of the fold.

If the larger folds fail to yield oil, the one remaining hope, probably more promising from the start, lies in the smaller folds. For reasons given above, when these folds do not affect the sandstone bed they are betrayed only by the most obscure outcrops in the Fort Pierre shales. Yet it is in this same formation, at a distance of a few miles from the harder rocks of the foothills, that they must be found.

Herein lies the large significance of the similar, often very small flexures, which affect the stronger and well-exposed strata of the foothills, from Jurassic to Niobrara, inclusive. In these stronger rocks the folds may be very small, the looping back generally being less than a quarter of a mile; but the same stress will be found to have produced larger results in the weaker Fort Pierre.

If the Pierre shales are to be prospected in this region of echelon folding, much time will be saved by making a preliminary examination of the stronger strata. Where the sandstone bed is exposed, it is the natural index of structure and the best. Where it does not outcrop, the basal Niobrara limestone is the nearest criterion. In the area to be reported on beautiful echelon folding, correlated with the structure of the oil field, is found as low as the Morrison (Jurassic).

In these suggestions no account is taken of the possibility of folds running strictly parallel to the foothill outcrops. This is, of course, possible, especially south of Boulder, where the echelon type is not prevalent. The suggestions for procedure here laid down are those only which have been derived from the known structure of the already developed field. They are not intended to exclude all consideration of structures not yet exemplified.

The Maxwell gas well may seem to be an exception to all that has been said above regarding the location of oil (and, by inference, of the closely associated gas); and it might therefore be thought of as putting the generalization to a severe test. It is less than 2 miles north of Boulder and little more than half a mile from the Pierre-Niobrara contact. Nearby outcrops are too few and unsatisfactory to fix the structure with any definiteness, but it is a remarkable fact that this well lies south-southeast from an incipient echelon fold which affects the boundaries of all outcrops from the upper Wyoming to the Fort

Benton. The axis of that fold would seem to pass a little west of the Maxwell well.

Production of gas.—A well originally called the Buffalo, about 1 mile east of Boulder, struck gas in considerable quantity. The gas has been piped to Boulder for delivery to the local gas company. Tests made by the company were interpreted as showing that the well would yield 4,000 feet per hour. The quality is reported as poor, and there has been no long-continued use of it. The Maxwell well showed considerable pressure after long confinement, but this quickly fell off when the gas was allowed to flow. It has never been utilized, and there is no estimate of the capacity of the well.

Production of the field.—The number of productive wells drilled in 1903 is four. All of these are within the area which was known as producing territory in 1902, and all are near the north end of the line of older wells. The Stewart well, not a producer, is 10 miles north of Boulder, just beyond the northern limit of the map. It is noteworthy for the valuable stratigraphic evidence which it afforded and for its yield of flowing water from the lowest sandstone of the Morrison.

The total number of pumps working more or less regularly at the opening of the year was thirteen. During the year five of these were discontinued and five pumps were installed at new wells. This apparently slow rate of development is not due to lack of output (see below). Plans for the immediate future point to a more rapid development.

The shipments of 1902 were 11,000 barrels (of 42 gallons each). Those of 1903 were 39,000 barrels. To this latter figure should be added a small margin for that which was refined at the local refinery. The quantity handled by the latter during the previous year was insignificant. Some wells have shown a marked decrease, though probably no more rapid than is common in other fields. In but one instance has the pumping of a new well decidedly lessened the flow of an older producer.

Almost the whole product continues to be bought by the United Oil Company, which refines the oil at Florence, Colo. The small remainder is taken at the local refinery. The present price paid by the United Oil Company is $1.10 per barrel at the mouth of the well.

HYNER GAS POOL, CLINTON COUNTY, PA.

By M. L. Fuller.

The Hyner gas pool is of interest as being one of the newest and most easterly of the gas pools of Pennsylvania. It is located on the West Branch of Susquehanna River between Hyner and Ritchie stations, on the Pennsylvania Railroad, in the central portion of Clinton County. The two stations are about 3 miles apart, the gas wells being about midway between them, or at the point where, according to the second geological survey of Pennsylvania, the crest of a notable anticline crosses the river.

The first well in the region was located one-half mile southeast of Hyner, or about a mile north of the crest of the anticline. It was drilled in 1877, before the anticlinal theory of the occurrence of gas and oil had been extensively exploited, but its situation was more favorable than that of most of the "wild-cat" wells of northern Pennsylvania. Gas was encountered at several horizons, both in the Catskill and Chemung rocks, as were also traces of oil. Some of the gas flows were fairly strong. The principal gas flows were from beds with tops at 242, 294, 585, and 1,207 feet, while the oil shows were from beds at 715, 1,207, and 1,604 feet. The well was 1,983 feet deep.

The shows of oil and gas encountered in the early well, together with local conditions which appealed to the operator, finally in 1903 led to the drilling of a second well by the Interstate Development Company. This well was started May 16 and was drilled to a depth of about 2,000 feet, when the tools were lost. The tubing was completed on August 31.

The well is notable as having been located on scientific lines, the aim being to develop the pool on the anticline principle. It is located almost exactly at the crest of the Hyner anticline as mapped by the Pennsylvania survey. The well starts in Catskill rocks, 200 feet of which are here brought to the surface in outcrops which, according to H. M. Chance, are among the most northwesterly exposures of Catskill red rock in the State. From the vicinity of the well the rocks dip both north and south at a rate of not far from 200 feet to the mile, disappearing from the surface near Hyner on the north and near Ritchie on the south. The red rocks, on which the differentiation of the

Catskill is based, occur in the well to a depth of 471 feet, indicating a total thickness of about 670 feet. The remainder of the rocks encountered are Chemung. The following is a record of the well as reported by G. W. Seguine, contractor, and furnished by W. M. Harrison, superintendent:

Record of Hyner gas well No. 1, Interstate Development Company.

	Thickness.	Depth.
Catskill formation:	*Feet.*	*Feet.*
Conductor through disintegrated rock	25	25
Red shale	55	80
Red sandstone	10	90
Red sandstone	190	280
Red sandstone	5	285
Red shale	18	303
Gray sandstone	10	313
Red shale	108	421
Brown shale	20	441
Gray slate	20	461
Red shale	60	521
Gray slate	55	576
Gray sandstone (with gas)	10	586
Red shale	35	621
Shelly gray sandstone	49	670
Shelly gray sandstone	26	696
Red rock	20	716
Chemung formation:		
Gray slate	55	771
White sandstone	10	781
White close sandstone	15	796
Blue slate	75	871
Blue sandy white shells	79	950
Blue sandstone (with gas)	8	958
Blue slate	24	982
Blue slate	50	1,032
Blue slate	50	1,082
Blue slate, soft	25	1,107
Blue slate, shells	25	1,132
Blue slate	51	1,183
Brown shale	35	1,218
Dark-gray sandstone (gas at 1,225)	25	1,243
White slate	30	1,273
Blue slate and shells	100	1,373

Record of Hyner gas well No. 1, Interstate Development Company—Continued.

	Thickness.	Depth.
Chemung formation—Continued.	*Feet.*	*Feet.*
Gray sandstone and shells	25	1,398
Blue slate	125	1,523
Gray sandstone with mica	30	1,553
Gray slate shales	400	1,953
Gray sandstone	12	1,965

From this record it will be noted that gas was encountered at 576, 950, and 1,225 feet. The gases at 576 and 950 feet appear to come from local pockets, but a large and persistent supply was obtained at a depth of 1,225 feet. The gas is reported to have shown a rock pressure of 480 pounds, and the pressure is said to be increasing instead of diminishing. The horizon of the producing sand is 509 feet below the top of the Chemung, or about 300 feet higher than the Atwell oil sand of the Gaines oil field in Potter County to the north.

The success of the well led to the sinking of another, located close to the river, about 1,800 feet from the first and 30 feet lower. Like the earlier well, it is supposed to be situated on the crest of the anticline. Gas from the first was used in sinking the second. Fresh water was encountered at various depths, and the well was cased to a depth of 832 feet. Gas was found at 430, 480, 604, 815, 1,068, 1,133, and 1,225 feet. Strong flows of salt water were obtained at 736 and 815 feet, and traces of oil at 860 and 1,135 feet. The main gas supply is from 1,222 feet and has an open pressure of 20 pounds in a 2-inch pipe and 500 pounds closed pressure in an hour. If, as the drillers believe, and as seems probable, the gas is from the same sand in both wells, it must be conceived either that the anticline is much flatter than described or its axis passes midway between the two wells.

Except for the amount used in drilling the lower well, the gas has not yet been put to practical uses. If the supply is found to be satisfactory it will doubtless pay to connect it with the main pipe lines in this region, or pipe it to Lock Haven or other towns. It is too early to make any prediction as to the ultimate extent and value of the pool, but the Interstate Development Company, which controls the field, proposes to thoroughly test it.

The pool is in rocks which are very gently folded, the dip amounting, as indicated, to only 200 feet to the mile. Gas pools, and even oil pools, occur in many cases in equally or more strongly folded rocks, and there are therefore no known geologic reasons why both should not be found. The oil and gas fields in regions of folded rocks, however, are generally relatively small, both in area and in quantity of production. The absence of any large field is borne out by the considerable number of unsuccessful "wild-cat" wells which have been sunk in northern Pennsylvania at various times in the past. Oil and gas may occur at depths greater than any yet reached in the region, but profitable pools are unlikely.

The geologic structure most favorable to the accumulation of gas or oil is the anticline, the gas normally occurring at the crest and the oil a little to one side. The Hyner anticline is very low at Hyner, but gradually increases in height to the east. The chances for oil and gas are generally better in the lower and flatter portions. In the Hyner locality, considered by itself, it is probable that less trouble would be had with the salt water at a point slightly to the east of the present wells and higher up on the gradually rising crest of the anticline.

OIL AND GAS FIELDS OF EASTERN GREENE COUNTY, PA.

By Ralph W. Stone.

INTRODUCTION.

The purpose of this paper is to present at an early date what is known concerning the geologic structure in the territory described and the distribution of the oil and gas fields with relation to the structure. A geologic survey has been made of all of the field except a strip south of Dunkard Creek, which is a blank on the accompanying sketch map (fig. 11).

Location.—Greene County occupies the southwest corner of the State of Pennsylvania, and extends eastward to Monongahela River. It is bounded on the north by Washington County, on the east by Fayette County, and on the south and west by West Virginia. The western edge of the sketch map is the western boundary of the Waynesburg quadrangle

TOPOGRAPHY.

The surface relief of Greene County is characteristic of a considerable portion of western Pennsylvania. The region is hilly, with no strong features, and everywhere the general character of the topography is that of mature dissection. The difference in elevation between Monongahela River and the highest hilltops is less than 900 feet. All of the drainage is tributary to Monongahela River, so, in a general way, this half of the country has an eastward slope.

GEOLOGY.

The rocks which are exposed at the surface in the eastern half of Greene County are limited to the Monongahela and Dunkard formations and a small portion of the Conemaugh formation. The Pittsburg coal, which is the base of the Monongahela or Upper Productive series, outcrops just above water level at the mouth of Tenmile Creek, and is seen in the river bluff from Cats Creek southward to beyond the State line, and on Dunkard Creek for about 2 miles from its mouth.

Monongahela formation.—The Upper Coal Measures are from 320 to 380 feet thick in this area, thinning toward the west. The formation includes the Pittsburg, Redstone, Sewickley, Uniontown, and Waynesburg coals; the Benwood and Waynesburg limestones are its most conspicuous members. That the Pittsburg coal underlies all of this field is proved by the logs of a large number of deep wells. The Redstone and Uniontown coals are thin and have no economic value. The Sewickley coal varies from 20 inches to 5 feet in thickness, and is mined in the southeast part of the county. Benwood limestone is the new name proposed by Prof. I. C. White for the 100 feet or more of

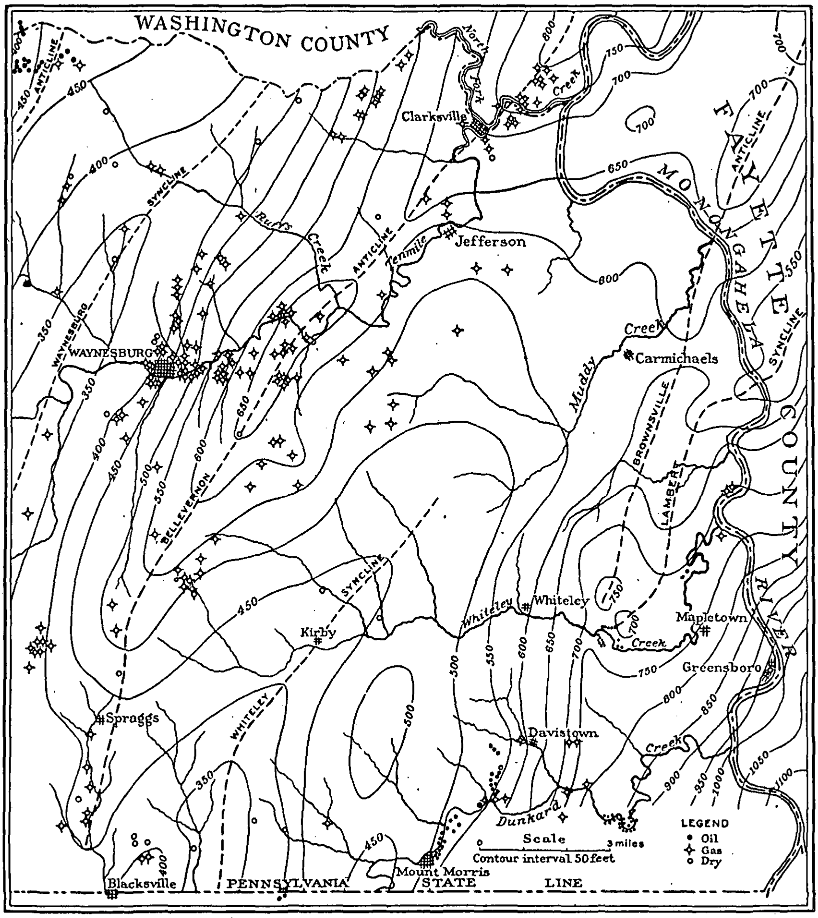

FIG. 11.—Sketch map of eastern Greene County, Pa.

calcareous rocks known as the Great limestone, which lie between the Sewickley and Uniontown coals. The Waynesburg coal is about 5 feet thick, and is mined in many places for local use.

Dunkard formation.—Above the Monongahela formation is a series of comparatively soft rocks extending from the roof shales of the Waynesburg coal to the topmost beds of the Appalachian region. In the eastern half of Greene County the greatest thickness of the formation is about 800 feet. The Dunkard contains a number of small coal seams, none of which are of economic importance in this area. The Waynesburg sandstone and the Upper Washington limestone are conspicuous and fairly persistent members. The greater part of the formation is composed of soft, thin beds of sandstone and shale.

DEEP-WELL RECORDS.

The gas and oil companies and private individuals operating in this county usually require the drillers to keep a record of the thickness of strata passed through in sinking wells. It is from this source that information is obtained concerning the underground structure and stratigraphy. The contractors and drillers, however, in too many cases do not realize the value of accurate and carefully kept logs, and furnish meager, incomplete records.

The accumulation of gas and oil in this region is dependent upon the structure of the rocks, and the precise location of anticlinal and synclinal axes can be determined only by the aid of good logs. It would seem at first thought that the depth of the Pittsburg coal and two or three sand rocks would be sufficient, and this is all that is noted by some drillers, but the omission of intermediate details leaves the geologist little basis for correlating the records of wells. As might be expected, drillers make mistakes in recognizing sand rocks, and their errors are not easy to confirm when records are incomplete.

In comparing the logs of deep wells it is necessary to bear in mind the changes in the character of beds which are likely to occur even in short distances. The possibility of error on the part of the driller in recognizing any particular bed, and inaccuracy of measurements made by manila cable, which probably stretches several feet when supporting two tons of tools at a depth of 2,000 or 3,000 feet, have to be considered.

The logs of most of the wells in this territory have been obtained and studied. The measurements in about 100 of them have been compiled and the averages determined in order to construct a generalized section for the region. The Pittsburg coal, which underlies the entire county, is several feet thick and easily recognized, so the drillers use it as a starting point in figuring the depths at which the producing sands will be found. This coal varies in depth from 10 to 1,060 feet below the well mouth, according to the location of the well. The intervals between the coal and the tops of ten well-known sands are shown in the following table, together with the number of well records from which the average of each interval was computed:

Average depth of top of sands below Pittsburg coal.

Sand.	Number of wells.	Depth.
		Feet.
Gas sand	20	765
Salt sand	32	932
Big Injun sand	86	1,228
30-foot sand	19	1,795
Gantz sand	43	1,916
50-foot sand	53	1,937
Gordon sand	58	2,147
4th sand	43	2,230
5th sand	63	2,313
Bayard sand	62	2,433

It should be understood that these figures are averages, and may not be duplicated by exact measurements in any well. They should be found to be most nearly like actual conditions along the Bellevernon anticline.

GENERAL SECTION BELOW PITTSBURG COAL.

Many of the logs of wells drilled in Greene County give no details of stratigraphy in the first few hundred feet below the Pittsburg coal. It is known, however, from an occasional well and from the general section in those parts of the State where these rocks are exposed at the surface, that a limestone should be found within 50 feet of the coal, and that this is underlain by a massive sandstone which is sometimes 50 feet thick. Another heavy sandstone is met with at a distance of from 150 to 300 feet, and is often underlain by a considerable thickness of red shales. Whether this belt of red shales is continuous throughout the county can not be asserted as a fact, because the logs are often incomplete at this point. Beginning at a depth of 425 feet below the Pittsburg coal, there is an interval of over 150 feet which may often be largely occupied by a massive sandstone. This is the sandstone which produced oil in the Dunkard Creek field in 1860, and is generally known as the Dunkard sand.

A trace of the Upper Freeport coal, if it is present beneath this county, as noted in a very few wells, should be found about 600 feet below the Pittsburg coal. Succeeding this, and in an interval of 250 feet, there may be traces of two or three other coal seams.

Gas sand.—The first sand rock, which is commonly recognized by the drillers and watched for in order to determine the horizon, is what is commonly known as the Gas sand. The position of this sand varies considerably according to the different drillers, and it seems probable that there may be a number of sandstones at this horizon, any one of which may be taken to be the Gas sand. The average depth of the sand below the Pittsburg coal is 765 feet.

This sandstone usually is regarded as the Homewood sandstone, the uppermost member of the Pottsville formation, but in some records the Gas sand is recognized at the Clarion horizon and in others it is placed as high as the Kittanning coal. Its thickness ranges from 15 to 140 feet, the variations being due in part to undoubted changes in the amount of sandstone present at this horizon and in some instances to a tendency on the part of the driller to class everything as sandstone for a considerable distance, when in reality it may be much broken by shale beds. For these reasons the average distance below the Pittsburg coal can not be depended on for anything like correctness.

Salt sand.—At an average distance of 932 feet below the Pittsburg coal there is encountered a sandstone, which, according to the records in hand, varies in thickness from 15 to 175 feet. This is commonly known among the drillers as the Salt sand, and probably in most cases is the lower member of the Pottsville formation, or Connoquenessing sandstone. It should be noted at this point that those records which give a thickness of over 100 feet for either the Gas or the Salt sand omit mention of the other, which would seem to point to a difficulty on the part of the drillers in determining which one is encountered.

Red shales and limestone.—At a depth of from 1,100 to 1,200 feet below the horizon of the Pittsburg coal there generally occurs a bed of red shales. The thickness of these red shales is a point of interest. In Monongalia and Marion counties, W. Va., thicknesses of 250 feet have been recorded, while in Washington County some records show no red shales at this horizon. In fact, it seems to be well proved that these shales, which are a portion of the Mauch Chunk formation, thin out in a general way toward the northwest and disappear in Washington County, so that the overlying shales and sandstones of the Pottsville formation lie unconformably upon the Greenbrier or Mountain limestone.

The Greenbrier limestone, commonly known to Greene County drillers as the Big lime or Mountain lime, is persistent throughout this area, and shows almost as great thickness in Washington County as it does in West Virginia. Its reported thickness varies, however, because the upper portion of the Pocono formation is sometimes decidedly calcareous and the driller is unable to distinguish between the limestone of the Mauch Chunk and the calcareous sandstone at the top of the Pocono.

Big Injun sand.—A sand rock which the drillers always recognize from its thickness and position is the Big Injun, which is the term commonly applied to the Pocono formation in these well records. The top is about 1,225 feet below the Pittsburg coal, and the bed is usually from 250 to 300 feet thick. This average depth is very close to the actual depths of the Big Injun sandstone as found in Franklin Township. The interval varies, however, from 1,275 feet in Dunkard and Perry townships to 1,182 feet in Morris Township. In other words, the interval is nearly 100 feet greater in the southeastern part of Greene County than it is in the vicinity of the Fonner oil field.

The Big Injun sand produces oil in the Mount Morris field, Dunkard Township, and it is commonly expected to contain more or less gas wherever it is drilled through. This sand was named the "Big Injun" by some driller in Washington County, Pa., on account of its thickness and hardness.

Below the Big Injun sand the drill passes through a series of interbedded shales and sandstones about 1,000 feet thick. There is something like definite succession of beds, as exhibited by well records, but the sandstones and shales replace each other abruptly, so that the log of one well may be unlike that of one on an adjoining location.

Thirty-foot sand.—The first sand below the Big Injun which is recognized at all commonly in Greene County is known as the Thirty-foot. Its average distance below the Pittsburg coal is about 1,800 feet. It is not productive anywhere in this locality so far as known, nor does its name mean much as to its thickness, for records show variations from 20 to 60 feet. The horizon of the Thirty-foot is not the same as in Armstrong County, but probably corresponds with what is sometimes known there as the Gas, Butler, or Murraysville sand. Somewhere between the Thirty-foot and the Big Injun there is an occasional development of a sandstone which has been recognized and recorded in a few logs as the Squaw sand. Its presence beneath this territory, however, is not well enough known to be affirmed.

Gantz and Fifty-foot sands.—At an average distance of 1,916 feet below the Pittsburg coal the Gantz sand is struck. It is usually 15 to 25 feet thick, and produces both gas and oil. It is so closely underlain by the Fifty-foot sand that the two are frequently recorded as continuous. It is very probable that the shale between these two sands becomes very thin in some localities, and gives way to shaly sandstone. In such cases the driller records a thickness of 60 to 100 feet for one of the sands, and makes no mention of the other.

The horizon of these sands is occupied in Armstrong and other counties by a heavy, continuous deposit known as the Hundred-foot sand, a term which is little used in Greene County. The Gantz sand takes its name from a well on the Gantz farm, Franklin Township, Washington County, Pa., which was drilled in 1885, and was the first paying oil well in the county.

Gordon sand.—A sand which occasionally produces a small amount of gas, and lies at an average distance of 2,147 feet below the Pittsburg coal, has a thickness of 15 to 50 feet, and is usually recorded in wells which reach this depth. The Gordon sand is named from the farm near Washington, Washington County, where it was discovered in August, 1885.

Fourth sand.—Another sand which produces only a small amount of gas is the Fourth sand. Its top is at an average distance of 2,230 feet below the Pittsburg coal, and its thickness is variously regarded as from 7 to 70 feet. The presence of the Fourth sand is noted almost as frequently as that of the Gordon, which indicates something of its persistence.

Fifth sand.—The great gas producers of the group of sands which are known in Greene County are the Fifth and Bayard sands. By far the larger number of wells in Greene County, excepting those in Dunkard and Morris townships, are sunk to one or both of these horizons. The Fifth sand is at an average distance of 2,313 feet below the Pittsburg coal, and, according to the various records, ranges in thickness from 10 to 65 feet. A study of the average distances from the Pittsburg coal to the Fifth sand shows that the distance between the least and greatest intervals is barely more than 100 feet, while the average distances in five townships vary only 23 feet. In other words, the Fifth sand seems to lie very nearly parallel with the Pittsburg coal.

Bayard sand.—Gas is found more frequently in paying quantities in the Bayard than in any other sand in this field. The distance from the top of the Fifth to the top of the Bayard sand in 60 wells averages 120 feet. The depths at which the drill has found it below the Pittsburg coal are from 2,388 feet to 2,464 feet, averaging 2,433 feet. The thickness of the Bayard sand seems to vary considerably. A few wells, which have passed completely through it, give 3 to 12 feet as the thickness, while other wells, which stopped when the gas was struck and did not go to the bottom of the sand, have noted 20 to 30 feet. The Bayard is also known by some drillers as the Sixth sand. The name Bayard was introduced in gas-sand nomenclature in February, 1895, when a successful well was completed on the Thomas Bayard farm, Whiteley Township, Greene County.

Elizabeth sand.—This term is applied to a sand which carries some gas, and is found at depths ranging from 100 to 175 feet below the top of the Bayard. Its thickness, as recorded in three wells, is not more than 7 feet. Probably the number of holes sunk to this sand in the eastern half of Greene County is less than 10.

GEOLOGIC STRUCTURE.

The structural features of the eastern half of Greene County have the northeast-southwest strike which is characteristic of the whole Appalachian province. These are shown by contour lines on the sketch map (fig. 11). The floor of the Pittsburg coal is selected as a reference surface, and these contour lines, drawn with a vertical interval of 50 feet, represent the shape of the folds. The Pittsburg coal is seen at the surface only at the mouth of Tenmile Creek and on the river above Cats Creek. Its position has been calculated from higher beds in sight at the surface and also from the records of a large number of deep wells which have been drilled in this territory. Enough such data have been obtained to make the determination of the position of the coal accurate within a contour interval, although the bed is several hundred feet below the surface throughout much of the county.

Fayette anticline.—The Pittsburg coal in the southeast part of Greene County dips sharply to the west, as shown by the contour lines along Dunkard Creek. This is the western flank of the Fayette anticline, a structural feature which is strongly developed across Fayette and Westmoreland counties, and terminates at Conemaugh River near Blairsville. The axis of this anticline crosses Redstone Creek above Waltersburg and approaches Monongahela River at the State line. The contour lines on the west flank of this fold near Greensboro show the relation of this feature to the axes in this county. A full description of this anticline will be found in the Masontown-Uniontown and Brownsville-Connellsville folios of the Geologic Atlas of the United States.

Lambert syncline.—A basin next on the west of the Fayette anticline has an irregular outline and its axis pursues an indirect course, crossing the Monongahela near the mouth of Middle Run and entering this county with a westerly trend. It turns south through Paisley and terminates near Willow Tree. The axis rises to the south, so that the coal which is 550 feet above sea level at the river is 150 feet higher at the southern end of the basin.

Brownsville anticline.—The coal rises westward from the Lambert syncline in an irregular arch which is called the Brownsville anticline. The axis of this fold crosses the Monongahela at East Riverside and pursues a southerly course to Turkey Knob. In Greene County this anticline is but a slight undulation and poorly defined, but it has the effect of throwing the contour lines on the flank of the Fayette anticline in the vicinity of Davistown into a north-south direction.

The Brownsville anticline and the Lambert syncline extend northward into the Brownsville quadrangle, where they terminate between Fayette City on Monongahela River and Perryopolis on Youghiogheny River. The publications mentioned in the description of the Fayette anticline also describe these folds.

Whiteley syncline.—Between the Brownsville and the Bellevernon anticlines there is a broad basin which, so far as can be determined, has a fairly regular shape, with a south-pitching axis. The character of this basin has been ascertained largely from the records of a very few deep wells which show the position of the Pittsburg coal.

Conditions are such that the accurate determination of the structure of this basin is almost impossible. Few wells have been drilled in the region, and the rocks showing at the surface are of such a character that actual tracing and definite correlation are impracticable; therefore the locations of the structure contours in this part of the map are regarded as approximate only, and subject to revision when more definite evidence is available.

This syncline has the same position with relation to the anticlines on both sides as the Port Royal syncline in the Brownsville quadrangle. But the Port Royal syncline loses its basin-like character in the vicinity of Fayette City, on Monongahela River, and the axis does not seem to be continuous with the one here described. The axis of the basin in Greene County seems to lie about on a line through Fordyce and Kirby and crosses Dunkard Creek just south of the State line in West Virginia, about three-fourths of a mile west of Pentress. In order to have a convenient appellation for this structural feature, the name Whiteley syncline will be used in this report. It is taken from the township in Greene County in which the basin is broadly developed.

Bellevernon anticline.—Next to the Fayette anticline the most pronounced and important structural feature in the eastern half of Greene County is the Bellevernon anticline. The axis of this fold enters the county at Clarksville and pursues a southwesterly direction for nearly 14 miles to the head of Dyers Fork, where it turns south and gradually flattens out. A natural continuation of the axis would cross the State line nearly a mile west of Blacksville, but for 2 miles west of the village the rocks are horizontal, or rise to the east. It seems probable that the anticline disappears soon after entering West Virginia, if it crosses the State line at all. A low anticline which is seen just east of Blacksville probably is the northern end of another axis.

The Pittsburg coal, which is the reference stratum on which the structure contour lines are drawn, is at an elevation of 1,000 feet where the Bellevernon anticline crosses Monongahela River, between Bellevernon and Charleroi; it is 750 feet above tide at Clarksville, and only 400 feet above tide at Blacksville. It should be noted that conditions were favorable for the accurate determination of the position of the reference stratum along the Bellevernon anticline in Greene County. The Waynesburg coal outcrops on Tenmile Creek from the river to Waynesburg, and the interval between it and the Pittsburg coal is known. The depth of the Pittsburg coal below the surface is shown in 150 deep wells along the anticline, and when the elevation of the well mouths is known the elevation of the reference stratum above mean sea level is easily determined. It is believed that the position of the Pittsburg coal on the west flank of the anticline down to the 400-foot contour line will vary scarcely more than 10 feet from the position indicated on the sketch map (fig. 11).

The eastern slope of the Bellevernon anticline is short and gentle in the region of the greatest development of the Waynesburg gas field. From the crest of the fold near the mouth of Bradens Run on Tenmile Creek to the bottom of the Whiteley syncline on Muddy Creek the fall is scarcely more than 200 feet. From the crest at the same point to the axis of the Waynesburg syncline on the west the reference stratum descends fully 400 feet. The regularity of the western flank of the Bellevernon anticline is shown by the contour lines on the sketch map. This axis is commonly known in Greene County as the Waynesburg anticline.

Waynesburg syncline.—The structural basin which lies west of the Bellevernon anticline is the Waynesburg syncline. This term was used by Professor Stevenson in 1876, but he described the axis as lying much nearer the village of Waynesburg. The axis crosses the Washington-Greene county line about a mile west of Castile, crosses Ruff Creek near the mouth of Boyd Run, and Browns Fork at Rees Mill 2 miles west of Waynesburg. The basin deepens gradually to the south, and it is possible that the Pittsburg coal is less than 300 feet above tide where it crosses Tenmile Creek, although the contour line was not drawn.

Amity anticline.—The structural feature which shows for a short distance across the northwest corner of the sketch map is a low anticlinal fold which has been traced northward in Washington County to the village of Amity, and is named from that place. The crest of this fold is probably not more than 100 feet above the axis of the Waynesburg syncline, where it enters the county from the north, but it rises in Washington County and becomes a more pronounced structural feature. Stevenson and White called it the Pin-hook anticline, from a locality in Amwell Township, Washington County. The name is taken from a burlesque appellation of a little village known as Pleasant Valley or Lone Pine, and is not suitable for geologic nomenclature.

ORIGIN OF OIL AND GAS.

There is no place in this paper for a discussion of the theories which have been advanced to explain the origin of petroleum. It is sufficient to state briefly that all of the theories can be grouped in three classes: (a) Those which ascribe the origin of oil to inorganic agencies, (b) those which advocate organic origin, and (c) those which argue for a combination of organic and inorganic agencies.

It is generally conceded that petroleum of the Pennsylvania type is of vegetable origin and is derived from organic matter disseminated through bituminous shales. It is also believed that the natural gas found in the sedimentary rocks of Pennsylvania is commonly derived from petroleum.

CONDITIONS FAVORING ACCUMULATION OF OIL AND GAS.

These two hydrocarbons are widely distributed through the rocks which form the earth's crust, but usually in small quantities. Certain conditions are essential to the accumulation of either gas or oil in quantities sufficiently large to be of commercial importance. These conditions are practically the same for both the fluid and the gas.

The most important conditions governing the natural storage of oil and gas are (1) a sufficient supply from some source, (2) a porous reservoir rock in which it may be stored, and (3) an impervious cap rock which will prevent its escape.

Further conditions, not necessary, but favoring, are (1) gentle but considerable undulations of the strata, forming anticlinal arches, (2) the complete saturation of the rocks with water and its slow circulation.

All of the conditions which favor the accumulation of oil and gas are too well known or too readily apparent to need much elaboration. That there must be a source of supply is apparent. Organic material, either animal or vegetable, is generally to be found in some of the beds of any great deposit of sedimentary rocks, and from these remains an abundant supply of hydrocarbon might be derived.

The reservoir rocks in which the pay streaks of oil and gas are found in Pennsylvania are usually porous sandstone. The porosity depends upon the shape of the grains, their uniformity in size, and the amount of cementing material. The porosity or vacant space of an ordinary compact fine-grained sandstone is from 8 to 10 per cent.

The impervious cover which retains oil and gas in the sandrock and prevents its escape is shale. These shales are interbedded with the several sandstone strata which act as reservoirs.

The geologic structure in Pennsylvania plays an important part in the accumulation. The gentle folding of the rocks into broad arches which lie generally parallel gives a repetition of conditions which favor the formation of pools. It was here that the anticlinal theory was developed and proved. This theory is that when gas and oil occur in a porous bed along with water, they are forced to move upward toward the surface, and will rise until the surface is reached or some obstruction is met. A horizontal layer of impervious material is the most formidable obstruction. It not only checks the progress, but keeps the oil and gas spread out over a large area instead of allowing it to collect in a pool. If, however, the impervious stratum is inclined, the movement will continue upward along the under surface of the impervious stratum so long as the incline of the rocks continues steep. When it reaches the crest of a fold, progress is stopped and accumulation begins. If oil and water only are present, the oil will be collected in the porous rock beneath an impervious bed along the crest of the fold. If gas, oil, and water are present, they arrange themselves according to specific gravity, the gas at the top of the fold, the oil on the flanks, and the water in the basins on the side.

Complete saturation of the strata with water aids largely in the movement of oil, but in the Appalachian field the deep-lying rocks are usually dry.

RELATION OF OIL AND GAS POOLS TO STRUCTURE.

Beginning at Monongahela River on the flank of the Fayette anticline, the description will continue westward to the Fonner field on the Amity anticline.

The wells on the west bank of the river are four in number. Two wells on the Keener-Durr farm, about a mile below the mouth of Whiteley Creek, obtained light flows of gas in the Gantz sand. The Shay well at the mouth of the same creek and a little higher on the anticline obtained a good supply in the Gantz.

A well, started about 150 feet below the outcrop of the Pittsburg coal and about 30 feet above the river, was sunk by Williams and Ruppert near the pottery at Greensboro. The Mahoning sandstone was encountered at 300 feet, and it is said to have yielded about a barrel of oil a day. The Big Injun sand yielded some gas and a show of oil. The quantity of oil is so slight that the presence of a pool can not be considered as established.

Blackshire pool.—On Whiteley Creek, about 1½ miles north of Mapletown, is a small oil pool. Several wells were drilled here, but only two were productive, drawing their supply from the Big Injun sand at depths of from 1,250 feet to 1,350 feet below the Pittsburg coal. The original Blackshire well gave 100 barrels a day at the start, but the production rapidly declined and soon ceased. The pool is situated near the bottom of the western slope of the Fayette anticline, where the dips are very gentle. In the immediate vicinity of the wells there appears to be a local flattening, which interrupts the general northwestward dip and may account for the occurrence of oil at this point.

Whiteley Creek field.—The wells in this field are confined to the immediate vicinity of Whiteley Creek about halfway between Whiteley and Mapletown. The field contains a considerable number of wells, some of which produced 100 barrels or more a day at the start. Oil has been obtained only from the upper sands, at depths of from 120 to 500 feet below the Pittsburg coal. On the Gregg farm, half a mile south of Willow Tree, a number of wells have been sunk to the "Dunkard" sand, which here lies at a depth of 480 feet below the coal. Many of these were successful and were good producers at the start, but the caving of the soft shales soon gave trouble and shut off some of the flows. The oil in the upper horizons is heavy and not fit for illuminating purposes, while that from the Dunkard is lighter, having a gravity of about 40°.

The Whiteley Creek field is located west of the Fayette anticline near the point where the axes of the Lambert syncline and Brownsville anticline merge in a nearly flat structural area. The oil field is on the western rise of a shallow local basin.

Dunkard Creek field.—The first oil field in Greene County was located on Dunkard Creek, about 2 miles above its mouth. A number of wells were drilled here between 1860 and 1864. The average depth of the wells was less than 500 feet, because oil was found in the Dunkard sand about 450 feet below the Pittsburg coal, which outcrops along the creek at this point. Some of the wells produced very largely for a time, but, having been drilled without casing, the soft shales were soon converted to mud by the flow of oil and water, and the wells caved, thus effectually stopping the flow. Had the wells been properly cased the history of the field would have been different. The Dunkard Creek, or Bobtown, field, as it is sometimes called, seems to be located at a point midway up the flank of the Fayette anticline, where for a short distance the structure has a lower grade than elsewhere between Mount Morris and the Monongahela.

Between the Dunkard Creek and Mount Morris oil fields there are a number of gas wells. These wells are also on the flank of the Fayette anticline, and structurally lower than one oil pool and higher than the other. The gas in these wells comes from the Big Injun sand at a depth of about 1,400 feet below the Pittsburg coal.

Mount Morris field.—A long line of oil wells, known as the Mannington-Mount Morris field, which is so extensively developed in West Virginia, extends across the State line, through Mount Morris, and across Dunkard Creek toward Davistown. The first wells in this field were drilled in 1886, but the northern extension in this county does not date back farther than 1892. The pool along Dunkard Creek is only about 1,000 feet wide, but very rich, producing at one time 800 barrels a day. The producing sandstone in this field is the Big Injun, the first pay streak being about 100 feet below the top of the sand, or 1,380 feet below the Pittsburg coal. The Pittsburg coal in the Mount Morris field is between 500 and 550 feet above tide, or 300 feet lower than at the Dunkard Creek field.

This oil pool seems to be located close to the base of the western flank of the Fayette anticline. At least a small synclinal trough can be seen on Dunkard Creek about a mile west of Mount Morris, and there appears to be a flattening and possibly a doming of the structure 3 miles west of Davistown. It is interesting to note that gas is found in wells drilled east of the oil belt and higher on the limb of the fold.

Wells in Whiteley syncline.—A group of wells on the State line 4 miles west of Mount Morris, on the Shriver and Brown farms, are producing a small amount of oil. In this small field the oil is found in the Big Injun sand, which also carries considerable water here. The Pittsburg coal is 400 feet above sea level in these wells. A number of holes drilled in this syncline have proved to be dry or very light producers, and have been abandoned.

Wells on Bellevernon anticline.—This fold in the rock structure is marked by a large number of wells in Greene County. The several groups of wells are usually known as the Clarksville, Zollarsville, Waynesburg, Kneisley, and Roberts Run fields.

The Clarksville field is composed of about 20 wells in Greene and Washington counties, near the village of the same name on Tenmile Creek. These wells are close to the anticlinal axis and get most of their gas from the Gantz sand; a smaller amount comes from the Fifty-foot and Bayard sands.

The Zollarsville field extends from Washington County southward to Castile Run, and that part of it which is in Greene County lies about 3 miles west and northwest of Clarksville. There are about a dozen wells in the group south of the county line, all of which produce gas. The records show that the Fifty-foot and Bayard are the principal producing sands in this locality, with lesser amounts of gas in the Big Injun and Fifth sands. This field is on the western flank of the Bellevernon anticline, about midway between the arch and the basin on the west. According to the structure lines on the sketch map, this field finds the producing sands from 200 to 300 feet lower than in the Clarksville field. The territory between the two fields is supposed to be good gas country.

The Waynesburg field is one of the largest groups of wells in this corner of the State. The earliest drilling was in 1889, but active operations were not begun until after the discovery of the Bayard sand in 1895. The wells in the immediate vicinity of the village of Waynesburg have all been drilled since 1900. A number of wells which may be included in this field are scattered along the eastern limb of this fold from Jefferson to the head of Whiteley Creek, but the majority are on the western flank and within about 3 miles of Waynesburg. The producing wells are located not only on the crest of the fold but also down the western flank to the 400-foot contour on the Pittsburg coal, where there is a flattening of the dip. Within the limits there is a descent in structure of more than 250 feet.

Many of the wells get small quantities of gas in the Big Injun, Gantz, Gordon, and Fifth sands. By far the largest producer is the Bayard sand, which is found in this field at an average depth of 2,435 feet below the Pittsburg coal. Very few dry holes have been drilled in this field.

The Kneisley gas field is about 2 miles northwest of Spraggs and surrounds Kneisley schoolhouse. There are about a dozen wells in this group, and most of them are producing gas from the Fifth sand. These wells are located below the 400-foot contour on the Pittsburg coal, and the gas pressure is strong. The Guthrie No. 1 showed a rock pressure of 865 pounds. The Hoy well got a hole full of water in the Salt sand, but this was cased off and a big flow of gas was obtained in the Fifth sand. This field is on the flank of the Bellevernon anticline, seemingly about midway between the crest and the bottom of the Waynesburg syncline.

On Roberts Run, between Spraggs and Blacksville, a number of wells have been drilled. All seem to be near the anticlinal axis, but the fold is low, disappearing to the south. About half of the wells here were strong gasers when they came in, while the others were dry or so weak that they were abandoned as soon as completed.

Wells in the Waynesburg syncline.—Fewer than 20 wells have been drilled in that portion of the Waynesburg syncline which is shown on the accompanying sketch map. Nine of these holes are classed as dry; they produced nothing, or yielded salt water and only a smell of gas. Six others are light gasers and two have been fairly strong wells. The records on hand show that the Ellen Ross well on Ruff Creek and the E. M. Sayers well at Waynesburg produced a little oil, but not enough to pay for pumping. In the Wisecarver well, which is nearest to the bottom of the basin, the hole was filled with salt water to a depth of 1,200 feet when the Bayard sand was struck. Two other wells struck salt water in the Salt and Big Injun sands. Three of the gas wells are producing from the Big Injun sand, while others derive their supply from the Gantz, Fifty-foot, or lower sands.

The presence of gas in large quantity and under high pressure over so much of the western flank of the Bellevernon anticline near Waynesburg, and the almost total absence of oil in the Waynesburg syncline, excites some curosity. The Ross well yielded about one barrel of oil a day from the Gantz sand when first struck, while the Sayers well had only a show of oil in the Fifth sand. The presence of so much gas farther up the slope suggests that this syncline originally contained a considerable quantity of oil, but that it has been entirely vaporized. It may be imagined that oil is preserved as such where it is closely confined under high pressure, and that it changes to gas where the reservoir rock is widely porous and offers plenty of space above for expansion. Such conditions seem to exist here, for most of the sands contain some gas, and oil is not found where expected.

Wells on Amity anticline.—The group of wells in the northwest corner of the area mapped is known as the Fonner oil field. The first well in this field was drilled in 1897, and produced 1,800 barrels per day for a short time. Ten wells were being pumped in February, 1903, with a total daily production of about 50 barrels. The pay streak is the Gantz sand, which is here about 1,940 feet below the Pittsburg coal. The sand is from 2,680 to 3,000 feet below the surface, depending on the location of the well.

The anticline on which the Fonner field is located is a low undulation in this part of the county. The Pittsburg coal is about 450 feet above tide, and rises to the northeast. Near Hackneys, in Washington County, the coal is 50 feet higher, and wells drilled near the crest of the fold have produced gas. Gas has been found in the Fonner field on top of the oil in the Gantz sand. This shows that the normal arrangement of the hydrocarbons exists here, and the presence of the oil under the crest of the fold is not abnormal when it is considered that the anticline is low at this point and rises in one direction at least along the strike.

PRODUCTION.

In January, 1904, the Whiteley Creek oil field was producing about 80 barrels daily. Of this amount 60 barrels came from the wells at Willow Tree and 20 barrels from the Tanner wells. The oil is transported by a pipe line belonging to the Standard Oil Company.

The oil from the Mount Morris field is pumped to a central station on Monongahela River 2 miles above Morgantown, W. Va., and from there to the seaboard. The pipe lines are under control of the Standard Oil Company. The production of that portion of the field which is in Greene County amounts to about 1,000 barrels a day.

The production of the Fonner field, which is about 50 barrels of oil a day, is carried by Southwest Pennsylvania Pipe Lines to storage tanks at Meadow Lands, Washington County, Pa.

The gas from the fields in this area is carried by pipe lines to Pittsburg where it is used largely by manufactories for steaming and heating purposes and by the city in general for heating and lighting. Gas is used at Waynesburg and on many farms which are near producing wells for heating, lighting, and cooking.

The Carnegie Natural Gas Company has a pump station 2 miles east of Waynesburg, which is fed by wells in the Waynesburg field and by two 10-inch lines, one from Mount Morris and the other comes into Greene County at Dent, 3 miles west of Blacksville. The gas is sent toward Pittsburg from this station through a 12-inch and a 16-inch pipe line.

The Philadelphia Company has a 16-inch line extending across the county from northeast to southwest; a 10-inch line from Blacksville to Waynesburg; two or three lines to the Waynesburg field, and a second 16-inch line from Waynesburg northeast toward Pittsburg.

The People's Natural Gas Company has lately completed a 20-inch line which enters Greene County at Dent, passes 4 miles east of Waynesburg, and goes out of the county near Zollarsville.

The Manufacturers' Light and Heat Company takes gas from the field south of Waynesburg through a 16-inch line, and the Fort Pitt Gas Company has a 12-inch line which crosses the county from a point 4½ miles east of Blacksville to Zollarsville, and carries gas to Pittsburg.

SUMMARY.

From the above statements it is seen that in various parts of the territory—

1. Oil is contained in the sandstones of the Lower Barren measures, or Conemaugh formation, and in the Big Injun and Gantz sands.
2. Gas is found in commercially important quantities in the Big Injun, Gantz, Fifty-foot, Fifth, and Bayard sands.
3. Salt water from the Salt sand, Big Injun, and Bayard has flooded some holes.

It is shown also that the principal accumulations of gas are either on the crests of the anticlinal folds or on the steep flanks. The oil pools are located at points on the flank of an anticline where the dip is considerably flattened or at a low point on the crest of an arch. Wells drilled in the bottoms of the synclinal basins have, for the most part, been unproductive. These relations of the accumulations of gas, oil, and water to geologic structure are in accord with the anticlinal theory and show the value of an accurate determination of structure in the location and extension of oil and gas fields.

PUBLICATIONS ON PETROLEUM, NATURAL GAS, AND ASPHALTS.

The following list contains the more important papers relative to oil, gas, and asphalt published by the United States Geological Survey or by members of its staff:

ADAMS, G. I. Oil and gas fields of the western interior and northern Texas coal measures, and of the Upper Cretaceous and Tertiary of the western Gulf coast. Bulletin U. S. Geol. Survey No. 184, 64 pp. 1901.

ELDRIDGE, G. H. The Florence oil field, Colorado. In Trans. Am. Inst. Min. Eng., vol. 20, pp. 442–462. 1892.

—— The uintaite (gilsonite) deposits of Utah. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 909–949. 1896.

—— The asphalt and bituminous rock deposits of the United States. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 209–452. 1901.

—— Origin and distribution of asphalt and bituminous rock deposits in the United States. In Bulletin U. S. Geol. Survey No. 213, pp. 296–305. 1903.

—— The petroleum fields of California. In Bulletin U. S. Geol. Survey No. 213, pp. 306–321. 1903.

FENNEMAN, N. M. The Boulder, Colo., oil field. In Bulletin U. S. Geol. Survey No. 213, pp. 322–332. 1903.

FULLER, M. L. The Gaines oil field of northern Pennsylvania. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 573–628. 1902.

—— Asphalt, oil, and gas in southwestern Indiana. In Bulletin U. S. Geol. Survey No. 213, pp. 333–335. 1903.

GRISWOLD, W. T. The Berea grit oil sand in the Cadiz quadrangle, Ohio. Bulletin U. S. Geol. Survey No. 198, 43 pp. 1902.

—— Structural work during 1901 and 1902 in the eastern Ohio oil fields. In Bulletin U. S. Geol. Survey No. 213, pp. 336–344. 1903.

HAYES, C. W. Oil fields of the Texas-Louisiana Gulf Coastal Plain. In Bulletin U. S. Geol. Survey No. 213, pp. 345–352. 1903.

—— Asphalt deposits of Pike County, Ark. In Bulletin U. S. Geol. Survey No. 213, pp. 353–355. 1903.

HAYES, C. W., and KENNEDY, W. Oil fields of the Texas-Louisiana Gulf Coastal Plain. Bulletin U. S. Geol. Survey No. 212. 1903.

HILGARD, E. W. The asphaltum deposits of California. In Mineral Resources U. S. for 1883–1884, pp. 938–948. 1885.

MCGEE, W J. Origin, constitution, and distribution of rock gas and related bitumens. In Eleventh Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 589–616. 1891.

PHINNEY, A. J. The natural gas field of Indiana. In Eleventh Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 617–742. 1891.

RICHARDSON, C. Asphaltum. In Mineral Resources U. S. for 1893, pp. 626–669. 1894.

VAUGHAN, T. W. The asphalt deposits of western Texas. In Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, pp. 930–935. 1897.

WILLIS, B. Oil of the northern Rocky Mountains. In Eng. Min. Jour., vol. 72, pp. 782–784. 1901.

STONE.

During the last year many important quarry districts were examined by members of the Survey. Particular attention was given to the slate industry, and a Survey bulletin on the slate deposits and slate industry of the United States is now in course of preparation. Brief papers on several important western slate districts are presented below. During 1904 it is planned to have examinations made of the slate deposits of Maine, Arkansas, Virginia, and Minnesota, and to review the slate deposits of other sections of the country which have previously been reported on. It will then be possible to issue a comprehensive report on the slate industry.

NOTE ON ARKANSAS ROOFING SLATES.

By T. Nelson Dale.

A few specimens of black, reddish, and greenish roofing slate from Polk County, Ark., received at the office of the United States Geological Survey, were referred to the writer for microscopic examination. Polk County borders on the Indian Territory and lies about midway between Red and Arkansas rivers. The results of this examination are as follows:

1. Black slate (phyllite) from Mena, near Big Forks.—This is a black sonorous slate with a remarkably smooth cleavage surface and a very fine cleavage. The aggregate polarization is very brilliant, indicating complete sericitization of the matrix. The texture is unusually fine and the matrix very homogeneous. Quartz grains do not exceed 0.01 millimeter in diameter. The "slate needles" (TiO_2) are unusually minute. Carbonaceous matter in particles of various sizes accounts for the color. There is no carbonate present, nor is there any effervescence in cold dilute hydrochloric acid. A little pyrite is present. There is no trace of false cleavage. This is a very superior quality of roofing slate, splitting readily, and not liable to discoloration on exposure.

2. Black "slate" (clay slate) from West Caney.—This is not a phyllite, but a clay slate. While it is not without sonorousness, its surface is lusterless and it does not split with marked facility or fineness. Aggregate polarization very faint, owing to incomplete sericitization of the matrix. There is a noticeable parallelism in the particles, distinguishing the rock from a shale. The particles are generally coarse; some are visible with an ordinary magnifier. Quartz grains are as much as 0.04 millimeter in diameter. There are present lenses of cryptocrystalline quartz, spherules of pyrite, and carbonaceous and argillaceous material. Although the hand specimen shows no effervescence in cold dilute hydrochloric acid, a chemical analysis would probably show the presence of carbonates. This slate is of very doubtful commercial value.

3. Dark-red slate (phyllite) from Mena, near Big Forks.—The color of this slate is somewhat darker than that of the well-known "red slate" of Granville, N. Y. It is sonorous and splits easily. The surface is not so smooth as that of the slate first described, and it is also speckled with minute lenses which, under the microscope, are found to be rhombs measuring from 0.1 to 0.2 millimeter in diameter; these consist of chlorite and probably rhodochrosite ($MnCo_3$), pseudomorphic possibly after hematite or siderite. The aggregate polarization is brilliant. Quartz grains range up to 0.025 millimeter. Muscovite and chlorite scales and the usual hematite pigment are present. No other carbonate is visible, nor is there any effervescence in cold dilute hydrochloric acid. No trace of false cleavage was seen. As to cleavability and durability this slate compares favorably with the Granville "red slate."

4. Reddish slate (phyllite) from an unnamed locality.—This is intermediate in color between the Granville "red slate" and the dark-red slate last described. It differs, however, from the latter in the greater smoothness of its cleavage surface and in the absence of lenses. It is sonorous and splits with facility. The aggregate polarization is brilliant. Quartz grains reach 0.03 millimeter in diameter. Muscovite and chlorite scales and hematite pigment are present, but there is no carbonate, and no effervescence in cold dilute hydrochloric acid. This is slightly superior to the slate last described.

5. Gray-green slate (phyllite) from Mena.—The surface of this specimen has a fine waxy luster, but is marked by a very close bedding foliation, making an angle of 13° with the surface obtained in splitting. There is also an obscure "false" or secondary cleavage at about 40° to that surface. The aggregate polarization is brilliant and the material is remarkably fine grained and homogeneous. Very few and very minute quartz grains are present. No carbonate is present, nor is there any effervescence in cold dilute hydrochloric acid. Several pseudomorphic rhombs, 0.08 millimeter in diameter, of chlorite scales were found.

Whether the two extra foliations will prove detrimental in this particular slate could be determined by physical tests or by continued use; but secondary cleavage in roofing slate generally facilitates fractures parallel to it, and is therefore regarded as a very doubtful feature. In this slate the bedding will probably operate like a second "false cleavage."

6. Light-green slate (phyllite) from an unnamed locality.—This slate occurs in association with the reddish slate (No. 4). It is more greenish than No. 5, being a delicate pea green. Its surface is smoother than that of No. 5, owing to the absence of the transverse foliation, and has a waxy luster. It is sonorous and splits with great facility and fineness. The aggregate polarization is brilliant and the parallelism of the sericite is almost perfect. A microscopic bed of quartz grains with chlorite and muscovite lies in the cleavage, which is, therefore, the bedding plane also. The "grain" is indicated by the transverse position of some of the muscovite scales and prismatic crystals. The material is fine grained. Quartz is not very abundant, but attains a diameter of 0.037 millimeter. Slate needles are abundant and are as much as 0.012 millimeter in length. Muscovite and chlorite scales are present, and to the latter the slate owes its color. Some opaque granules (limonite?) and pyrite are seen. There are also occasional lenses consisting of a central mass, probably rhodochrosite ($MnCO_2$), with secondary muscovite at both ends, measuring in all 0.14 millimeter in length. There are not a few prisms of apatite 0.025 millimeter long. No other carbonates are present, nor is there any effervescence with cold dilute hydrochloric acid.

This is a very superior quality of slate. Its ready fissility, attractive color, and the absence of calcium and magnesium carbonate all commend it.

Conclusion.—While all but one of these slates have been denominated phyllites on account of sericitization of the matrix, they all show clastic quartz. The remarkably fine cleavage and the absence of calcium and magnesium carbonate in the black (1) and the green (6) render them exceptionally good. The reddish slate (4) is good and (3) may prove equally so. If (1) and (6) occurred in a populous region they would doubtless be in great demand. For commercial purposes the microscopic examinations of (1) and (6) ought to be supplemented by partial chemical analyses to show whether they are entirely free from carbonate, as the microscope indicates.

THE SLATE DEPOSITS OF CALIFORNIA AND UTAH.

By Edwin C. Eckel.

This paper is based upon the results of field work by the writer during the early fall of 1903. Acknowledgments must be made to Messrs. W. J. Dingee and C. H. Dunton, of the Eureka Slate Company, for aid extended to the writer during his investigation of the California slate deposits. Without the facilities for close examination of the quarries offered by these gentlemen, and the cordial cooperation of all the officials and employees of their company, the results would have been comparatively few.

A summary of the more purely scientific results of this work has been recently published,[a] and a more detailed discussion of the economic features, with maps and other illustrations, will appear in a bulletin of the United States Geological Survey on the slate deposits and industry of the United States.

CALIFORNIA.

Location and general relations.—Though roofing slate has at different times been quarried on a small scale in other parts of California, the only important slate-producing area in the State is located in Eldorado County. The quarries which have been opened in this district are located along a line running about N. 15° W. from Placerville, at distances of 1 to 6 miles from that town. The location and geographic and geologic relations of the slate deposits and quarries can best be understood by reference to the maps included in the Placerville folio of the United States Geological Survey. The workable roofing-slate deposits of this district occur in a belt of the Mariposa slates, of late Jurassic or early Cretaceous age. The quarries which have been opened are all situated near the western boundary of this belt of Mariposa slates, where it is bordered by a large area of diabase. This diabase has been described by Lindgren and Turner as being "of the age of the Mariposa slates, or older." A number of linear areas of

[a] Eckel, E. C., On a California roofing slate of igneous origin: Jour. Geol., vol. 12, No. 1, Feb., 1904, pp. 15-29.

amphibolite occur in the Mariposa slates. These amphibolites are described as being derived from diabase or gabbro. They are in part altered to serpentine.

Previous work on the slate deposits.—The Placerville folio, No. 3, United States Geological Survey, published in 1894, contains the results of detailed geologic work by Lindgren and Turner in the area in which the roofing-slate deposits occur. At that date the roofing-slate industry had not assumed its present importance, though all the quarries now in existence had then been opened. The existence of roofing-slate deposits is noted in the text of the folio, and the locations of the quarries are indicated on the map showing the economic geology of the area. No reference is made to the "green slates," or to the dikes cutting the Eureka quarry.

Excellent, though brief, descriptions of the different quarries and of the condition of the slate industry at various dates are to be found in the reports of the State mineralogist of California, particularly in the eighth and twelfth reports.

At present the most important quarry is that of the Eureka Slate Company, and this is now being worked on a large scale. This quarry is located at Slatington, about one-half mile southwest from Kelsey.

Structural relations in Eureka quarry.—The cleavage planes of the slates in the Eureka quarry strike N. 25° W. The dip of the cleavage is practically vertical, with slight local variations to 80° E. or 80° W. The upper weathered beds in the quarry are overturned, by local pressure, so as to give dips of 40° to 60° to the east or west, according to local conditions. This overturning is evidently due merely to the weight of the overlying soil and decomposed slate, and the effects are shown only for a depth of from 3 to 15 feet. It is of interest, however, as a warning against accepting dip readings taken from surface beds of the slate.

The slate body shows rather frequent, but narrow, "ribbons." These ribbons are bands (from one-sixteenth to one-half inch thick usually, but occasionally as thick as 2 inches) of material differing in composition from the mass of the slate. They are in general more siliceous than the normal slate, and do not furnish merchantable material. Their geologic interest arises from the fact that they represent differences of original sedimentation. The plane of the ribbons in a slate quarry is, therefore, the plane of original bedding. In the Eureka quarry, and, indeed, throughout the roofing-slate belt, the plane of original bedding seems to be usually within 10° of the plane of slaty cleavage.

The slate mass is cut by a series of joints parallel to the "grain" of the slates, striking N. 55° E. and dipping from 70° to 80° NW. Joints across the "grain" of the slate, which would be practically horizontal, do not occur in this quarry; but many of the thin quartz seams occupy this position.

Quartz and calcite occur in thin layers, filling joint spaces and occasionally cleavage spaces. Pyrite also occurs in very much flattened nodules, which were apparently parallel to the original bedding.

Character of the normal slate.—The mass of the Eureka quarry product is a dense, deep-black slate, splitting very finely and regularly, with a smooth glistening surface much like that of the Bangor and Lehigh slates of Pennsylvania. The frequency of the ribbons and of the pyrite nodules prevents the slate from being serviceable as mill stock, but as a roofing material it is excellent.

A specimen of the black slate, free from ribbon, was selected for analysis in the laboratory of the United States Geological Survey. The results of this analysis, by Mr. W. T. Schaller, follow:

Analysis of black slate, Eureka quarry, Slatington, Cal.

	Per cent.
Silica (SiO_2)	63.52
Alumina (Al_2O_3) and titanic oxide (TiO_2)	16.34
Iron oxides (FeO, Fe_2O_3)	6.79
Lime (CaO)	.98
Magnesia (MgO)	2.50
Carbon dioxide (CO_2) / Water	4.86

Eureka quarry green slate.[a]—A band of green slate several feet in width crosses the Eureka quarry. On examination it is found that the borders of this band are not parallel to the "ribbon" of the black slate. The green band can not, therefore, be interbedded with the black slates. The probability that it represents a dike of massive igneous rock which has been changed into a slate by pressure subsequent to its intrusion is strengthened when the chemical composition of the green slate is considered. Two analyses of the green slates are presented on the next page. The first is of a sample selected by the writer and analyzed in the laboratory of the United States Geological Survey by Mr. W. T. Schaller; the second was given by Mr. C. H. Dunton, manager of the Eureka quarry, but the name of the analyst is unknown. As the analyses show a close agreement in essential features, it is probable that they are fairly representative of the composition of the green slates, and that their average, which is given in the third column of the table, may be regarded as typical of this interesting and apparently unique type of roofing slate.

[a] For a more detailed discussion of this interesting "igneous slate" the reader is referred to the paper by the writer in the Journal of Geology, vol. 12, 1904, pp. 15-29.

Analyses of green slates, Eureka quarry, Slatington, Cal.

	(1)	(2)	Average.
	Per cent.	*Per cent.*	*Per cent.*
Silica (SiO_2)	45.15	47.30	46.22
Alumina (Al_2O_3)	16.33	15.53	15.93
Iron oxides (FeO, F_2O_3)	8.42	8.00	8.21
Lime (CaO)	6.42	7.83	7.12
Magnesia (MgO)	8.72	7.86	8.29
Sulphur (S)	([a])	.12	.12
Alkalies (K_2O, Na_2O)	([a])	3.17	3.17
Carbon dioxide (CO_2), Water	11.28	9.92	10.60

[a] Not determined.

These analyses have been compared[a] with a series of 36 analyses of American roofing slates derived from clays by pressure, and remarkable differences in composition are apparent. The green slate, on the other hand, approximates closely in composition to certain "basic" igneous rocks of the district, and it is probable that it was derived from a gabbro or similar rock.

The "green slate" is in reality grayish green in color. It splits readily, though not with as smooth a surface as the black slate. It stands punching and trimming well, and is sufficiently strong for roofing use. Considering its origin and composition it is probable that it will be a highly durable slate, holding its color well. At present it is sold entirely for trimming and lettering on black slate roofs, for which purpose it is particularly well adapted, giving a strong but pleasant color contrast.

Chili Bar Slate Company quarry.—This quarry is located about 3 miles north of Placerville, in sec. 36, T. 11 N., R. 10 E., on the south side of the South Fork of American River, a few hundred yards east of the Placerville-Kelsey stage road.

This is the oldest quarry in the district, having been opened about twenty years ago. It has been shut down since 1897.

Several openings were made in a bluff forming the river bank at this point. In the easternmost of these openings, which is about 40 feet high and 30 feet wide, a rather poor slate with irregular joints is shown. The cleavage strikes N. 20° W., and dips 75° E. The westernmost opening is small, with a tunnel which was apparently run in on a band of better slate. The slate piled in the yard has kept its color fairly well.

It seems possible that this quarry may be flooded at high water. Both it and the one next mentioned (San Francisco quarry) are badly

[a] Jour. Geol., vol. 12, 1904, p. 26.

located, having no large dumping area available near the quarries. Neither quarry has gone deep enough to get really good slate, which might have been found at a greater depth.

San Francisco Slate Company quarry.—This quarry is located in T. 11 N., R. 10 E., within a quarter mile of that of the Chili Bar Slate Company, but on the north side of the river and west of the Placerville-Kelsey road. The principal opening was located about 600 feet north of the river, at an elevation of 150 feet above its bank. A tramway led down to the dressing yards, which were situated at the river bank.

The cleavage of the slates in the large opening strikes about N. 30° W., and has an almost vertical dip. No slate has been quarried here since 1897. A large stock of trimmed slates is still piled in the dressing yard, and many of these have already discolored badly.

Transportation and market.—The Eldorado County slates have practically no competition on or near the Pacific coast, while the Eureka quarry has recently placed large shipments in Hawaii and Guam. Until recently the principal problem has been the transportation of the slates from the quarry to the railroad. This was formerly done by wagon hauling over a 6-mile stretch of very hilly road. During the last season, however, the Eureka Slate Company has installed an aerial tramway system from its quarry to a point near Placerville. This tramway is an engineering feat of no mean order, the crossing of the South Fork of American River being the principal difficulty encountered.

Production of roofing slate in California.—The following table, compiled from figures given in various volumes of Mineral Resources of the United States, shows the amount and value of California slate production for a number of years:

California production of roofing slate, 1890–1901.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Squares.			*Squares.*	
1890	3,104	$18,089	1896	4,597	$20,388
1891	4,000	24,000	1897	1,000	7,000
1892	3,500	21,000	1898	400	2,700
1893			1899	928	6,642
1894	900	5,850	1900	3,500	26,500
1895	1,500	10,500	1901	2,500	18,608

UTAH.

For some years past a small amount of slate has been annually gotten out, chiefly for samples and trial shipments, at various points in Utah. Deposits of slate, believed to be of workable extent and of good quality, have been described as occurring on the islands in Great Salt Lake, and some attempt has been made to develop these deposits.

The locality which has been most widely discussed, however, is that near Provo. This has been exploited to some extent by F. W. C. Hathenbuck, of Provo. The slate deposits occur about 2 miles southeast of Provo station, in Slate Canyon. The slate here covers a considerable area, but that exposed at the surface is so badly broken up that large slabs can not be obtained. It is possible, however, that this condition will disappear if the deposits are worked deeper.

The Provo deposits furnish green and purple slates, the latter being apparently present in greater quantity. The green slates show little tendency to cleavage in their surface outcrops, and will probably be less satisfactory for roofing purposes than the purple. The green slates rub very smoothly, however, and would make good slabs or mill stock if obtainable in masses of sufficient size.

The purple slates split well, with a surface about as smooth as that of Peach Bottom (Penna.-Md.) slate. From samples seen it appears that they also bear punching well.

A specimen of the purple slate selected by the writer was analyzed by Mr. W. T. Schaller in the laboratory of the United States Geological Survey, the results being as follows:

Analysis of purple slate, Provo, Utah.

	Per cent.
Silica (SiO_2)	54.05
Alumina (Al_2O_3)	20.95
Iron oxides (FeO, Fe_2O_3)	.28
Lime (CaO)	.22
Magnesia (MgO)	9.12
Carbon dioxide (CO_2) / Water	3.90

Of a series of 36 analyses of American roofing slates collected and discussed[a] recently by the writer, the above slate from Provo stands lowest in its percentages of silica and magnesia, while its lime is very far below the average.

Nothing definite is known as to the geologic age of these slates, though they are supposed to be Ordovician, or even older.

[a] Jour. Geol., vol. 12, 1904, p. 26.

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HILLEBRAND, W. F. Chemical notes on the composition of the roofing slates of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 301-305. 1899.

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——— Brownstones of Pennsylvania. In Eighteenth Ann. Rept., pt. 5, pp. 1025-1043. 1897.

HOPKINS, T. C., and SIEBENTHAL, C. E. The Bedford oolitic limestone of Indiana. In Eighteenth Ann. Rept., pt. 5, pp. 1050-1057. 1897.

KEITH, A. Tennessee marbles. In Bulletin No. 213, pp. 366-370. 1903.

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3, pp. 795-811. 1896.

SHALER, N. S. Preliminary report on the geology of the common roads of the United States. In Fifteenth Ann. Rept., pp. 259-306. 1895.

——— The geology of the road-building stones of Massachusetts, with some consideration of similar materials from other parts of the United States. In Sixteenth Ann. Rept., pt. 2, pp. 277-341. 1895.

SIEBENTHAL, C. E. The Bedford oolitic limestone [Indiana]. In Nineteenth Ann. Rept., pt. 6, pp. 292-296. 1898.

CEMENTS.

During the field season of 1903 most of the cement-producing districts of the United States were visited, data being collected for a report on the cement resources and industry of the United States, to be issued as a Survey bulletin. The districts not visited in 1903 will be taken up early in 1904, and a detailed report on the subject will be published as soon as possible. The papers presented below cover three interesting districts, one of which now produces about 60 per cent of the total annual United States production of Portland cement, while the other two, but slightly developed at present, give promise of becoming very important factors in the cement situation in the near future.

Pure limestones in Pennsylvania and West Virginia, suitable for Portland-cement manufacture, will also be found described on pp. 516–517; while California cement materials are noted on pp. 176–177.

THE CEMENT RESOURCES OF ALABAMA.

By Eugene A. Smith.

In Alabama is found an extensive series of limestones capable of furnishing excellent raw material for the manufacture of Portland cement, while the shales and clays necessary to complete the mixture are found in every county in the State. As a matter of convenience, the Portland cement materials of northern Alabama and of central and southern Alabama will be discussed separately, because there is a marked geologic as well as geographic distinction between the two portions of the State.

PORTLAND CEMENT MATERIALS OF NORTHERN ALABAMA.

The raw materials for the manufacture of Portland cement occurring in the Paleozoic formations of northern Alabama are limestones, shales, and clays. Of these the limestones belong mainly to the lower Carboniferous and the Trenton formations; the shales to the Coal Measures, and the clays to the Cambrian, lower Carboniferous, and Coal

Measures. Although these materials have not yet been utilized for this purpose in Alabama, they have been so used in other States, and there is no reason to doubt that the future will witness their utilization in Alabama.

AVAILABLE LIMESTONES.

General geology.—In northern Alabama the combined effects of geologic structure and erosion have resulted in certain definite topographic types with which the geologic outcrops are closely connected.

Structurally, northern Alabama is made up of a series of parallel synclines and anticlines, trending usually a little north of east. The anticlines are sharp, narrow folds; the synclines are flat, wide basins. The effect of erosion has been to cut away the synclines, and the streams of the region now run along anticlinal valleys bordered by flat-topped synclinal plateaus.

The plateaus throughout most of northern Alabama are capped by conglomerates, shales, and sandstones of the Coal Measures. The lower Carboniferous limestones commonly outcrop along the sides and at the immediate base of the plateaus. The Ordovician (lower Silurian) beds occur as long, narrow outcrops in the valleys. The middle of the valley is usually occupied by Cambrian shales and the Knox dolomite. The Trenton limestones would normally outcrop as two parallel bands in each valley—between the middle of the valley and the foothills of the plateaus. Faulting has, however, been so common that only one of these bands is usually present, the other being cut out by a fault.

Lower Carboniferous.—Limestones of suitable quality for cement manufacture occur in the Mountain limestone or Chester formation of the lower Carboniferous. Perhaps the most accessible occurrences of this rock are in the Tennessee Valley to the west of Tuscumbia and south of the river and railroad. Here the quarries of Fossick & Co. were formerly located. Their quarries at this time are farther eastward, but at a greater distance from the river, in Lawrence County north of Russellville. This outcrop extends thence eastward along the base of Little Mountain as far as Whitesburg, above which place to Guntersville the river flows through a valley floored with lower Carboniferous limestone. The Southern Railway passes over outcrops of this rock in most of the mountain coves east of Huntsville, and from Scottsboro to the Tennessee line the country rock is almost entirely of this formation. The Louisville and Nashville Railroad south of Decatur nearly to Wilhite is mostly in the same formation. These two lines, together with Tennessee River, would provide ample means of transportation for the rock or for the finished product. Analysis of the rock from the Fossick quarries is given in the table on p. 432.

In Browns Valley south of Brooksville the Mountain limestone is the prevailing rock across the valley, and at Bangor and Blount Springs, on the Louisville and Nashville Railroad, there are extensive quarries which have been worked for many years to supply rock for fluxing purposes to the furnaces of the Birmingham district. Analyses Nos. 2, 3, 4, 5, 6, 7, 8, and 9, on p. 432, show the composition of average samples from these quarries; 5 to 9, inclusive, are of carload samples.

From Brooksville to the Tennessee line a great thickness of this limestone is exposed along the western escarpment of Sand Mountain, below the sandstones of the Coal Measures, which there cap the mountain. In this area the river runs near the foot of the mountain and would afford the means of transportation.

In similar manner the lower Carboniferous limestone outcrops along the western flank of Lookout Mountain in Little Wills Valley, from near Attalla to the Georgia line, and south of Attalla it forms the lower part of the escarpments of Blount and Chandlers Mountain. The Alabama Great Southern Railroad passes very near to the outcrop from the Georgia line down to Springville, Ala. South of Springville large outcrops occur in Shades Valley, and at Trussville are quarries which have supplied the Birmingham furnaces. Analyses 10 to 17, inclusive, p. 432, are of material from Trussville; and analyses 12 to 17, inclusive, represent average samples from carload lots delivered to furnace.

In Murphrees Valley the main outcrop of this rock is on the western side, and quarries at Compton have for many years been worked to supply the Birmingham furnaces. Analyses 18, 19, and 20 of the rock from these quarries show somewhat varying composition, but by proper selection suitable material could easily be obtained.

In the valleys lying east of Shades Valley and in parts of Shades Valley itself this formation becomes one of prevailing shales and sandstones and the limestones are of limited occurrence and of inferior quality.

Trenton limestone.—The Trenton limestone outcrops in Alabama in three principal areas. In the Tennessee River Valley some of the smaller streams which flow into the river from the north, like Flint River, Limestone Creek, Elk River, Bluewater Creek, and Shoal Creek, have eroded their valleys into the Trenton limestone. These areas are crossed at only a few points by the railroads leading out from Huntsville and Florence, and no commercial use has as yet been made of the rock.

In the narrow anticlinal valleys below enumerated erosion has in most cases sunk the floors of the valleys into Cambrian strata, and, as a consequence, the Trenton limestone occupies a narrow belt on each side, near the base of the Red Mountain ridges. But since a fault usually occurs on one side of these valleys, the Red Mountain ridges and the accompanying Trenton limestone are more fully represented on the unfaulted side, which is the eastern side in all except Murphrees Valley. While the Trenton forms practically a continuous belt along the undisturbed side, extensive areas are sometimes found on the faulted side also. This is the case, for instance, at Vance, on the Alabama Great Southern Railroad, where the rock is quarried for flux for the furnace of the Central Iron Company at Tuscaloosa. Analysis 1 of the second table on p. 432 shows its composition here. Other series of analyses from lower ledges in the quarry show only 1.22 per cent of silica, but more magnesia.

In cases where erosion has not gone so deep as to reach the Cambrian the Trenton may be found extending entirely across the valleys. This is the case in the lower part of Browns Valley from Brooksville to beyond Guntersville. Above Guntersville the Trenton is seen mainly on the eastern side of the valley. The river touches these outcrops at many points, and at Guntersville the railroad connecting that city with Attalla would afford an additional means of transportation. No developments have yet been made in this area.

The valley separating the Warrior from the Cahaba coal field is known as Roups Valley in the southern and as Jones Valley in the northern part. In these the Trenton occupies a narrow, continuous belt, usually near the base of the eastern Red Mountain ridge, though in places it is high up on the ridge and even at its summit, as at Gate City, where the quarries of the Sloss Iron Company are located. Many analyses of the rock from this quarry have been made, and several are given in the second table on p. 432 (Nos. 2, 3, 4, 5, 6).

In Murphrees Valley the continuous belt of the Trenton, as above explained, is on the western side, while the faulted remnants are on the eastern side. No quarries have been opened in the Trenton limestone here, but the Louisville and Nashville Railroad goes up the valley as far as Oneonta and would afford means of transportation.

In Cahaba Valley, which separates the Cahaba coal field from the Coosa coal field, the Trenton is well exposed on the eastern side for the entire length of the valley from Gadsden down. It expands into wide areas near the southern end, where it has been quarried for lime burning at Pelham, Siluria, Longview, Calera, and other places on the line of the Louisville and Nashville road. Analyses 7, 8, and 9 of the table on p. 432 show the composition of the rock in this region.

The Central of Georgia and the Southern railroads cross this belt about midway of its length at Leeds, in Jefferson County, and near its northern end it is crossed by the Louisville and Nashville Railroad, where a quarry at Rock Springs, on the flank of Colvin Mountain, supplies the rock for lime burning. Analyses 10 shows the character of the rock at this point.

At Pratts Ferry, on the Cahaba River, a few miles above Centerville, in Bibb County, the Trenton limestone makes high bluffs along the river for several miles, and is in most convenient position for easy quarrying.

Marble works have in former days been established here and should be again put in operation, since the marble is of fine quality and beautifully variegated. No analyses are available, but there is no doubt that much of the rock is sufficiently low in magnesia to be fit for use in cement making. Cahaba River and a short spur from the Mobile and Ohio Railroad would afford transportation facilities for this deposit.

In Big Wills Valley, which separates Sand and Lookout mountains, the Trenton limestone occupies perhaps 25 square miles, but it is crossed only by the railroad connecting Gadsden with Guntersville. No analyses are available.

In the great Coosa Valley region the Trenton outcrops are found mostly on the western border near the base of Lookout Mountain, as in Broomtown Valley, and in other valleys extending south toward Gadsden. While these belts have been utilized in the past for the old Gaylesville, Cornwall, and Round Mountain furnaces, and possibly for some furnaces now in blast, no analyses are available.

Similarly, farther south, along this western border of the Coosa Valley, and running parallel with the Coosa coal field in Calhoun, St. Clair, and Shelby counties, there are numerous long, narrow outcrops of Trenton limestone. The Calcis quarry of the Tennessee Coal, Iron and Railroad Company, on the Central of Georgia Railroad, near Sterritt, is upon one of these outcrops, and furnishes limestone with a very low and uniform percentage of silica and magnesium. Analyses 11, 12, 13, 14, 15, and 16 exhibit the quality of the rock as received at the Ensley Steel Works, but care is taken at the quarry to select ledges low in silica and magnesia, and the analyses therefore represent only the selected ledges and not the average run of the quarry as a whole.

Near Talladega Springs, Marble Valley, and Shelby are other occurrences of the rock, and a quarry a few miles east of Shelby furnace has for many years supplied that furnace with its flux. The quality of the material here is shown by analyses 17, 18, 19, and 20.

The Cambrian limestones contain generally a very considerable proportion of magnesia, and for this reason are not suited for Portland-cement manufacture, though admirably adapted for furnace stone.

Along the eastern border of the Coosa Valley, near its contact with the metamorphic rock, there is a belt of limestone which, in places, is a white crystalline marble of great purity, as is shown by analyses 1 to 7, inclusive, of the table on p. 433. The Louisville and Nashville Railroad, from Calera to Talladega, passes close to this belt at many points. This marble has been quarried at several places for ornamental stone. It is mentioned here because it is near the railroad and its description completes the account of the limestone.

THE CLAYS.

The most important clays in the Paleozoic region occur in the Coal Measures, in the lower Carboniferous, and in the lower Silurian and Cambrian formations. But, inasmuch as a later formation—the Tuscaloosa of the Cretaceous—borders the Paleozoic on the west and south, and as it contains a great variety as well as abundance of clays, we shall include it here, although it is not Paleozoic.

Coal Measures.—In this group are numerous beds of shale which have been utilized in the manufacture of vitrified brick and fire brick, but many of them will probably be adapted to cement making. A great body of these shales occurs in connection with the coal seams of the Horse Creek or Mary Lee group, in Jefferson and Walker counties, and in position where they are conveniently situated with reference to limestone and coal and also to transportation lines. They are therefore well worth the attention of those contemplating the location of cement plants.

On the property of Mr. W. H. Graves, near North Birmingham, overlying the coal seam mined by him, there are two beds of shale—one yellowish, the other gray. These two shales have been tested and analyzed, and their composition is shown in Nos. 107 and 108 of the table.

Similar shales are used also at Coaldale, in Jefferson County, and at Pearce's mill, in Marion. Of these we have reports of physical tests, but no analyses.

So also most of the coal seams mined in Alabama rest upon clay beds which have not as yet been specially examined as to their fitness for cement making; but, in view of the proximity of the coal mines to the limestones, it might be worth while to investigate these underclays of the coal seams.

Lower Carboniferous.—Associated with the cherty limestones of the lowermost division of the lower Carboniferous of some of the anticlinal valleys are beds of clay of excellent quality, much of it being of the nature of china clay.

Probably the best of the exposures of these clays are to be seen in Little Wills Valley, between Fort Payne and the Georgia border, and on the line of the Alabama Great Southern Railroad, where for many years quarries have been in operation in supplying material for tile works and potteries. The clays lie near the base of the formation, close above the black shale of the Devonian, and average about 40 feet in thickness, though in places they reach 200 feet. The clay beds alternate with seams of chert which are from 2 to 8 inches in thickness, while the clay beds vary from 12 to 18 inches. The upper half of the clay is more gritty than the lower half, which often contains material suitable for the manufacture of the finer grades of porcelain ware. Analyses 3–6 in the table on page 433 show the composition of several varieties of clay from this section.

Lower Silurian and Cambrian.—Associated with the cherty limestones and brown iron-ore beds of the formations above named—beds of fine white clay, much of it china clay—are not uncommon. Analysis 7 of the table shows the composition of a white clay from the brown ore bank at Rock Run, in Cherokee County, where the clay is about 30 feet in thickness. Analyses 8 and 9 are also from Rock Run. No. 10, from near Gadsden, No. 11, from Blount County, and No. 12, from Oxanna, in Calhoun County, are of clays which seem to be adapted to cement making. While no great number of the clays of these formations have been analyzed, they are known to be widely distributed in Calhoun, Talladega, Jefferson, Tuscaloosa, and other counties in connection with the brown ore deposits.

Cretaceous.—In many respects the most important formation of Alabama, in respect of its clays, is the lowermost division of the Cretaceous, which has been called the Tuscaloosa, and which is, in part at least, of the same geologic horizon as the Raritan clays of New Jersey. The prevailing strata of this formation are yellowish and grayish sands, but subordinated to them are great lenses of massive clay varying in quality from almost pure-white burning clay to dark-purple and mottled varieties high in iron.

The formation occupies a belt of country extending from the northwestern corner of the State around the edges of the Paleozoic formations to the Georgia line at Columbus. Its greatest width is at the northwest boundary of the State, where it covers an area 30 or 40 miles wide in Alabama and of about the same width in Mississippi. The breadth at Wetumpka and thence eastward to the Georgia line is only a few miles. The most important part of this belt is where it is widest, in Elmore, Bibb, Tuscaloosa, Pickens, Fayette, Marion, Lamar, Franklin, and Colbert counties, and the deposits are traversed by the lines of the Mobile and Ohio; the Alabama Great Southern; the Louisville and Nashville; the Southern; and the Kansas City, Memphis and Birmingham railroads; as well as by the Warrior and Tombigbee rivers.

These clays have been described in some detail. Many analyses and physical tests have been presented in Bulletin No. 6 of the Alabama Geological Survey. From this bulletin have been selected certain analyses which appear to indicate the fitness of the clays for cement making.

In Elmore County in the vicinity of Coosada, along the banks of the river, about Robinson Springs, Edgewood, and Chalk Bluff, there are many occurrences of these clays, some of which have been used in potteries for many years. Analyses 13, 14 and 15, on p. 433, are of clays from Coosada, Edgewood, and Chalk Bluff, respectively.

In Bibb County clay has been quarried very extensively at Bibbville and near Woodstock for making fire brick. For this purpose the material is carried to Bessemer by the Alabama Great Southern Railroad. No. 16, from Woodstock, and 17, from Bibbville, will represent the average quality of the clay from these beds, which are very extensive both in thickness and in superficial distribution. The Mobile and Ohio crosses other extensive deposits in the southern part of the county, but no analyses are available.

The most important of the clay beds in Tuscaloosa County are traversed by the Mobile and Ohio Railroad and by the Alabama Great Southern.

Analysis 18, from Hull's, and analysis 19, from the Cribbs beds, are on the Alabama Great Southern, and 20 and 21 are from cuts of the Mobile and Ohio, a few miles west of the city of Tuscaloosa.

Many large beds are exposed along the Mobile and Ohio road in Pickens County also, but very few have been investigated. No. 22 is from Roberts Mill, in this county.

In Lamar and Fayette counties the same conditions prevail as in Pickens and Tuscaloosa. Analysis 23 is of pottery clay from the Cribbs place, in Lamar, and No. 24 is of clay from Wiggins's, 4 miles west of Fayette, and 25 and 26 are clays from W. Doty's place, 14 miles west of that town, in Fayette County.

Marion is one of the banner counties of the State for fine clays, but it is touched by railroads only along its southern border and in the extreme northeastern corner. Although at present not available because inaccessible, the clays mentioned below are worthy of consideration: No. 27, from Bexar; No. 28, from Briggs Fredericks', in sec. 8, T. 10, R. 13 W. This is from the great clay deposit which gives the name to Chalk Bluff and which underlies about two townships. No. 29 is from a locality about 16 miles southwest of Hamilton, the county seat.

No. 30 is from a locality near the Mississippi line, in sec. 20, T. 8, R. 15 W., in Franklin County, from land of Mr. Thomas Rollins.

Of the numerous fine clays of Colbert County analyses are given of two from Pegram station, on the Southern Railway near the Mississippi State line. These are Nos. 31 and 32.

Analyses of lower Carboniferous limestones.

Number.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica	0.50	1.73	0.77	1.14	1.02	1.40	0.68	0.81	0.82	2.16
Iron and aluminum oxide	1.45	.78	.35	.34	1.38	1.17	1.02	.89	.60	2.31
Calcium carbonate	96.58	96.54	97.60	98.53	95.25	94.67	96.54	97.45	97.37	89.15
Magnesium carbonate	2.58	......	......	......	1.73	2.26	1.26	.35	.75	4.20
Sulphur	......	......	......	......	......	......	......	......	.029	......
Number.	**11.**	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica	3.12	0.85	1.08	0.73	0.64	1.12	0.42	2.05	4.45	2.80
Iron and aluminum oxide	2.32	.65	.61	.65	.62	.90	.37	.76	3.30	.70
Calcium carbonate	85.87	96.64	96.91	97.60	97.48	96.38	97.32	89.64	86.35	94.59
Magnesium carbonate	4.20	1.36	.90	.52	.76	1.10	1.39	8.15	......	......
Sulphur	......	.024	.019	.018	......	......	.020	......	......	......

1. Average sample from Fossick quarry, near Rockwood, Franklin County. Analyzed at Government Arsenal, Watertown, N. Y.
2. Average sample from Blount Springs quarry—a compact limestone. Henry McCalley, analyst.
3. Average sample from Blount Springs quarry—a granular oolitic limestone. Henry McCalley, analyst.
4. Average sample upper 75 feet, Blount Springs quarry. J. L. Beeson, analyst.
5–9. Average sample Blount Springs quarry. J. R. Harris, analyst.
10, 11. From Worthington quarry, near Trussville, Jefferson County. C. A. Meissner, analyst.
12–17. From Vanns, near Trussville. J. R. Harris, analyst.
18. Average of about 150 feet thickness of rock used for flux, Compton quarry, Blount County. J. L. Beeson, analyst.
19, 20. Stockhouse sample, Compton quarry. Wm. B. Phillips, analyst.

Analyses of Trenton limestones.

Number.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica	4.48	5.70	2.43	3.65	3.29	3.82	0.39	0.15	0.78	1.00
Iron and aluminum oxides	1.22	1.87	3.30	.91	1.49	1.96	.13	Tr.	.35	.30
Calcium carbonate	88.85	91.16	89.88	92.38	92.61	90.44	99.11	99.16	97.52	97.00
Magnesium carbonate	3.52	......	......	......	......	......	.75	.75	1.27	Tr.
Sulphur	......	......	......	......	......	......	......	......	......	Tr.
Number,	**11.**	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica	0.43	0.58	0.38	0.34	0.39	0.98	2.50	2.09	1.08	2.25
Iron and aluminum oxides	.42	.25	.47	.46	.37	.52	1.40	1.01	.63	.68
Calcium carbonate	98.49	95.78	98.35	96.53	94.27	96.92	96.70	93.77	98.91	95.40
Magnesium carbonate	.16	2.89	.30	2.17	4.47	1.08	......	2.48	.58	.94
Sulphur	......	......	......	......	......	......	......	......	......	......

1. Average of several carloads flux rock from quarry at Vance, Tuscaloosa County, of Central Iron Company at Tuscaloosa. H. Buel, analyst.
2. Gate City quarry, Jefferson County. Average sample from the crusher. Henry McCalley, analyst.

3-6. Gate City quarry. J. W. Miller, analyst.
7, 8. Longview quarries, Shelby County. Used in lime burning. Report of Alabama State Geologist, 1875.
9. Jones quarry, near Longview. Report of Alabama State Geologist, 1875.
10. Rock Spring quarry, Etowah County. Used in lime burning and for flux. Wm. B. Phillips, analyst.
11-16. Rock from Calcis quarry, St. Clair County. J. R. Harris, analyst.
17-20. Shelby quarry, Shelby County. Used for flux in Shelby furnaces. Report of Alabama State Geologist, 1875.

Analyses of crystalline marbles.

Number.	1.	2.	3.	4.	5.	6.	7.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica	Tr.	2.70	2.95	4.65	2.80	1.35	0.28
Iron and aluminum oxides	....	.40	1.15	.75	.48	.30	.28
Calcium carbonate	99.47	90.80	95.25	94.40	95.60	97.60	99.19
Magnesium carbonate	.38	Tr.	.62	.41	.66	Tr.	.14

1. Herd's upper quarry, Talladega County. Tuomey's Second Report.
2. Herd's quarry, sec. 16, T. 21, R. 4 E., Talladega County. Wm. B. Phillips, analyst.
3. Taylor's mill, Talladega County, white marble. Wm. C. Stubbs, analyst.
4. Taylor's mill, Talladega County, blue marble. Wm. C. Stubbs, analyst.
5. Taylor's mill, Talladega County. A. F. Brainerd, analyst.
6. Nix quarry, sec. 36, T. 20, R. 4 E., Talladega County, white marble. Wm. B. Phillips, analyst.
7. Gannt's quarry, sec. 2, T. 22, R. 3 E., Talladega County, white marble. A. F. Brainerd, analyst.

Analyses of clays—Paleozoic and Lower Cretaceous.

Number.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica	61.55	57.80	79.80	82.04	66.25	82.11	60.50	72.20	57.00	67.95
Alumina	20.25	25.00	11.75	12.17	22.90	11.41	26.55	22.04	17.80	20.15
Ferric oxide	7.23	4.00	1.75	Tr.	1.60	1.40	.30	.16	5.60	1.00
Lime	Tr.	2.10	.75	Tr.	Tr.	Tr.	.90	.50	2.10	1.00
Magnesia	.99	.80	Tr.	.33	Tr.	.66	.65	.40	1.20	Tr.
Alkalies	1.25	1.80	1.50	.60	.75	1.80	2.70	.60	6.00	1.87
Ignition	6.19	7.50	4.11	4.33	9.05	4.00	7.90	5.80	9.45	8.00
	98.66	99.00	99.16	99.47	100.55	101.38	99.50	101.70	99.15	99.97

Number.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct,*	*P. ct.*
Silica	61.50	84.21	66.61	62.60	60.38	65.82	74.25	61.25	65.35	60.03	58.13
Alumina	26.20	9.75	21.04	26.98	20.21	24.58	17.25	25.60	21.30	24.66	24.68
Ferric oxide	2.10	.69	2.88	.72	6.16	1.25	1.19	2.10	2.72	3.69	3.85
Lime	.50	.70	.40	.40	.09	....	.40	.25	.60	.13	.15
Magnesia	.43	.14	.58	.36	.72	Tr.	Tr.	.82	.86	.38	.32
Alkalies	.70	....	.70	.65	1.80	.60	.52	1.35	Tr.	Tr.	1.78
Ignition	7.29	4.10	7.00	9.30	10.21	8.16	6.30	8.10	8.79	11.34	11.78
	98.72	99.59	99.21	101.01	99.57	100.41	99.39	99.47	99.62	100.23	100.51

Analyses of clays—Paleozoic and Lower Cretaceous—Continued.

Number.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica	68.23	60.90	63.27	67.10	65.58	68.10	65.49	70.00	67.50	66.45	64.90
Alumina	20.35	18.98	19.68	19.37	19.23	21.89	24.84	21.31	19.84	18.53	25.25
Ferric oxide	3.20	7.68	3.52	2.88	4.48	2.01	Tr.	2.88	6.15	2.40	Tr.
Lime	.34	Tr.	1.30	Tr.	Tr.	.80	1.26	.20	.12	1.50	Tr.
Magnesia	Tr.	Tr.	Tr.	.73	Tr.	.28	Tr.	Tr.	.10	1.25	Tr.
Alkalies	.74	Tr.	1.20	.67	......	.40	Tr.	Tr.	......	Tr.	......
Ignition	7.16	13.36	9.80	7.79	6.90	5.75	7.80	6.85	7.65	9.46	8.90
	100.02	100.92	98.77	98.54	96.19	99.23	99.39	101.24	101.36	99.59	99.05

Coal Measures.
1. Dark yellow shale from Coal Measures, W. H. Graves, near Birmingham, Jefferson County.
2. Light gray shale from same locality.

Lower Carboniferous.
3–5. Fire clay, near Valley Head, Dekalb County.
6. China clay, Eureka mines, Dekalb County.

Silurian and Cambrian.
7. China clay, Rock Run, Cherokee County (Dykes ore bank).
8. Fire clay, Rock Run, Cherokee County.
9. Pottery clay, Rock Run, Cherokee County.
10. China clay, J. R. Hughes, Gadsden, Etowah County.
11. Stoneware clay, Blount County.
12. Stevens, Fire clay, Oxanna, Calhoun County; probably too much free sand.

Lower Cretaceous (Tuscaloosa).
13. Stoneware clay, Coosada, Elmore County.
14. Pottery clay, McLean's, near Edgewood, Elmore County.
15. Stoneware clay, Chalk Bluff, Elmore County.
16. Fire clay, Woodstock, Bibb County.
17. Fire clay, Bibbville, Bibb County.
18. Fire clay, Hulls Station, Alabama Great Southern Railroad, Tuscaloosa County.
19. Pottery clay, H. H. Cribbs, Alabama Great Southern Railroad, Tuscaloosa County.
20. Pottery clay, J. C. Bean, Mobile and Ohio Railroad, Tuscaloosa County.
21. Fire clay, J. C. Bean, Mobile and Ohio Railroad, Tuscaloosa County.
22. Stoneware clay, Roberts's mill, Pickens County.
23. Pottery clay, Cribb's place, Lamar County.
24. Stoneware clay, H. Wiggins, Fayette County.
25–26. Pottery clay, W. Doty, Fayette County.
27. Blue clay, railroad cut near Glen Allen, Marion County.
28. China clay, Briggs Frederick, Marion County.
29. Pottery clay, 10 miles southwest of Hamilton, Marion County.
30. Pottery clay, Thomas Rollins, Franklin County.
31. Pottery clay, J. W. Williams, Pegram, Colbert County.
32. China clay, Pegram, Colbert County.

THE PORTLAND CEMENT MATERIALS OF CENTRAL AND SOUTHERN ALABAMA.

The raw materials suitable for the manufacture of Portland cement which occur in central and southern Alabama are argillaceous limestones, purer limestones, and clays.

The limestones valuable as cement materials occur mainly at two horizons, viz, in the Selma chalk or Rotten limestone of the Cretaceous, and in the St. Stephens formation of the Tertiary. The clays available are residual clays derived from the decomposition of these two limestone formations, the stratified clays of the Grand Gulf formation, and alluvial clays occurring in the river and creek bottoms. It is possible that later investigation may show that some of the other stratified clays of the Tertiary formations are suitable for cement making, and this is especially likely to be the case with the clays of the lowermost Cretaceous or Tuscaloosa formation.

THE SELMA CHALK OR ROTTEN LIMESTONE.

Geologic horizon.—The Cretaceous system in Alabama is susceptible of classification into four divisions. These are, in ascending order: (1) The Tuscaloosa, a formation of fresh-water origin, made up in the main of sands and clay in many alternations. In places the clays occur in deposits of sufficient size and of such a degree of purity as to make them of commercial value. (2) The Eutaw, which is of marine origin and composed of sands and clays more or less calcareous, but nowhere showing beds of limestone properly so called. (3) The Selma chalk, which is of marine origin, and is composed, in part at least, of the microscopic shells of Foraminifera. This formation, throughout the western part of the belt covered by it in Alabama, is about 1,000 feet in thickness, and is made up of beds of chalky and more or less argillaceous limestone. In a general way it may be said that the lower and upper thirds of the formation contain 25 per cent or more of clayey matters mixed with the calcareous material, while the middle third will hold less than 25 per cent of these clayey impurities. (4) The Ripley. This, like the preceding, is a marine formation, in which, generally, the calcareous constituents predominate, but in places it contains sandy and clayey beds.

From this summary it will be seen that the Selma chalk is the only Cretaceous formation in Alabama which offers limestone in such quantity and of such composition as to be fit for Portland cement material.

General description.—As has been stated above, the Selma chalk is a calcareous formation throughout its entire thickness of about 1,000 feet. The rock, however, varies in composition between somewhat wide limits, and taking account of the composition we may readily distinguish three divisions of it. The rock of the upper or Portland division is highly argillaceous, holding 25 per cent or more of clayey matters; portions of it are composed of calcareous clays or marls rather than limestone, and in these beds are found great numbers of fossils, mainly oysters. Along Tombigbee River these beds make the bluffs from Paces Landing down nearly to Moscow, and on the Alabama they form the banks of the river from Elm Bluff down to Old Lexington Landing. The strata exhibited in these bluffs consist of dark-colored, fossiliferous, calcareous clays alternating with lighter-colored and somewhat more indurated ledges of purer, less argillaceous rock. At Elm Bluff, which is about 125 feet high, the upper half of the bluff is of this character. The lower half of the bluff is composed of rock more uniform in composition and freer from clay, and is the top of the middle part of the Selma formation (the Demopolis division), which is made up of limestone of more uniform character, containing generally less than 25 per cent of clayey material.

In this middle or Demopolis division of the Selma formation the fossils are rarer than in either of the others, oysters and anomias being the most common forms. This variety of the rock forms the bluffs along Alabama River from Elm Bluff up to Kings Landing. It is seen in its most typical exposure at White Bluff, where it is at least 200 feet in thickness and makes on the right bank of the river an almost perpendicular bluff. On Tombigbee River it extends from near Bartons Bluff past Demopolis up to Arcola and Hatchs Bluff. Its lowermost beds, a compact limestone of great purity, form the upper parts of Bartons and Hatchs bluffs. On Little Tombigee River the same rock makes the celebrated bluffs at Bluffport and at Jones Bluff (Epes), beyond which for several miles it is shown along the stream.

Judging from the width of its outcrop, this division of the Rotten limestone must be about 300 feet in thickness. It underlies the most fertile and typical "prairie" lands of the South. At intervals throughout this region the limestone rock appears at the surface in what are known as "bald prairies," so named from the fact that on these spots there is no tree growth. The disintegration and leaching out of the limestone leaves a residue of yellowish clay, which accumulates sometimes to a thickness of several feet in low places. This clay is used at the Demopolis plant in the manufacture of cement, and in most localities where suitable limestone is found the clay is present in sufficient quantity to supply the needs of the cement manufacturer.

At the base of this middle or Demopolis division occurs a bed consisting of several ledges of compact, hard, pure limestone, which weathers into curious shapes, and has received the names horse-bone rock and bored rock. This bed, as above mentioned, appears at the top of Hatchs Bluff; also at Arcola Bluff, and between Demopolis and Epes, at Jordans Ferry, and other places. Where it outcrops across the country it makes a ridge easily followed and characterized by the presence on the surface of loose fragments of the limestone.

The lower part of the formation (the Selma division), like the upper, is composed of clayey limestone, in many places being rather a calcareous clay. The color is dark gray to bluish, and in most exposures there is a striping due to bands of lighter-colored, purer limestone alternating with the prevailing quality. Along Alabama River the strata of this division are seen in the bluffs from Kings Landing up to Selma and beyond. On the Warrior River they are seen in the bluffs at Arcola, Hatchs, Millwood, and Erie, occupying in the last-named locality the upper part only of the bluff. On the Tombigbee, the bluffs at Gainesville, at Roes, and Kirkpatricks are formed mainly of the rocks of this division, while above Roes, at Jordans, occurs the line of junction of this with the middle division. Near this line of division there is a very characteristic feature to be observed at many points, viz., about 10 or 15 feet below the hard ledges of pure limestone forming the base of the middle (Demopolis) division the dark-colored argillaceous rock shows a tendency to flake off and weather into caves, sometimes several feet deep and 20 feet or more in length. These holes extend in some places for great distances along the bluffs, as on Alabama River just above Kings Landing, on the Tombigbee below Roes Bluff, and at Jordans Ferry. The outcrop of the argillaceous rocks of this division gives rise to black prairie soils, in which beds of fossil shells, mainly oysters, are common.

It has been suggested that the argillaceous rocks of this and the uppermost division could be mixed with the purer limestone of the middle division in such proportions as to constitute a good cement mixture. In this case it would be easy to select localities near the junction of the two divisions where both varieties of the rock could be quarried, if not in the same pits, at least in pits closely adjacent. This would do away with the need of adding other clay to the limestone. Localities of this sort would be found along the borders north and south of the belt of outcrop of the white Demopolis rock.

Details of localities.—The general characters of the rocks of this formation have been mentioned above, and it remains to give details of the special localities examined, together with analyses of the limestones collected. In making the collections material from the middle or Demopolis division of the formation has been generally chosen, since most of the limestone of the formation which contains 75 per cent or more of carbonate of lime is to be found in this division. At the same time specimens of the more argillaceous material, especially of the lower (Selma) division of the formation, have been taken for comparison and analysis, with a view to ascertaining whether or not it will be practicable to provide a cement mixture by using the proper proportions of the purer and more argillaceous materials.

Inasmuch as suitable material for cement manufacture can be had in practically unlimited quantity all along the outcrop of the purer limestone of the Demopolis division, the location of the plants for the manufacture of this product will be determined by other considerations than the quality of the rock. Chief among these will be facilities for transportation, cheapness of fuel, and cost of labor and abundance of it at command.

Examinations have consequently been confined to those localities which appear to be most favorably situated in these respects, and especially to those localities which are on navigable streams or on north-south railroad lines, or on both.

The first place considered on Tombigbee River is Gainesville, where the limestone appears on the river bluff in a thickness of 30 to 40 feet, beneath a heavy covering of Lafayette sands and pebbles. A short distance inland from the river, however, the rock appears at the surface and may be quarried without difficulty. Specimens have been taken from the different parts of the bluff near the ferry which will show the composition of the limestone here (see analyses 1, 2, 3, and 4, p. 445). Other specimens are from the Roberts place, 3 miles east of Gainesville—one of which was taken from the top of a 30-foot bluff, others from the surface 1 mile and 5 miles from the river (analyses 5 and 6).

At Jones Bluff, on the Tombigbee, near Epes station, on the Alabama Great Southern Railroad, white limestone of remarkably uniform composition shows along the river bank for a distance of a mile or so, with an average height of perhaps 60 feet. Here the bare rock forms the surface, so that there would be no overburden to be removed in quarrying. The railroad crosses the river at this locality, which thus has the advantage of both rail and water transportation. From the lower end of this exposure down to Bluffport the white rock is seen at many points, e. g., below Lees Island, Martins Ferry, Braggs, etc. It generally has a capping of 15 to 20 feet of red loam and other loose materials.

Specimens have been analyzed from Epes and Hillmans (analyses 7, 8, and 9, p. 445).

At Bluffport the white rock in places forms a bluff 100 feet or more in height along the right bank of the river for a distance of a mile or more. This is the counterpart of Jones bluff, above mentioned, and the character of the material is shown by analysis No. 10, p. 445. As at Epes, the rock extends up to the surface, so that quarrying would be attended with little or no difficulty. Below the Bluffport bluffs the easterly course of the river brings it into the territory of the lower strata of the formation, and the white rock does not appear again below Jordans Ferry, except in thin patches at tops of some of the bluffs. The character of the material of these lower beds may be seen from the analyses of specimens taken from Jordans and Belmont and Roes bluff, Nos. 11, 12, 13, and 14. The two specimens from the last-named locality represent the composition of the prevailing dark-colored argillaceous rock and of the lighter-colored ledges.

At Demopolis there is an important occurrence of the white rock extending along the left bank from a mile above the landing to about 2 miles below, with average height perhaps of 40 or 50 feet. The rock is remarkably uniform in appearance and probably in composition (analysis 30, p. 446). At McDowell's the main bluff is on the right bank and the rock is of great purity, as shown by analysis 16. The exposures continue down to Paces Landing, 9 miles below Demopolis, and beyond this the bluffs are much darker in color and striped with lighter bands, characteristic of the strata of the upper part of the formation. Thence down nearly to Moscow occur the exposures of these upper beds.

Above Demopolis at Arcola and Hatchs Bluff the bluish clayey limestones of the Selma division are seen in force, with the lowermost ledges of the Demopolis division—the horse-bone rock—capping them. Two analyses of these varieties at Hatchs will show well the contrast in their chemical composition (analyses 19 and 20, p. 446.)

From Demopolis eastward the line of the Southern Railway is located on the outcrop of this white rock, at least as far as Massillon, where it passes into the territory of the lower or Selma division. Two miles from Demopolis on this road is the cement manufacturing plant of the Alabama Portland Cement Company, with six kilns in place. The quarry is on the opposite side of the railroad track from the kilns, but only a few hundred feet distant. The clay used is residual clay derived from the decomposition of the limestone, and is obtained from the river bank a few yards away. The composition of the rock and of the clay used in the manufacture is shown by analyses 15, 18, 46. A specimen taken from Knoxwood station, between the cement works and Demopolis station, shows similar composition (see analysis 17). The analyses below given (61–63, p. 447) show the chemical character of the cement manufactured at Demopolis.

At Van Dorn station the white rock outcrops in the fields over considerable territory, and just east of the station there is a deep cut through it. Analyses from about Van Dorn show sufficiently well the character of the material at these points (analyses 21, 22, 47, 48, 49, 50, 51, 52).

About Uniontown the bare rock is exposed at numerous points, and the advantages of this place for the location of manufacturing plants seem to be very great. Specimens have been taken from the Bradfield and Shields places, west of the town, from the Pitts place east of it, and from a point south of the town along the McKinley road. Other specimens have come from plantations near the road for several miles eastward and the analyses are appended (analyses 23, 24, 25, 26).

The composition of the residual clay overlying the limestone at the Pitts Home place is shown by analysis 55. South of Massilon, near the crossing of the Southern and Louisville and Nashville railroads, in the vicinity of Martins station, the white rock shows in numerous exposures through the fields, making a country somewhat similar to that about Uniontown. At many points the rock has no overburden and is admirably adapted to cheap quarrying. On the banks of Bogue Chitto Creek, near Martins station, on the Milhous place, the rock is exposed in a bluff with a bed of plastic clay overlying, but here it is below a considerable thickness of red loam and sands of the Lafayette formation. The character of the rock at Milhous station, west of Martins, may be seen from the analysis No. 27.

The same rocks make the great bluff of White Bluff, on Alabama River. Specimens were selected from this bluff at two points—one about halfway down the bluff, the other 20 feet lower. Generally there is a capping of the red loam and sands of the Lafayette over the limestone, but near the upper end of the bluff the white rock extends to the summit, where it has a capping of plastic clay only. The character of the limestone is shown in analysis 28 (see p. 446).

At Elm Bluff, as has already been shown, the upper and middle divisions of the formation are in contact. At Kings Bluff the middle and lower parts of the formation are in contact. At the other bluffs of the river between Kings Landing and Selma the rock of the lower division is exhibited. No. 31 is an analysis of the material as exposed at Cahaba; No. 53 of the river bluff at the steamboat landing in Selma, and No. 32 at Benton.

To summarize: From Demopolis eastward along the line of the Southern Railway, by Van Dorn, Gallion, Uniontown, Massillon, and thence by Martins and Milhouse stations to White Bluff, the white or Demopolis type of rock appears at the surface in clean exposures at almost innumerable points, either immediately on the railroad or at very short distance from it. So far as the quality, quantity, and accessibility of the limestone rock are concerned, manufactories of cement might be located almost anywhere in this territory. From Demopolis westward the same conditions prevail up the river to Epes, and thence to Gainesville, beyond which point the white rock is to the west of the river at greater or less distance.

East of Alabama River the outcrop of the cement rock is crossed by the Louisville and Nashville Railroad (Repton branch), as before stated, between Berlin and Pleasant Hill stations. At Benton, on Alabama River and on the railroad, the limestone has the composition shown by analysis 32.

On the Montgomery and Selma road, at the crossing of Pintlala Creek near Manack station, the limestone is exposed in the creek banks and in the open fields, often with little or no overburden. On page 446 is given an analysis of a specimen from the fields along the wagon road (No. 33) and from the creek bank (No. 34).

On the main branch of the Louisville and Nashville Railroad the white rock shows between the city and McGhees switch, and an analysis of a specimen from McGhees is given (No. 35).

Examinations have not been carried beyond Montgomery, but it is known that the white prairie rock is crossed by the Central of Georgia Railroad between Matthews and Fitzpatrick stations, and there seems to be no doubt that along this stretch of the road suitable rock will be found convenient to the line.

THE ST. STEPHENS LIMESTONE.

General description.—The St. Stephens or White limestone formation of the Alabama Tertiary, which includes the uppermost of the

Eocene strata, is in general equivalent to the Vicksburg limestone of the Mississippi geologists.

In Alabama it exhibits three rather well-defined phases, which, in descending order, are (1) the Upper or Salt Mountain division, observed at one locality only in Clarke County; (2) the Middle or St. Stephens division; and (3) the Lower or Jackson division. Of these it is only the Middle division with which we are here concerned, since the first is, so far as known, restricted to one locality, and the third is seldom exposed along Alabama rivers and railroads.

The following section of the St. Stephens Bluff, Tombigbee River, will give an idea of the strata of this division:

Section of St. Stephens Bluff.

	Feet.
1. Red residual clay	1 to 5
2. Highly fossiliferous limestone holding mainly oysters, and full of holes due to unequal weathering	10 to 12
3. Orbitoidal limestone (chimney rock), a soft, nearly uniform porous limestone, making smooth perpendicular face of the bluff except where bands of harder limestone of very nearly similar composition alternate with the softer rock. Both varieties hold great numbers of the circular shells of *Orbitoides mantelli.* These harder ledges are nearly pure carbonate of lime, take a good polish, and are often burned for lime	60
4. Immediately below 3, for 5 or 6 feet, the strata were not visible, being hidden by the rock falling from above, but the space seems to be occupied by a bluish clay. Then follows a soft rock somewhat of same consistency as No. 3 above, but containing a good deal of green sand. The fossils are mostly oysters and *Plagiostoma dumosa.* This bed is in places rather indurated superficially, and forms projecting ledges	10 to 15
5. Bluish clayey marl with much green sand, containing the same fossils as No. 4. It washes or caves out from under No. 4, which overhangs it	4 to 5
6. Massive joint clay, yellow on exposed surface, blue when freshly broken; no fossils observed. Extends below the water level to unknown depth; exposed	3 to 4

The rock of this formation, which seems to be the best suited for cement material, is the soft "chimney rock" or orbitoidal limestone of bed No. 3 above. This is usually quarried for chimneys and other constructions by sawing it out and dressing it down with a plane into blocks of suitable size, which are then laid like brick.

The numerous analyses given below will show that this rock is a purer limestone than most of the material of the Selma chalk of the Cretaceous formation above considered. In cement making it will, in consequence, require a larger proportion of clay to be mixed with it, and the question of obtaining suitable clay in sufficient quantity and in close proximity becomes one of some importance. The residual clay left after decomposition and leaching of the limestone seems to be fairly well adapted to the purpose. Besides this residual clay some analyses have been made of the clays of the river and creek bottoms of the country near the limestone outcrops, and of the clays of the Grand

Gulf formation, which very generally in this section overlies the limestone. Some analyses of the last-named clays have been made from material occurring near St. Stephens, and near Manistee Junction on the Repton Branch of the Louisville and Nashville Railroad. At this last-named locality the clay is present in sufficient quantity to be of value if the composition is suitable.

DETAILS OF LOCALITIES.

St. Stephens.—The first locality to be considered is the bluff at St. Stephens, a section of which has been given, and it may be taken as a typical section of the formation everywhere. At St. Stephens the whole of the soft orbitoidal limestone or "chimney rock" might be used, as the composition is uniform throughout. The overlying harder limestone has almost the same composition, but it is less easily crushed and handled. It may be quarried here from the surface down, as it is covered only by a thin layer of residual clay. The characters of the limestone and of the clay from here are sufficiently well shown by the subjoined analyses (36, 56). The character of the clay near St. Stephens at the water level (No. 6 of the St. Stephens section) is shown in analysis 60.

Below St. Stephens there is deep water to Mobile, with the exception of one bar, which may be removed without much trouble or expense.

Oven Bluff.—From Hobson's quarry, just above the Lower Salt Works Landing, down to Oven Bluff, a distance of 2 miles, the orbitoidal limestone or chimney rock occurs at the base of bluffs of Tertiary age.

At the quarry the hard limestone, which is being taken up for riprap work, lies, as at St. Stephens, just above the soft chimney rock. Along the stretch of river above described this chimney rock is seen in a bed 15 or 20 feet in thickness, just above the river bottom, and is easily accessible. As regards clay three varieties have been examined, a residual clay from over the limestone, a swamp-bottom clay from the low grounds of Leatherwood Creek, and clay from strata of the Grand Gulf formation, which here overlies the St. Stephens limestone. The analyses of these clays have not yet been made.

The first shoal in the river above Mobile is a few miles above Oven Bluff, so that from this place down there is a 9-foot channel at all seasons, which will give to Oven Bluff a certain advantage over other localities in regard to transportation. The shoal mentioned is one which can be removed, so that St. Stephens may be classed with Oven Bluff as regards transportation by water, except that the former is some miles farther from the Gulf than the latter.

Analyses by Doctor Mallett of other specimens of this chimney rock are here presented. No. 43 is of a clay from Colonel Darrington's place, in the lower part of Clarke County near Gainestown, and 44 and 45 are from other localities in Clarke County near the rivers.

Localities along the line of the Southern Railway.—At Glendon station, a few miles east of Jackson, there is an exposure of the chimney rock close to the track. The rock here is about 20 feet thick, and the limestone is covered by a bed of red residual clay similar to that at St. Stephens and Oven Bluff. The same chimney rock may be seen along the road between the station and Jackson, and no doubt it occurs from Glendon up to Suggsville station, within convenient reach of the railroad. At Suggsville station the same rock occurs along the road leading from station to the town. This place is within a short distance of the railroad.

Between Suggsville and Gosport the country rock is the St. Stephens limestone, but no particular attention was given to it for the reason that no railroad crosses the country along this line.

Along Alabama River.—At Perdue Hill the St. Stephens rock outcrops near the base of the hills which descend to the terrace on which the town of Claiborne stands. The bluff at Claiborne Landing shows near the summit the calcareous clays or clayey limestone which lies at the base of the St. Stephens formation, and which is generally thought to be the equivalent of the Jackson group of the Mississippi geologists. It is quite possible that this rock, where it occurs in sufficient quantity, may be suitable for cement making, since it has a composition not far different from much of the Rotten limestone or Selma chalk. No investigations have yet been made concerning it, for the reason that there are comparatively few points where it appears in adequate thickness and in favorable localities as regards transportation.

At Marshalls Landing, just above the mouth of Randons Creek, is the first exposure of the chimney rock along Alabama River. This occurs at the top of the bluff. It has the usual covering of residual clay. Below the orbitoidal or chimney rock at Marshalls there are 20 feet or more of a porous limestone. In the same bluff there are beds of calcareous clay, which might possibly be used in mixing with the limestone. At the landing these would be difficult to quarry because of overlying strata, but they would certainly be found without cover along the bluffs above Marshalls if they should prove of value.

From Marshall's down to Gainestown Landing the river bluffs show beds of the limestone at numerous points. At Gainestown, the topmost bed of the St. Stephens, the hard crystalline limestone occurs not far above the water level in the river. This stone has been cut and polished and proves to be a first-rate marble, inasmuch as it takes a good polish and shows agreeable variations in color. The soft chimney rock underlies the hard limestone here as at other points.

At Choctaw Bluff, some miles below Gainestown, there is the last exposure of the Tertiary limestones on this river. The material is an argillaceous limestone with numerous fossils, but it seems hardly likely to be of use in cement making.

Between Alabama River and the main line of the Louisville and Nashville Railroad.—A few miles east of Marshalls Landing, at Manistee Mills, the terminus of a sawmill road, there is a quarry of the chimney rock, which is conveniently situated as to transportation, since it is on the railroad. Across the county to the Repton Branch of the Louisville and Nashville Railroad, the St. Stephens limestone may, of course, be found at thousands of places, but no mention is made of these occurrences where they do not lie on railroad line.

Below Monroe Station, near Drewry, on the Repton Branch, this road crosses the line of outcrop of the chimney rock, which at a number of points in the vicinity of Drewry lies within easy reach of transportation.

A few miles below Drewry, at Manistee Junction, there is a fine exposure of Grand Gulf clays in railroad cuts both north and south of the station.

Analysis is given (59) of the clays from three horizons in these cuts, from which their suitability for admixture with the limestone may be determined.

On the main line of the Louisville and Nashville Railroad.—The chimney rock may be found at many points below Evergreen in the vicinity of Sparta and Castleberry stations. There are many bluffs of this rock on the banks of Murder Creek in this vicinity, and there are several quarries from which the stone has been obtained for building purposes, within short distances of the railroad line. At the foot of Taliaferros Heights the limestone forms high bluffs on the creek, at Ellis Williams Spring there are bluffs with the soft rock at the base and the hard horse-bone rock at the top, and on the creek bank a few hundred yards away is one of the quarries mentioned above. In fact the localities where the rock may be found within convenient distance of the railroad, and in a position favorable to cheap quarrying, are numerous in all this region. No clays were seen except the usual residual clays from the decomposition of the limestone and a clay occurring close to Evergreen in the pits of Wild Brothers. Analyses 41 and 42 will show sufficiently well the character of the limestone in in this section.

These Evergreen occurrences have attracted attention because of their location on the line of a great railroad system within short distance of tide water.

Farther to the east this limestone formation extends across Alabama and into Georgia and Florida, but as there is no north-south railroad east of the Louisville and Nashville at this time, the investigations have gone no further.

To summarize: While the St. Stephens limestone outcrops across the State from the Mississippi line to the Chattahoochie River, often occupying broad belts, attention has been concentrated on those localities which lie upon navigable streams or upon railroad lines terminating in Gulf ports. As compared with the Demopolis division of the Selma chalk, this limestone is more uniform in composition, higher in lime content, softer and more easily quarried and crushed, and in geographical position many miles nearer the Gulf.

Its thickness, on the other hand, is much less, although sufficient to supply an indefinite number of manufactories with raw material for cement.

Analyses of Cretaceous and Tertiary limestones.

Locality.	Insoluble matter.	Iron and aluminum oxides.	Calcium carbonate.	Magnesium carbonate.	Sulphuric anhydride.	Total sulphur.	Water and organic matter.	Alkalies.	Total.
1. Gainesville Bluff, Tombigbee River, 5 feet from top of bluff; R. S. Hodges, analyst	29.50	5.00	56.71	1.69	1.32	......	5.78	......	......
2. Gainesville Bluff, Tombigbee River, lower part of bluff; R. S. Hodges, analyst	23.00	3.14	67.67	2.26	1.97	......	1.96	......	......
3. Gainesville limestone; F. P. Dewey, analyst	18.42	10.79	65.21	1.57	.30	0.83	......	......	97.12
4. Gainesville limestone; A. W. Dow, analyst	27.25	15.96	54.00	1.11	.44	1.23	......	......	99.99
5. Roberts's place, near Gainesville, top of bluff; R. S. Hodges	19.10	3.70	75.57	1.24	.69	......	1.70	......	......
6. Roberts's place, near Gainesville, 5 feet above water; R. S. Hodges	21.98	4.10	69.75	1.50	1.02	......	1.65	......	......
7. Jones Bluff, at Epes; R. S. Hodges	9.44	1.76	86.28	1.02	......	......	1.30	......	100.00
8. Jones Bluff, at Epes; Dr. J. W. Mallet	16.69	2.22	80.48	.53	......	......	......	......	99.92
9. Hillmans Bluff, below Epes; R. S. Hodges	16.41	3.14	77.43	1.30	......	......	1.99	......	100.27
10. Bluffport Ferry, Tombigbee River; R. S. Hodges	11.68	1.82	85.10	1.25	......	......	......	......	99.85
11. Jordans Ferry, Tombigbee River; R. S. Hodges	26.26	3.06	67.28	1.87	......	......	1.53	......	100.00
12. Belmont Bluff, Tombigbee River; R. S. Hodges	31.16	5.44	55.84	2.12	......	......	5.44	......	100.00
13. Roes Bluff, Tombigbee River, main part of bluff; R. S. Hodges	31.74	4.42	55.82	2.10	......	......	5.92	......	100.00
14. Roes Bluff, Tombigbee River, light-colored ledges; R. S. Hodges	14.92	3.46	78.52	1.02	......	......	2.08	......	100.00
15. Demopolis limestone, F. P. Dewey; U. S. Mint analyst	13.32	8.74	73.94	1.40	.27	.64	......	......	98.31
16. McDowells Bluff, below Demopolis; R. S. Hodges	6.06	1.62	90.40	1.15	......	......	.77	......	100.00
17. Knoxwood, near Demopolis; R. S. Hodges	15.18	2.22	78.57	1.38	.91	......	1.74	......	100.00
18. Material used in Demopolis Cement Works; R. S. Hodges, analyst	12.50	2.76	80.71	1.05	1.62	......	1.36	......	100.00

Analyses of Cretaceous and Tertiary limestones—Continued.

Locality.	Insoluble matter.	Iron and aluminum oxides.	Calcium carbonate.	Magnesium carbonate.	Sulphuric anhydride.	Total sulphur.	Water and organic matter.	Alkalies.	Total.
19. Hatchs Bluff, Warrior River above Demopolis; main part of Bluff; R. S. Hodges	41.18	4.16	44.78	2.68	......	......	7.20	......	100.00
20. Hatchs Bluff, Warrior River above Demopolis; ledges at top of bluff; R. S. Hodges	3.02	1.10	93.52	1.38	......	......	.98	......	100.00
21. At Van Dorn station, from roadside; R. S. Hodges	14.36	2.80	80.47	1.30	......	......	1.07	......	100.00
22. At Van Dorn station, railroad cut east of station; R. S. Hodges	15.63	2.02	78.77	1.04	......	......	2.54	......	100.00
23. Uniontown, P. H. Pitts, Home Place; R. S. Hodges	16.18	3.08	75.35	1.35	......	......	4.04	......	100.00
24. Uniontown, P. H Pitts, Houston Place; R. S. Hodges	19.20	3.58	72.21	1.98	......	......	3.03	......	100.00
25. Uniontown, P. H. Pitts, Rural Hill Place; R. S. Hodges	18.62	3.28	74.52	1.17	......	......	2.41	......	100.00
26. Uniontown, 1 mile south on McKinley road; R. S. Hodges	12.14	......	83.45	......	......	......	......	......	......
27. Railroad cut, Milhous station, Southern Railway, Dallas County; R. S. Hodges	15.30	2.44	80.10	.98	......	......	1.18	......	100.00
28. White Bluff, Alabama River; lower part of bluff; R. S. Hodges	26.14	2.78	64.25	......	......	......	......	......	......
30. Demopolis, Tombigbee River; Dr. J. W. Mallet, analyst	21.81	2.23	75.07	.72	......	......	......	......	99.83
31. Limestone from Cahaba, Alabama River; Dr. J. W. Mallet, analyst	31.04	2.94	64.37	.79	......	......	......	......	99.14
32. Limestone from Benton, Alabama River; W. B. Phillips, analyst	19.74	11.67	54.83	5.14	.85	......	4.96	2.88	100.07
33. Limestone from Manack station, Lowndes County; R. S. Hodges	20.90	4.06	67.16	1.08	1.01	......	5.79	......	100.00
34. Limestone from Manack station; B. B. Ross, analyst	13.20	9.00	74.26	1.46	......	......	......	......	......
36. St. Stephens orbitoidal limestone, St. Stephens, Tombigbee River; R. S. Hodges, analyst	3.38	1.04	92.85	1.92	.13	......	......	......	99.32
41. St. Stephens orbitoidal limestone, near Evergreen; Dr. W. B. Phillips, analyst	1.26	1.72	95.15	.65	.02	......	.65	.11	99.56
42. St. Stephens orbitoidal limestone, near Evergreen; Dr. W. B. Phillips, analyst	2.75	2.73	93.30	.23	.02	......	.60	.14	99.77
43. St. Stephens orbitoidal limestone, Colonel Darrington's, near Oven Bluff, Clarke County, Dr. J. W. Mallet, analyst	1.69	2.12	94.84	.96	......	......	......	......	99.61
44. St. Stephens orbitoidal limestone, Clarke County, near river; Dr. J. W. Mallet, analyst	2.44	.27	94.85	......	......	......	......	......	99.13
45. St. Stephens orbitoidal limestone, Clarke County, near river; Dr. J. W. Mallet, analyst	4.15	1.29	93.19	1.09	......	......	......	......	99.72
46. Rock used in Alabama Portland Cement Works, Demopolis; analysis sent in by T. G. Cairns, general manager	9.88	6.20	77.12	1.08	......	......	5.72	......	100.00
47. Limestone from property of J. B. Kornegay, at Vandorn, sample No. 1; R. S. Hodges, analyst	16.74	2.09	77.88	.92	......	......	2.37	......	100.00

Analyses of Cretaceous and Tertiary limestones—Continued.

Locality.	Insoluble matter.	Iron and aluminum oxides.	Calcium carbonate.	Magnesium carbonate.	Sulphuric anhydride.	Total sulphur.	Water and organic matter.	Alkalies.	Total.
48. Limestone from property of J. B. Kornegay, at Vandorn, sample No. 2; R. S. Hodges, analyst.	13.19	2.12	81.89	1.03	......	......	1.77	......	100.00
49. Limestone from property of J. B. Kornegay, at Vandorn; sample No. 3; R. S. Hodges, analyst.	20.01	2.93	73.64	1.01	......	......	2.41	......	100.00
50. Limestone from property of J. T. Collins, at Vandorn, sample No. 1; dark color; R. S. Hodges, analyst	16.92	2.94	75.60	1.78	1.10	......	1.66	......	100.00
51. Limestone from property of J. T. Collins, at Vandorn, sample No. 2; light color; R. S. Hodges, analyst	11.44	1.50	82.61	1.51	.90	......	2.04	......	100.00
52. Average of three samples of limestone from near Vandorn; L. H. Conard, Demopolis; R. S. Hodges, analyst	16.04	2.46	81.84	......	......	......	......	......	100.34
53. Limestone from bluff at steamboat landing, Selma; T. W. Miller, analyst	16.11	11.22	65.08	2.42	1.40	......	3.37	......	99.65

Clay (Cretaceous and Tertiary) and cement analyses.

Number of analysis.	Silica.	Aluminum oxide; iron oxide.	Calcium oxide.	Magnesium oxide.	Sulphuric anhydride.	Sulphur (total).	Ignition.	Total.
55. Residual clay over limestone at P. H. Pitts's home place, Uniontown; R. S. Hodges, analyst	69.57	19.04	0.37	......	......	......	9.68	98.66
56. Residual clay over St. Stephens limestone, St. Stephens Bluff; R. S. Hodges, analyst	59.71	24.79	.48	......	......	......	14.96	99.94
59. Grand Gulf clay, Manistee Junction, Monroe County; T. W. Miller, analyst; average of bed	66.60	25.86	.34	0.34	0.89	......	5.11	99.14
60. Clay at water's edge, St. Stephens Bluff; R. S. Hodges, analyst	49.23	24.42	......	......	......	......	......	......
61. Cement, manufactured by Alabama Portland Cement Co., Demopolis; A. W. Dow, United States inspector of asphalts and cements, analyst	20.25	13.44	63.60	1.03	.41	0.99	......	99.72
62. Cement manufactured by Alabama Portland Cement Co., Demopolis; analysis from T. G. Cairns, general manager	19.99	13.74	61.36	.61	......	......	......	......
63. Cement manufactured by Alabama Portland Cement Co., Demopolis; R. S. Hodges, analyst	19.99	13.63	63.82	.83	1.16	......	......	99.35
64. Residual clay overlying orbitoidal limestone, Marshalls Landing; R. S. Hodges, analyst	51.30	33.22	1.37	.96	.41	......	9.42	97.68

CEMENT-ROCK DEPOSITS OF THE LEHIGH DISTRICT OF PENNSYLVANIA AND NEW JERSEY.

By EDWIN C. ECKEL.

The following description of the cement-rock deposits and cement industry in the Lehigh district is based largely upon field work by the writer during the early summer of 1903. Acknowledgments are due to the managers and chemists of various cement plants in the Lehigh district, who have aided the writer greatly in this work. Use has also been made of the report by Professor Kümmel, on the Portland-cement industry in New Jersey,[a] and of an unpublished report by Prof. T. N. Dale, on the geology of the Slatington quadrangle.

GEOLOGY OF THE CEMENT ROCKS.

The "Lehigh district" of the engineer and cement manufacturer has been so greatly extended in recent years that the name is now hardly applicable. Originally it included merely one small area about 4 miles square, located along Lehigh River partly in Lehigh County, and partly in Northampton County, and containing the villages of Egypt, Coplay, Northampton, Whitehall, and Siegfried. The cement plants which were located here at an early date secured control of most of the cement-rock deposits in the vicinity, and plants of later establishment have therefore been forced to locate farther and farther away from the original center of the district. At present the district includes parts of Berks, Lehigh, and Northampton counties, Pa., and Warren County, N. J., reaching from near Reading, Pa., at the southwest, to a few miles north of Stewartsville, N. J., at the northeast. It forms, therefore, an oblong area about 25 miles in length from southwest to northeast, and about 4 miles in width. Within this area about twenty Portland cement plants are now in operation, and the Portland cement produced in this relatively small district amounts to about two-thirds of the entire United States output.

GENERAL GEOLOGY OF THE DISTRICT.

Within the "Lehigh district," as above defined, three geologic formations occur, all of which must be considered in attempting to

[a] Ann. Rept. New Jersey State Geologist for 1900, pp. 9-101.

account for the distribution of the cement materials used here. These three formations are, in descending order, the (1) Hudson shales, slates, and sandstones; (2) Trenton limestone (Lehigh cement rock); (3) Kittatinny limestone (magnesian). As all these rocks dip, in general, north-westward, the Hudson rocks occupy the northwestern portion of the district, while the cement rock and magnesian limestone outcrop in succession farther southeast.

Hudson shale.—This series includes very thick beds of dark-gray to black shales, with occasional thin beds of sandstone. In certain localities, as near Slatington and Bangor, Pa., and Newton, N. J., these shales have been so altered by pressure as to become slates, the quarrying of which now supports a large roofing slate industry.

The composition of the typical shales and slates of the Hudson formation is well shown by the following analyses:

Analyses of Hudson shale and slate in Pennsylvania and New Jersey.

	1.	2.	3.	4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Silica (SiO_2)	68.62	68.00	56.60	[a] 76.22
Alumina (Al_2O_3)	12.68	14.40	21.00	13.05
Iron oxide (Fe_2O_3)	4.20	5.40	5.65	
Lime (CaO)		2.68	3.42	2.67
Lime carbonate ($CaCO_3$)	2.34			
Magnesia (MgO)		1.51	2.30	.93
Magnesium carbonate ($MgCO_3$)	3.76			
Alkalies	3.73	.11	.50	
Carbon dioxide (CO_2)		2.30	2.20	
Water (H_2O)	4.47	2.70	3.00	

[a] Insoluble.

1. East Bangor, Pa., Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 436.
2. 1 mile northwest Colemanville, N. J. Geology New Jersey, 1868, p. 136.
3. Delaware Water Gap, N. J. Geology New Jersey, 1868, p. 136.
4. Lafayette, N. J. Rept. New Jersey State Geol. for 1900, p. 74.

The geographic distribution of the Hudson shales and slates in the Lehigh district can be indicated only approximately without the presentation of a geologic map of the area. It may be said that they cover practically all of Northampton, Lehigh, and Berks counties north of a line passing through Martins Creek, Nazareth, Bath, Whitehall, Ironton, Guthsville, Monterey, Kutztown, Molltown, and Leesport.

As above noted, the rocks of the Lehigh district have a general dip to the northwest, though there are numerous local exceptions to this rule. The lowest beds of the Hudson series, therefore, are those which outcrop along the southern boundary of the formation, as above outlined. These lowest beds carry much more lime and less silica, alumina, and iron than the higher beds whose analyses are given on page 449. The lowest beds form a natural transition into the underlying cement rock.

Trenton limestone.—The Lehigh cement rocks, which are approximately equivalent in age to the lowest Trenton beds of New York, are made up of a series of more or less argillaceous limestones. The formation appears to vary in thickness from 150 feet in New Jersey to 250 feet or even more at Nazareth and on Lehigh River. Its upper beds, near the contact with the overlying Hudson shales, are very shaly or slaty black limestones, carrying approximately 50 to 60 per cent of lime carbonate and 40 to 50 per cent of silica, alumina, iron, etc. Lower in the formation the percentage of lime steadily increases, while that of clayey material decreases correspondingly, until near the base of the formation the rock may carry from 85 to 95 per cent of lime carbonate with only 5 to 15 per cent of impurities. This change in chemical composition is accompanied by a change in the appearance and physical character of the rock, which gradually loses its slaty fracture and blackish color as the percentage of lime increases, until near the base of the formation it is often a fairly massively bedded dark-gray limestone. Even so, it can usually be readily distinguished from the magnesian Kittatinny limestone, described below, for the cement rock is always darker than the magnesian limestone and contains none of the chert beds which are so common in the magnesian rock.

The Lehigh cement rock is never nearly so high in magnesia as is the underlying Kittatinny limestone. It does, however, carry considerable magnesia (as compared with other Portland-cement materials) throughout its entire thickness, and few analyses will show less than 4 to 6 per cent of magnesium carbonate. The following series of analyses is fairly representative of the lower, middle, and upper beds of the formation. The specimens from the upper beds, near the Hudson shales, show considerably less lime and more clayey matter than those from the lower parts of the formation.

Analyses of Trenton limestone (Lehigh cement rock.)[a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Silica (SiO_2)	1.86	5.03	8.38	11.90	11.71	11.11	17.04	22.71	19.53	24.45
Alumina (Al_2O_3)	.60	2.06	4.03	4.42	4.36	4.40	6.90	5.84	6.03	5.68
Iron oxide (Fe_2O_3)	.51	1.23	1.32	1.70	1.62	1.91	2.13	2.13	1.70	1.57
Lime (CaO)	53.64	49.73	45.45	44.18	43.47	42.51	37.53	36.50	35.71	35.00
Magnesia (MgO)	.81	1.02	1.34	1.18	1.82	2.89	2.17	1.69	3.33	2.21
Carbon dioxide (CO_2)	43.03	40.19	37.18	36.01	36.15	36.57	32.88	30.52	32.73	29.89

[a] Ann. Rept. New Jersey State Geologist for 1900, p. 95.

The specimens whose analyses are given above were mostly from the vicinity of Belvidere, N. J., and, though representative in other respects, seem to have been rather lower in magnesia than the usual run of the Trenton limestone in the Lehigh district.

Magnesian Kittatinny limestone.—Underlying the cement-rock series is a very thick formation consisting of light-gray to light-blue massive-bedded limestone, with frequent beds of chert. These limestones are predominantly highly magnesian, though occasionally beds of pure nonmagnesian limestone will be found in the series. The magnesian beds are, of course, valueless for Portland-cement manufacture, but the pure limestone beds furnish part of the limestone used in the Lehigh district for addition to the cement rock. An excellent example of this is furnished by the quarry near the east bank of Lehigh River, just above Catasauqua. In this quarry most of the beds are highly magnesian, and are therefore useful only for road metal and flux; but a few pure limestone beds occur, and the material from these low-magnesia beds is shipped to a neighboring cement mill.

Numerous analyses of the highly magnesian limestones are available, from which a few typical results have been selected for insertion here. Analyses of the purer limestone, used to add to the cement rock, will be found in the table on page 452.

Analyses of magnesian Kittatinny limestone.[a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Silica (SiO_2)	9.9	9.9	8.8	5.5	9.8	4.9	2.0	8.0	4.1	16.9
Alumina (Al_2O_3), Iron oxide (Fe_2O_3)	1.7	1.7	.8	1.3	3.7	6.5	8.4	5.3	1.6	1.0
Lime (CaO)	27.6	28.5	29.4	28.2	26.4	27.3	32.4	26.3	30.3	28.3
Magnesia (MgO)	17.9	17.3	17.8	20.2	15.1	14.6	15.5	17.4	18.3	15.3
Carbon dioxide (CO_2)	41.9	41.5	42.8	44.3	45.0	44.8	42.5	41.1	44.1	38.9

1. Chandlers Island, Sussex County, N. J.
2. Sparta, Sussex County, N. J.
3. Asbury, Warren County, N. J.
4. Oxford Furnace, Sussex County, N. J.
5, 6. Clinton, Hunterdon County, N. J.
7. Pottersville, Somerset County, N. J.
8, 9. Peapack, N. J.
10. Annandale, N. J.

While all of the above analyses are from New Jersey localities the magnesian limestone of the rest of the Lehigh district would give closely similar results.

THE CEMENT INDUSTRY IN THE LEHIGH DISTRICT.

Combination of materials used.—Throughout most of the Lehigh district the practice is to mix with a relatively large amount of the "cement rock" or argillaceous limestone a small amount of pure limestone, in order to bring the lime carbonate content up to the percentage proper for a Portland-cement mixture. As above

[a] From various reports of the New Jersey Geological Survey.

noted, all of the "cement rock" is derived from the middle part of the Trenton formation, where the beds will run from 60 to 70 per cent of lime carbonate. The pure limestone which is required to bring this material up to the necessary percentage of lime carbonate (75 per cent or so) is obtained either from the lower portion of the Trenton itself or from certain low-magnesian beds occurring in the Kittatinny formation.

In the plants located near Bath and Nazareth, however, the practice has been slightly different. In this particular area the cement-rock quarries usually show rock carrying from 70 to 80 per cent of lime carbonate. The mills in this vicinity, therefore, require practically no pure limestone, as the quarry rock itself is sufficiently high in lime carbonate for the purpose. Indeed, it is at times necessary for these plants to add clay or slate, instead of limestone, to their cement rock, in order to reduce its content of lime carbonate to the required figure. In general, however, it may be said that Lehigh practice is to mix a low-carbonate cement rock with a relatively small amount of pure limestone, and analyses of both these materials, as used at various plants in the district, are given below.

Analyses of materials used in the Lehigh district.

	Cement rock.								Pure limestone.		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Silica (SiO_2)	15.05	19.06	19.08	22.22	13.80	9.52	19.62	14.20	2.14	3.02	1.98
Alumina (Al_2O_3)	9.02	4.44	7.92	7.24	6.08	4.72	5.68	6.14	1.46	1.90	.70
Iron oxide (Fe_2O_3)	1.27	1.14		.92							
Lime carbonate ($CaCO_3$)	70.10	69.24	67.07	63.45	76.08	80.71	69.78	74.30	94.35	92.05	95.19
Magnesium carbonate ($MgCO_3$)	3.96	4.21	4.06	4.56	4.51	4.92	4.90	3.24	2.18	3.04	2.03

Character and composition of the cement rock.—The cement rock is a dark-gray to black, slaty limestone, breaking with an even fracture into flat pieces, which usually have smooth, glistening surfaces. As the percentage of lime carbonate in the rock increases—i. e., as the lower beds of the formation are reached—the color becomes a somewhat lighter gray, and the surfaces of the fragments lose their slaty appearance.

The range in composition of the cement rock as used at various plants is well shown in the first eight columns of the above table. The nearer the material from any given quarry or part of a quarry approaches the proper Portland-cement composition (say 75 to 77 per cent lime carbonate) the less addition of pure limestone will be necessary. In by far the greater part of the district, as above noted, the cement rock is apt to run about 65 to 70 per cent of lime carbonate, therefore requiring the addition of a proportionate amount of limestone. Most of the quarries near Bath and Nazareth, however, have been opened on beds of cement rock running considerably higher in lime carbonate, and occasionally running so high (80 per cent, etc.) as to require the addition of shale or clay rather than of pure limestone.

Character and composition of the pure limestones.—The pure limestones added to the cement rock are commonly gray, and break into rather cubical fragments. The fracture surfaces show a finely granular structure, quite distinct in appearance from the slaty cement rock. In composition the limestones commonly used will carry from 90 to 96 per cent of lime carbonate, with rather less magnesium carbonate than is found in the cement rock. All of the cement plants own and operate their own cement-rock quarries, but most of them are compelled to buy the pure limestone. When this is the case only very pure grades of limestone are purchased, but when a cement plant owns its limestone quarry material running as low as 85 per cent of lime carbonate is often used.

Quarry practice.—In most of the cement-rock quarries of the Lehigh district the rock dips from 15° to 25°, usually to the northwest. At a few quarries, particularly in New Jersey, the dip is much steeper. The quarries are opened, preferably, on a side hill, and the overlying stripping, which consists of soil and weathered rock, is removed by scrapers or shoveling. The quarry of the Lawrence Cement Company has been extended in its lower levels so as to give a tunnel through which the material is hoisted to the mill. Several other quarries have been carried straight down, until now they are narrow and deep pits, from which the material is hoisted vertically. The Bonneville Portland Cement Company quarry is an extreme example of this type.

In quarries opened on a side hill, so as to have a long and rather low working face and a floor at the natural ground level, the rock is commonly blasted down in benches, sledged to convenient size for handling and crushing, and carried by horse carts to a point in the quarry, some distance from the face, where the material can be dumped into cars, which are hauled by cable to the mill. Occasionally the material is loaded at the face into small cars running on temporary tracks. The loaded cars are then drawn by horses or pushed by men to a turntable, where they are connected to the cable and hauled to the mill. While these methods seem clumsy at first sight, they are capable of little improvement. The amount of rock used every day in a large mill necessitates very heavy blasting, and this prevents permanent tracks and cableways from being laid near to the working face.

At several quarries the loading into the cars or carts is accomplished by means of steam shovels. The cement rock seems to be well adapted for handling by steam shovels, but even then much sledging is necessary, and the blasting operations are interfered with.

Mill practice.—What may be considered as typical American practice in the manufacture of Portland cement from dry materials owes its present success largely to the works of the Lehigh district. Previous to the commencement of Portland-cement manufacture in Pennsylvania, dry processes had not been looked upon with favor. The European plants then in existence used wet processes exclusively, differing only in the amount of water that was used.

A dry process can not well be used in stationary kilns, whether of dome or chamber type, for even if the mixing be done dry it will be necessary to add water in making the mixture into bricks. The natural result was that these early plants used water very liberally—almost as freely as the Michigan marl plants of to-day, and with far more excuse for doing so.

With the introduction of the rotary kiln a dry process became not only possible but advisable, and the Lehigh practice of to-day is the result. The usual Lehigh practice may be summed up as follows:

The cement rock is crushed and dried, the first of these operations often taking place in the quarry. Large gyratory crushers are commonly used for this work, while the drying is usually done in rotary driers. The necessary amount of limestone, also previously crushed and dried, is added, and the two materials are mixed and further reduced together. Occasionally a smaller gyratory crusher, breaking to say one-half inch, is the next step in the process of reduction. Commonly, however, the mixture goes to ball mills, comminuters or Williams mills, and then to tube mills. Some of the plants use Griffin mills in place of those noted, while the Atlas plant uses the Huntingdon mill.

The raw mixture is ground to a fineness usually not exceeding 85 per cent through a 100-mesh sieve, and often falling much lower. Compared with the practice at plants using limestone-clay mixtures, this is coarse work. It is less harmful than might be expected, however, owing to the fact that most of the mixture is made up of cement rock which is already naturally well mixed.

The mixture is usually dampened (to prevent too much of it being blown out of the kiln) and fed to rotary kilns. Except at the new Edison plant at Stewartsville, these kilns are commonly 6 feet in diameter and 60 feet in length.

Analyses of Lehigh district cements.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Silica (SiO_2)	21.30	21.96	21.1	20.87	19.06	21.65	22.68	21.08	24.23	24.48
Alumina (Al_2O_3)	7.65	8.29	8.0	7.60	7.47	8.09	6.71	7.86	4.80	4.51
Iron oxide (Fe_2O_3)	2.85	2.67	2.5	2.66	2.29	2.93	2.35	2.48	1.86	2.68
Lime (CaO)	60.95	60.52	65.6	63.04	61.23	63.10	62.30	63.68	63.01	64.33
Magnesia (MgO)	2.95	3.43	2.4	2.80	2.83	2.00	3.41	2.62	3.20	2.59
Alkalies (K_2O, Na_2O)	1.15	(a)	(a)	(a)	1.41	(a)	(a)	(a)	(a)	(a)
Sulphur trioxide (SO_3)	1.81	1.49	(a)	1.50	1.34	1.02	1.88	1.25	1.20	1.41

a Not determined.

Character and composition of the product.—The analyses given in the above table will serve to show the composition of the product of the Lehigh district. Of the 10 analyses quoted, those numbered 1 to 8, inclusive, are fairly representative cements. Analyses 9 and 10, on the other hand, are of a brand carrying a very low content of alumina and iron oxide and a correspondingly high percentage of silica.

The characteristics of the Lehigh district Portland cements are best brought out by the following summary of the range and average of the various constituents. In making up the average the silica, alumina, and iron oxide contents of analyses Nos. 9 and 10 have not been used, and the lime percentage of No. 3 has also been excluded. For comparison, 9 and 10 have been averaged for the first three constituents, and the results are placed in the fourth column.

Range and average of Lehigh district Portland cement.

	Maximum.	Average.	Minimum.	Average of 9 and 10.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Silica (SiO_2)	22.68	21.21	19.06	24.355
Alumina (Al_2O_3)	8.29	7.71	6.71	4.565
Iron oxide (Fe_2O_3)	2.93	2.59	2.29	2.270
Lime (CaO)	64.33	62.46	60.52	....
Magnesia (MgO)	3.43	2.82	2.00	....
Alkalies (Na_2O, K_2O)	1.41	1.28	1.15	....
Sulphur trioxide (SO_3)	1.88	1.43	1.02	....

Portland cement production of the Lehigh district, 1890–1902.

Year.	Lehigh district.		Entire United States.			Percentage of total product manufactured in Lehigh district.
	Number of plants.	Number of barrels.	Number of plants.	Number of barrels.	Value.	
1890	5	201,000	16	335,500	$439,050	60.0
1891	5	248,500	17	454,813	1,067,429	54.7
1892	5	280,840	16	547,440	1,152,600	51.3
1893	5	265,317	19	590,652	1,158,138	44.9
1894	7	485,329	24	798,757	1,383,473	60.8
1895	8	634,276	22	990,324	1,586,830	64.0
1896	8	1,048,154	26	1,543,023	2,424,011	68.1
1897	8	2,002,059	29	2,677,775	4,315,891	74.8
1898	9	2,674,304	31	3,692,284	5,970,773	72.4
1899	11	4,110,132	36	5,652,266	8,074,371	72.7
1900	15	6,153,629	50	8,482,020	9,280,525	72.6
1901	16	8,595,340	56	12,711,225	12,532,360	67.7
1902	17	10,829,922	65	17,230,644	20,864,078	62.8
1903 [a]	....	11,400,000	....	19,000,000	....	60.0

[a] Estimated.

Probable extension of the industry.—As noted in the earlier portion of this paper, the cement deposits have been developed only from near Reading, Pa., to a few miles from Stewartsville, N. J. Most of the readily accessible cement land between these points has been taken up by the cement companies or is being held at impossible prices by the owners. Under these circumstances it seems probable that few additional plants can be profitably established in the district now developed, and that the growth of the industry here will be brought about by extending the district. A few notes on the distribution of the same cement beds in adjoining areas may therefore be of interest to those desiring to engage in the manufacture of Portland cement from materials of the Lehigh district type.

Northeast of Stewartsville, N. J., the cement beds outcrop at frequent intervals in the Kittatinny Valley all the way across New Jersey, and a few miles into Orange County, N. Y. The exact locations of these deposits, with numerous analyses of the cement rocks, are given in the Annual Report of the State Geologist of New Jersey for 1900, pages 41–95. Many detailed maps in this report show the outcrops very precisely.

Southwestward from Reading the Trenton beds outcrop in a belt crossing Lebanon, Cumberland, and Franklin counties, Pa., passing near the towns of Lebanon, Harrisburg, Carlisle, and Chambersburg. In Maryland the Trenton rocks occur in Washington County, while in West Virginia and Virginia they are extensively developed. The distribution of these rocks in Virginia is discussed in the following paper.

Throughout this southern extension of the Lehigh rocks, the Trenton is not everywhere an argillaceous limestone, but it is frequently so, and it is always very low in magnesium carbonate. It is therefore probably safe to say that in southern Pennsylvania, Maryland, West Virginia, and Virginia the Trenton rocks are everywhere good Portland cement materials, though in some cases they will require pure limestone, and in other places clay, to bring them to proper composition.

CEMENT RESOURCES OF THE VALLEY OF VIRGINIA.

By Charles Catlett.

The section of Virginia lying west of the Blue Ridge is bountifully supplied with materials suitable for use in Portland cement manufacture. All the conditions of the Lehigh district of Pennsylvania are duplicated in this region, with the additional advantage that the coal supply is much nearer at hand. At present only one Portland cement plant is in operation in Virginia, but in view of the natural advantages presented by the western portion of the State, it seems probable that a great extension of the industry will soon take place.

The argillaceous limestones of the Trenton formation, which furnish the well-known "cement rock" of the Lehigh district of Pennsylvania and New Jersey, are well developed throughout the valley of Virginia. These limestones, with their overlying Hudson slates and shales, occur in a belt closely paralleling and in places touching the Valley Branch of the Baltimore and Ohio Railroad from the State line to Strasburg. From that point they lie close to the Southern Railway as far as Harrisonburg, and again from Harrisonburg to some miles south of Staunton they lie close to the Baltimore and Ohio Railroad. They are also encountered along the eastern edge of the synclinal basin of Massanutten Mountain. The writer has no specific information as to their development throughout this distance, but naturally the points which give greater promise of consideration for such a purpose as cement manufacture are those giving ready access to the coal fields, with favorable opportunities for the shipment of the product. It is thought, therefore, that the line of the Baltimore and Ohio between Harpers Ferry and Winchester, and Strasburg Junction, Riverton, Harrisonburg, and Staunton would represent the points in this State which would be most attractive in this connection.

At Strasburg Junction coal could be obtained over the Baltimore and Ohio Railroad with a haul of 272 miles, and the finished product could probably be transported to Baltimore, Washington, and tide water for $1 a ton. At Harrisonburg, about 144 miles from Washington, coal could be obtained from the New River district, about 200 miles away, and from the Kanawha district, about 250 miles distant, via the Chesapeake and Ohio and Baltimore and Ohio railroads. At this place coal could also be obtained from the Norfolk and Western Railroad by way of Elkton. Harrisonburg is favorably situated for reaching the Norfolk and Western, the Chesapeake and Ohio, the Baltimore and Ohio, and the Southern railroads.

At Staunton, Va., a plant could obtain coal on favorable terms over the Chesapeake and Ohio, while its shipments would necessarily be by that line and the Southern Railway, while the Baltimore and and Ohio would only be of use locally; it would be possible in times of strikes and labor disturbances in the New River field, to secure coal on reasonable terms from the Fairmont region. At Staunton the shaly Trenton limestones are very well developed. They resemble the Lehigh rock, being dark, smooth, and silky in texture on unweathered surface, and could undoubtedly be quarried, crushed, and ground with great ease. The following analyses by Charles Catlett are typical:

Analyses of Trenton limestone at Staunton, Va.

	1.	2.	3.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	23.08	19.92	19.28
Al_2O_3, Fe_2O_3	10.08	10.76	9.86
CaO	35.89	37.05	36.42
MgO	.94	1.72	1.08
Volatile	....	....	31.70

Closely associated with the beds making the border line between the Trenton limestones and Hudson shales are beds of pure limestone. They are not, however, well developed in the immediate neighborhood of Staunton. The following is the analysis of the best limestone there, which, however, is not in very large quantity:

Analysis of pure limestone from Staunton, Va.

[Charles Catlett, analyst.]

	Per cent.
SiO_2	1.79
Al_2O_3, Fe_2O_3	.74
CaO	50.36
MgO	1.79
CO^2	41.36
Alkalies, etc.	3.97

There are, however, one or two beds of a dark-colored, fine-grained limestone which weathers very readily, and which is astonishingly brittle, a slight tap with a small hammer on the outcrop often breaking off a piece weighing 4 or 5 pounds. The readiness with which these beds are decomposed makes the natural outcrop of them inconspicuous. But they can probably be found in abundant quantities.

The following is an analysis of a sample taken from an almost vertical outcrop which is 150 feet wide, and which immediately adjoins the Trenton limestones from which sample 3 was taken. This rock, and No. 3 combined, would produce a normal mixture. The physical characters of both are superior for the purpose.

Analysis of fine-grained limestone from Stanton, Va.

[Charles Catlett, analyst.]

	Per cent.
SiO_2	10.28
Al_2O_3, Fe_2O_3	4.36
CaO	45.79
MgO	0.79
Vol	38.20

The outcrop is immediately on the line of the Baltimore and Ohio Railroad, and probably three-fourths of a mile from the Chesapeake and Ohio. In the vicinity of Staunton, as at many points in the valley, there are greater or less deposits of fresh-water marl, which, in event of cement manufacture, would undoubtedly be utilized. For instance, the foundations of the houses in certain portions of Staunton are cut in solid marl 10 or 12 feet deep. The irregularity of such deposits, however, does not permit an estimate of quantity to be based upon surface investigations alone. The Trenton beds disappear a short distance south of Staunton, and, while their location is well defined, when they occur again they become less satisfactory in composition.

Lexington, on the Lexington branch of the Chesapeake and Ohio Railroad, is only about 6 miles from the Norfolk and Western Railroad. There is ample water here for manufacturing purposes and with reference to fuel supply and shipments the locality is an exceptional one. There is developed at that point very considerable deposits of high-grade soft-grained limestone which is found at a number of places near the border of the Trenton. The limestone and the associated beds, all of which are in large quantity, show the following composition:

Analysis of limestones and associated beds from Lexington, Va.

[Charles Catlett, analyst.]

	1.	2.	3.	4.	5.	6.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	0.73	9.31	11.86	12.92	17.42	22.60
Al_2O_3, Fe_2O_3	.79	3.47	1.76	3.88	4.70	7.06
CaO	53.71	46.30	46.64	45.14	42.44	36.72
MgO	.83	.86	.74	1.37	1.68	1.69
Ignition	....	....	38.32	37.20	35.62	32.52

It is possible to make at this point a mixture which theoretically would yield a high-grade Portland cement. It is a question whether the relatively high ratio of silica to iron and alumina, which would tend to increase the refractory character of the clinker and reduce the output, is offset by the extremely finely divided condition and intimate mixing of the material as naturally developed. It is noted that one of these beds closely approaches in composition the celebrated French hydraulic lime.

Near Indian Rock on the James River division of the Chesapeake and Ohio Railroad there is one of the largest pure limestone deposits in Virginia. The topographic conditions, however, are very unfavorable, and there are no known deposits of shales or clay readily accessible.

At Eagle Mountain, on the James River division of the Chesapeake and Ohio Railroad, is a large, but localized, deposit of good limestone. The black shales of the Devonian, which have been shown to be suitable for such purposes, and which are well developed just through the gap at the mouth of Craig Creek, could be utilized in combination. A most admirable site could be gotten at Bessemer, which is at the end of the Craig Valley Branch.

The only Portland cement manufactory of note which has been well established in the State is the plant of the Virginia Portland Cement Company, located at Craigsville, a description of which by F. H. Lewis will be found in "The Cement Industry." The conditions there are typical of a number of places either on or near the Chesapeake and Ohio Railroad. These conditions do not seem to be duplicated farther south on the line of the Norfolk and Western. The beds which go to make up No. 6 Rodgers, the lower Helderberg limestone, are well developed there in the following order measured from below:

Section near Craigsville.

	Feet.
1. Layer heavy fossiliferous limestone passing into sandstone.	
2. Very dark slaty siliceous limestone	10
3. Gray fossiliferous limestone	10
4. Dark, irregular siliceous magnesian limestone	2 to 20
5. Gray, soft, highly fossiliferous limestone	30 to 50
6. Dark, close-grained limestone of varying thickness and carrying varying quantities of flint.	

The most important beds of this series and the ones which would be used in the manufacture of Portland cement are (3) and (5). The principal facts to be determined are the extent and decomposition of the superimposed layers, and therefore the ease and cheapness with which (3) and (5) can be secured. The black slates of the Devonian everywhere fill the valleys in this section and afford very excellent material to combine with the limestone. The following analyses are of the limestones and slates taken from the property adjoining that of the Virginia Portland Cement Company:

Analyses of limestone and shale from near Craigsville.

[Charles Catlett, analyst.]

	Limestone.	Shale.
	Per cent.	*Per cent.*
Silica	0.43	58.07
Alumina	.21	19.08
Oxide of iron	.55	6.16
Lime	54.55	None.
Magnesia	.63	.64
Volatile matter	43.70	11.17

The physical condition of both of these is excellent.

While the conditions are unusually favorable in that immediate section, and will naturally lead to the construction of additional plants; in a general way the same geologic conditions are encountered at numerous points on or near the line of the Chesapeake and Ohio, both in Virginia and in West Virginia, and wherever this bed of limestone is found in a good state of development an opportunity more or less valuable, depending upon the local conditions, is presented for the manufacture of cement.

Along the line both of the Norfolk and Western and Chesapeake and Ohio roads in the "Tidewater" region are encountered beds of marl and clay which are suitable for cement manufacture; but the writer's impression is that the tendency is more largely to the use of rock for the purpose; for while finely divided material, such as marl and clay, is ideal if it is exactly of the right composition, it is almost impossible to find large deposits of the former which are free from sand. If it is necessary to grind the material and then to drive off the excess of water which is present, it is questionable whether it is not more economical and satisfactory to work on dry material from the start.

PUBLICATIONS ON CEMENTS.

The following list includes the principal publications by the United States Geological Survey, or by members of its staff, on cementing materials:

CUMMINGS, U. American rock cement. A series of annual articles on natural cements, appearing in the volumes of the Mineral Resources, U. S., previous to that for 1901.

DURYEE, E. Cement investigations in Arizona. In Bulletin U. S. Geol. Survey, No. 213, p. 372–380. 1903.

ECKEL, E. C. Slag cement in Alabama. In Mineral Resources for 1900, pp. 747–748. 1901.

——— The manufacture of slag cement. In Mineral Industry, vol. 10, pp. 84–95. 1902.

——— The classification of the crystalline cements. In Amer. Geologist, vol. 29. p. 146–154. 1902.

——— Portland cement manufacture. In Municipal Engineering, vol. 24, p. 335–336; vol. 25, p. 1–3, 75–76, 147–150, 227–230, 405–406. 1903.

——— The materials and manufacture of Portland cement. In Senate Document No. 19, 58th Congress, 1st session, p. 2–11. 1903.

NEWBERRY, S. B. Portland cement. A series of annual articles on Portland cements, appearing in the various volumes of the Mineral Resources, U. S., previous to that for 1901.

RUSSELL, I. C. The Portland cement industry in Michigan. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 629–686. 1902.

SMITH, E. A. The Portland cement materials of central and southern Alabama. In Senate Document No. 19, 58th Congress, 1st session, p. 12–23. 1903.

TAFF, J. A. Chalk of southwestern Arkansas, with notes on its adaptability to the manufacture of hydraulic cements. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 687–742. 1902.

CLAYS AND FULLER'S EARTH.

The clays of eastern United States were discussed in a professional paper issued by the United States Geological Survey during the last year. Owing to its comprehensive character, no abstract of this important work has been attempted for the present publication. The results of recent field work by the Survey on the clays of western Pennsylvania are given in the following paper.

CLAYS OF THE OHIO VALLEY IN PENNSYLVANIA.

By L. H. Woolsey.

INTRODUCTION.

A preliminary report on the clay resources and industries of this region is here presented as a result of the field work on the Beaver quadrangle, Pennsylvania. The clay industries of this region are at present practically confined to the valleys of Ohio and Beaver rivers in Beaver County, and this report is intended to treat only of this area, but for purposes of comparison analyses and notes of clays of other districts have been included.

NATURE OF CLAY.

Definition.—Popularly clay is the familiar gritless plastic earth which is readily molded when wet and which retains its shape on drying. To the manufacturer clay means the material he molds and bakes, and this may correspond to the above or to any mixture, natural or artificial. Technically clay is $Al_2O_32SiO_22H_2O$ plus sand, plus accessories. $Al_2O_32SiO_22H_2O$ is pure kaolin or kaolinite, and the sand is composed of grains of quartz and other minerals. The silica, therefore, occurs chemically combined in kaolinite and other minerals and also in the free state, as quartz sand. The chief accessories are iron oxide, lime, and magnesia, with potash and soda in smaller quantities.

Origin.—Clay originates from the disintegration of rocks containing minerals made up largely of alumina and silica. The most abundant of these minerals are the feldspars, augite, and hornblende, and nephelite and sodalite occur in smaller amounts.

Upon the decomposition of the rocks the more soluble elements of these minerals are mostly removed by water, leaving the alumina and silica, with small proportions of lime, magnesia, iron, and the alkalies. These are washed over and over and deposited in favorable places by water, much in the same manner as are river silts, and such deposits, whether fluviatile, lacustrine, or marine, are called clays. This manner of decomposition explains the banding and the presence of grains of sand and minerals in the clays. Clays so deposited are called sedimentary clays, and this name may be applied to all the clays mined in the upper Ohio Valley.

Clay which is formed by the disintegration of rock, but which, instead of being washed away by water, has remained near the parent rock, is called residual clay. Clay of this kind is found in the uplands, back from the rivers.

Physical properties.—The indispensable properties of clay are (1) plasticity when wet, (2) permanence when burnt, (3) refractoriness. To be commercially valuable a clay need not possess all these properties—as, for example, flint clays—but the manufacturer must, by mixture or otherwise, obtain these three properties in his clay before he can manipulate it.

By these three properties clays have been classed into flint, non-plastic, or china clays; plastic, ball, or pottery clays; brick clays, and refractory clays.

Plasticity seems to depend on some relation of the clay to water which is not yet well understood. No clay is plastic without water, and flint clays can not be made plastic by any amount of grinding with water.[a]

Plasticity, however, does not depend upon the degree of consolidation of the clay, for shales and slates, which are consolidated clay, may be made plastic by grinding with water, while flint clay, which is also consolidated, can not, as just stated, be made plastic. Many plastic clays, besides shales and slate, may at times be very hard, as the Lower Kittanning clay, and yet retain their plasticity. The clays of Beaver County are more or less consolidated, but perhaps those least so are the terrace clays of New Brighton.

Permanency when burnt does not necessarily depend on fusibility, for in crude ware, such as flower pots, the clay is not vitrified, but in high-grade ware vitrification is necessary. Fusibility of clays depends on the amounts of accessories—lime, magnesia, alkalies, and iron—present; and from this point of view, since fusibility is usually necessary, the fluxes should not perhaps be called accessories. They have been called detrimentals, because the presence of large amounts

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[a] Ohio Survey vol. 7, Orton.

of them renders the clay valueless, in contradistinction to alumina and silica, which are nondetrimentals. H. A. Wheeler[a] says fusibility depends not only on the amount of detrimentals present, but also largely on the density and fineness of the clay. He has deduced this formula for the calculation of the fusibility of clays:

$$\text{Fusibility equals } \frac{N}{D+D^1+C}$$

in which N is the sum of the nondetrimentals, or the total alumina, silica, water, and titanic acid; D the sum of the detrimentals; D^1 the sum of the alkalies, which have been found to have about double the fluxing value of the other fluxes; and C a constant depending on certain limits of specific gravity and fineness, when the clays to be compared differ in density and fineness, it is necessary to give C a value dependent on fineness and specific gravity. C equals 1 when the clay is coarse grained and its specific gravity exceeds 2.25; C equals 2 when specific gravity is 2 to 2.25; C equals 3 when specific gravity is 1.75 to 2; C equals 2 when clay is fine grained and specific gravity is 2.25 plus; C equals 3 when specific gravity is 2 to 2.25; and C equals 4 when specific gravity is 1.75 to 2.25. Not enough work has yet been done to establish a standard of fineness, but Wheeler contends that his is the only formula applicable indiscriminately to all grades of clay.

Refractoriness, the counterpart of fusibility, is also an essential property of clay; for a clay, whether it is intended to be fused or not, must be refractory enough not to melt out of shape or to combine with the alkaline slags of metals reduced in refractory furnaces.[b]

There are minor properties of clay which, while not essential, are commercially of great importance to the manufacturer, viz, fire shrinkage, air shrinkage, color, and tensile strength. Fire and air shrinkage are both due to loss of water and gases.

Air shrinkage is due to loss of mechanically combined water, while fire shrinkage is due to loss of chemically combined water and gases. Both may be decreased by addition of sand to the clay mixture.

The color of a clay is not always an indication of its quality. This is especially true when the color is due to carbonaceous or organic matter, but bright-red clays show at once their nonrefractory character. Carbonaceous clay must be burned slowly in order that the gases generated from organic matter may escape before the clay vitrifies; otherwise the imprisoned gases will cause it to puff up. The colors of clays are generally due to the presence of iron, and the color of the fired product depends not so much on the amount of iron as on the length of burning.

The tensile strength of clay is the resistance which it offers to rupture in its air-dried condition. It stands in some relation to plas-

[a] Eng. and Min. Jour., vol. 57, Nos. 10, 11 (March, 1894), p. 224, 244.
[b] Hill, R. T., Mineral Resources U. S. for 1891: U. S. Geological Survey. 1893.

ticity, but this relation is not always obvious. A high tensile strength is desirable, since it aids the ware to resist cracking in drying, and also permits it to withstand handling before burning.

Tensile strength of different kinds of clay.[a]

	Pounds per square inch.
Kaolins	5 to 10
Brick clays	60 to 100
Pottery clays	150 to 200
Some very plastic clays	200 to 400

Chemical properties.—The chemical analyses of clays given on page 471 show the chief constituents to be alumina, silica, lime, magnesia, potash, soda, iron, and water. These components stand in causal relation to some of the physical properties of clay just referred to, but the relations can not always be made out from the chemical composition alone. Plasticity, for example, runs through a wide range in chemical composition. The practical clay worker, therefore, usually considers a physical test far more valuable than a chemical analysis, and with good reason, for there is really no way to find out what a clay can be made to do but to try it. Clays of the same chemical composition yield diverse products on firing, and hence their physical characters are generally of greater importance in determining their value.

GEOLOGIC OCCURRENCE.

The clays of this region may be classified geologically into Carboniferous clays, those found in consolidated rocks of Carboniferous age; and Quaternary clays, those found in the unconsolidated Glacial and river deposits.

CARBONIFEROUS CLAYS.

The rocks of Beaver County belong in the middle of the Carboniferous system, which occurs over a great part of the Appalachian region of the United States. These rocks, which produce most of the clay used in western Pennsylvania, have, along Ohio River, been divided into Lower Barren Measures, or Conemaugh formation; Lower Productive Measures, or Allegheny formation; and Pottsville conglomerate. These beds rise gently toward the northwest in low northeast-southwest rolls.

Pottsville conglomerate.—This is made up of hard sandstones and conglomerates and is seen in the bed of Ohio River only near Smiths Ferry at very low water; elsewhere on the Ohio it is capped by river deposits. It is seen in the bed of Beaver River opposite Beaver Falls and New Brighton; thence it rises northward and is well

[a] Prof. Paper U. S. Geol. Survey No. 11, p. 21.

exposed at Homewood as the "Homewood sandstone." In the localities where it is exposed this formation carries several beds of fire clay, but being scarcely exposed in the region considered, very little can be said of its contents. As to facilities for exploitation, however, the Pottsville here is at a great disadvantage as compared with the Allegheny formation above it.

Allegheny formation.—Resting on the Pottsville sandstone and reaching to the top of the Upper Freeport coal, this formation shows in outcrop as a narrow belt bordering the river hills with its base just below river level. The average thickness of the Allegheny formation is about 300 feet. The following generalized section, presented in natural order from the top downward, shows its character and indicates the position of fire-clay beds:

Section of Allegheny formation.

		Feet.	
1.	Upper Freeport coal; "Four-foot" or "Hookstown vein"	0 to 4	
2.	Fire clay	2 to 4	
3.	Limestone	1 to 4	
4. 5.	Shale and Sandstone	50 to 70	
6.	Lower Freeport coal (usually absent)	0 to 2	
7.	Fire clay	0 to 5	180
8.	Limestone (sometimes present)		
9.	Sandstone or sandstone and shale	70 to 90	
10.	Darlington coal; "Block vein" at Smiths Ferry	1 to 2	
11.	Fire clay	4	
12.	Black slate with iron nodules	20 to 30	
13.	Lower Kittanning coal; "Sulphur vein"	2 to 3	
14.	Fire clay	6 to 10	
15. 16.	Sandstone Shale	40	
17.	Limestone, ferriferous, "Vanport limestone"	1 to 20	
	Black shale	15	
18.	Fire clay, Sandy shale, Fire clay	20	
19.	Clarion coal	1±	100
20.	Fire clay	4 to 6	
21.	Sandstone	23	
22.	Shale	25	
23.	Brookville coal	6	
24.	Fire clay	4	

This is by far the richest group of rocks along the upper Ohio River, containing as it does most of the workable clays, coals, limestones, and sandstones of central western Pennsylvania.

Brookville clay.—This deposit of clay, underlying the Brookville coal, first comes to the surface under the Pittsburg and Lake Erie Railroad bridge across the mouth of Bradys Run, then rises gently up Beaver River, but in most places it is covered by river deposits. So far as known it has not been exploited for clay in this county. No analysis of clay from this vicinity is available, but here are appended analyses of clay from nearby localities.

Analyses of Brookville clay.

	1.	2.
	Per cent.	*Per cent.*
SiO_2	45.45	62.05
Al_2O_3	36.125	27.71
Fe_2O_3		
FeO	2.275	.60
MnO_2		
CaO	.168	.15
MgO	.342	.20
Alkalies	1.29	2.40
H_2O, Org	13.73	6.67
	99.380	99.78

1. Roaring Run, three-fourths mile west of Woodland Station. Bed, 4 to 5 feet; hard clay. Second Geol. Surv. Pennsylvania, Rept. H, p. 123. S. A. Ford, analyst.
2. From Haydenville Mining and Manufacturing Company, Haydenville, Ohio. Geol. Surv. Ohio, vol. 7, p. 139. E. M. Reed, analyst.

At Haydenville this clay is made into paving bricks, fireproofing, and sewer pipe. The Brookville clay has been mined for thirty-five years in Indiana County, where it is a plastic clay of good quality, varying in thickness from 3 to 11 feet. It contains, however, many iron balls and has to be hand picked.[a] In Fayette County, also, where it is a flint clay of excellent quality, it has been extensively used for refractory materials.[b] At the typical locality of the overlying coal, Brookville, Jefferson County, the clay beneath is 15 feet thick, but only the upper 6 feet are used.[c] It seems, then, that the Brookville horizon in Beaver County may yet become a producer of good clay where the bed can be profitably mined. South of Beaver Falls it could be reached only by shaft, except at the locality noted at the mouth of Bradys Run.

Clarion clay.—This bed underlies the Clarion coal, and is exposed opposite Fallston, on Bradys Run, where it has been opened by the Fallston Pottery Company by a drift 150 feet long. The clay appears to be of uniform thickness and character, but it is not now used. It has been variously reported as 6, 10, and 12 feet thick, with no coal above; only contradictory reports of its quality could be obtained. It is exposed east of New Brighton on Blockhouse Run, above the Sherwood pottery; above New Brighton, on the railroad, where it is 3 or 4 feet thick; and, Hopkins reports, in Paved Run, but it has not been worked in any of these places. It is further exposed in the ravines along the railroad south of Beaver Falls, and thence runs under Beaver Falls terrace.

[a] Prof. Paper U. S. Geol. Survey No. 11, p. 218.
[b] Geologic Atlas U. S., Folio 82, U. S. Geological Survey, p. 20.
[c] Second Geol. Surv. Pennsylvania, Report H, p. 225.

S. Barnes & Co. state that they at one time mined a small quantity of it on the bank of Beaver River opposite their works, about a mile above Rochester. The Clarion horizon is below river level at this point. No analysis of this clay is available, but it has been used with good results at Bolivar, Pa.

The thickness of the Clarion clay at three localities in Pennsylvania is here given:[a]

Thickness of Clarion clay at localities in Pennsylvania.

	Ft.	In.
Johnstown, Cambria County	3	6
Bens Run, Cambria County	6	0
Pinkerton Point, Somerset County	6	0

As may be seen in the section on page 467, the Clarion clay is about 50 feet above the Brookville clay, and it may therefore be more easily mined than the Brookville.

Lower Kittanning clay.—This is the clay par excellence of this region. It is the source of practically all of the clay mined along the Ohio River in Pennsylvania and Ohio, as well as in West Virginia, where Prof. I. C. White says it attains its maximum thickness.

As the Lower Kittanning clay lies considerably above the clays last mentioned, it has accordingly a larger area of exposure above river level. It is, in short, to be found throughout this region above and on both sides of Ohio and Beaver rivers. Its elevation above low water varies from about 180 feet at Beaver Falls to zero at Freedom, just below which town it disappears under the river; and from 150 feet at State line to 50 at Phillis Island, 60 at Industry, 90 at Vanport, and 100 at Beaver. It is not, however, actually exposed throughout this whole extent, but is covered by broad, flat gravel terraces at Rochester, Beaver, Monaca, west of Bellowsville, east of Industry, Shippingport, Georgetown, and the terrace on the north side of the river between the last two towns. Elsewhere it is exposed along the more precipitous banks of the rivers and may be readily exploited. Where covered by river terraces it may be exposed by excavations varying from a few feet to 50 feet at Monaca, 70 feet at Georgetown, 35 feet at Bellowsville, and 45 feet east of Industry. At the other places the necessary excavation is less than 25 feet.

The Lower Kittanning clay bed is also exposed within the county on tributaries to these rivers. Of these Bradys Run, though not the largest tributary, uncovers the greatest extent of this clay bed; for while the clay is at present being mined only near Fallston, the coal above it has been opened for 4 miles along this stream. The North branch of Bradys Run exposes this coal for almost an equal distance. Bradys Run is a straight stream of the low grade, open valley type,

[a] Ries, H., Prof. Paper U. S. Geol. Survey No. 11, 1903, p. 222.

with its mouth near a railroad, and offers exceptional facilities for the manufacture of clay products. Moreover, mining here could be carried on by drifts instead of shafts.

As to mining facilities, Blockhouse Run ranks with Bradys Run, but Lower Kittanning clay is exposed for only a mile east of New Brighton. Nevertheless Blockhouse Run has been the site of clay-mining operations ever since the infancy of the industry.

On Raccoon Creek the Lower Kittanning clay bed dips under the stream just beyond the mouth of Fishpot Run, about 2½ miles from Ohio River. At several points, however, in this distance the clay is covered by stream gravels, which would have to be removed in mining. This same clay bed is further exposed on Mill Run and Little Mill Run, near Georgetown, for about a mile from the river. But here, as on Raccoon Creek, transportation facilities are lacking. On the opposite side of the river the Lower Kittanning clay bed extends several miles up Little Beaver River and its tributaries, which for the most part lie in Ohio, but some of the eastern branches head in Beaver County, as Island Run and Little Beaver Creek. So far as known this clay has not been mined on these streams, but at Darlington it has been reported as 10 feet thick.[a]

This clay bed varies in thickness from 5 to 11 feet, the lower half being usually more siliceous than the upper half. Different thicknesses are therefore mined, according to the purpose for which it is to be used, a greater thickness being removed for paving brick and other crude products than for pottery.

Thickness of Lower Kittanning clay at various points.

	Feet.
Spear Clay Company, Vanport	11
Vanport Brick Company, Vanport	9 to 11
Miller Brick Works, Rochester	10
American Sewer Pipe Company, New Brighton	9
Ingram Fire Brick Company, New Brighton	10
S. Barnes & Co., Rochester	7½ to 8
Pennsylvania Clay Company, Crow Run	5
Welch Fire Brick Company, Monaca	10
Sherwood Pottery, New Brighton	6
Standard Brick Company, Bradys Run	8½
E. Smith's Brick Works, New Brighton	5½ to 9
Fallston Fire Brick Company, Fallston	10
Enterprise Pottery, New Brighton	7
Park Fire Brick Company, Mahan[a]	10 to 12
Dando & McLain, Merrill[b]	10

[a] Second Penn. Geol. Surv., Report Q, p. 232.
[b] Prof. Paper U. S. Geol. Survey No. 11, p. 225.

Analyses of Lower Kittanning clays.

	1.	2.	3.	4.	5.	6.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	61.970	61.750	62.890	62.260	66.610	56.670
Al_2O_3	22.940	23.660	21.490	23.890	18.390	26.560
FeO	1.818	1.930	1.818	1.408	1.964	2.106
TiO_2	1.975	1.780	1.825	1.780	2.810	1.790
CaO	.440	.455	.380	.470	.490	.260
MgO	.522	.353	.569	.309	.547	.277
Alkalies	1.750	2.418	2.525	1.977	1.079	3.790
H_2O (hygroscopic)	1.480	.680	1.160	7.640	7.495	8.360
H_2O (combined)	7.370	7.200	7.580			
Total	100.265	100.226	100.237	99.734	99.385	99.813

	7.	8.	9.	10.	11.	12.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	57.670	60.190	61.980	68.92	56.37	60.30
Al_2O_3	27.520	24.230	23.880	22.38	29.62	24.12
FeO	1.494	2.097	1.395	.980	[a]1.14	1.46
TiO_2	2.540	2.345	1.830	....	....	1.20
CaO	.380	.850	.040	.19	.45	.59
MgO	.122	.036	.281	.172	.14	.68
Alkalies	.619	1.669	1.217 1.460	....	1.08	2.42
H_2O (hygroscopic)	9.680	9.015	7.820	6.14	1.92	.86
H_2O (combined)	....	....	....	....	8.71	7.77
Total	100.025	100.432	99.903	99.962	99.43	99.40

[a] As sesquioxide.

1-4. From Elverson & Sherwood's mines, near New Brighton, Beaver County, being, respectively, first, second, and third grades of clay and the raw clay. Analyses by David McCreath. Second Pennsylvania Geological Survey, Rept. MM, p. 262.
5. Mendenhall and Chamberlin mines, near New Brighton, Beaver County. Analyses by McCreath. Ibid.
6. Coale's clay, near New Brighton, Beaver County. Analyses by McCreath. Ibid.
7. Couch's clay, New Brighton, Beaver County. Ibid.
8. Severn's clay mines, near Vanporte, on Ohio River, New Brighton Township, Beaver County. Ibid.
9. S. Barnes & Co.'s clay, Bridgewater, 1 mile north of Rochester, Beaver County. Ibid.
10. Brady's Run Fire Brick Company, Beaver County, Mineral Resources, United States, 1896, Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5 (continued), p. 1155.
11. Flint clays from Mineral Point; analyses by Lord. Geol. Survey, Ohio, vol. 7, p. 221.
12. Yellow ware clay, East Liverpool; analyses by E. Orton, jr. Geol. Survey, Ohio, vol. 7, p. 119.

By comparing the analyses of Beaver County clays with those of clays of the same horizon in Ohio their similarity becomes evident. The Lower Kittanning bed in Ohio is used for the finer pottery manufactories, for saggers, also in part for the manufacture of yellow and Rockingham ware, and even for stoneware; besides sewer pipe, fire, building, and paving brick.[a]

In a similar manner the Lower Kittanning clay of Beaver County supplies all the potteries and hollow-ware, fire-brick, and paving-brick factories at New Brighton and the brickyards south of that place on

[a] Orton, Geol. Surv. Ohio, vol. 7, p. 47.

Beaver River and west on Ohio River. The coal above this clay is variously known by local names, such as "sulphur vein" and "blacksmith vein."

Darlington clay.—This occurs from 25 to 35 feet above the Lower Kittanning coal and is persistent throughout the region. The clay, however, is rarely worked, containing, it is said, too many iron nodules for most wares. The clay bed is from 4 to 6 feet thick, and in 1902 was being opened by Dando & McLain at Merrill, by E. Smith, and by the American Sewer Pipe Company, on Blockhouse Run. No analyses are available. This clay does not seem to be in general use and its quality can only be inferred.

Lower Freeport clay.—The coal of this horizon is usually absent in Beaver County and the underlying clay is equally variable in occurrence. When present the clay has a thickness of from 3 to 5 feet. At one place on Blockhouse Run, where it has been developed for sewer-pipe, it is reported to be locally 12 to 14 feet thick. With this exception it has not been exploited within this region, perhaps because it contains, as it is said, too much iron to be of high grade. Wherever it has been observed by the writer, it is a light-colored, plastic clay of good character. Occurring about 120 feet above the Lower Kittanning coal, the Lower Freeport clay has, of course, an exposure of much greater extent than the former along the streams noted under Lower Kittanning clay.

Upper Freeport clay.—This horizon is about 180 feet above the Lower Kittanning clay, and therefore has a very much greater line of exposure near the top of the irregular river bluffs and along all the lateral streams. For example, it dips under Raccoon Creek near Independence, under Mill Creek at Hookstown, under Dry Run and Island Run near Ohioville, and under Bradys Run near Blackhawk. The high elevation of the Lower and Upper Freeport clays is a drawback to their economical exploitation. As a clay bed of greater thickness and superior quality, the Lower Kittanning is much more accessible. The Upper Freeport clay bed is more persistent than the coal above it. Very often the clay is present as a pale-blue clay of excellent appearance with thin, papery layers of bituminous matter at the top representing the coal. In many places, however, the clay contains nodules of iron, which stain it considerably and which must be removed before using. Usually the clay is 3 to 5 feet thick, but opposite Fallston, on the south side of Bradys Run, it thickens locally to 10 feet. Here it is mined by the Fallston Fire Brick Company, and mixed with the Lower Kittanning clay to make different grades of brick. Aside from this instance, the Upper Freeport clay has not been exploited as far as is known along Ohio or Beaver rivers in this county, but in Big Beaver Township it has been extensively mined for fire brick. There it ranges in thickness from 2 to 10 feet, although in places it may be replaced by limestone and iron ore as at Adams.[a]

No analysis of the Upper Freeport clay from Beaver County is available, but analyses from other places follow:

Analyses of Upper Freeport clay.

	1.	2.	3.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	57.80	56.78	63.81
Al_2O_3	25.50	26.89	26.39
TiO_2	....	....	....
FeO	2.51	.322	[a]1.23
CaO	.25	.369	Tr.
MgO	.61	.987	Tr.
Alkalies	2.69	3.92	....
H_2O combined	8.35	[b]8.38	[b]9.12
H_2O uncombined	2.25		
	100.00	100.548	100.55

[a] As Fe_2O_3. [b] Loss by ignition.

1. East Palestine, Ohio. Paving-brick clay, Upper Freeport. Lord, analyst. Geol. Surv. Ohio, Vol. VII, p. 137.
2. Furnace clay on Jacobs Creek, 2 miles southeast of Jacobs Creek Station. McCreath, analyst. Second Geol. Surv. Pennsylvania, Rept. L, p. 112.
3. Bolivar, Pa. From King mine of Reese, Hammond & Co. Hopkins, Clay and clay industries of western Pennsylvania, p. 81.

The Upper Freeport clay in Beaver County, lying immediately under the Upper Freeport coal, is not at the horizon of the famous Bolivar clay. The horizon of the latter is, in fact, beneath the limestone which usually occurs just under the Upper Freeport clay, but, so far as observed, it seems replaced on Ohio and Beaver rivers by a less refractory shale. When the limestone is absent, however, both clays may lie together, as at Salina, Westmoreland County, without distinct line of demarcation.

The infrequent clay beds of the Conemaugh formation will be, with shales, discussed in the following chapter.

CARBONIFEROUS SHALES.

Allegheny group.—As has already been stated, shale is merely consolidated clay of character similar to the unconsolidated material. It has been found that a mixture of the two gives a stronger brick, when great strength and abrasive qualities are desired, as in paving brick,

[a] Prof. Paper U. S. Geol. Survey No. 11, 1903, p. 230.

than fire clay alone. Accordingly the shale overlying and underlying the clay beds in the Allegheny formation is used considerably in the brick industry of this region. Generally it is the shale nearest the Lower Kittanning clay which is most extensively employed. For example, the Fallston Fire Clay Company use the shale between the Lower Kittanning clay and the Clarion coal; the Vanport Brick Company uses the same shale and also that between the Darlington and the Lower Freeport coals. As shown by analysis No. 1 below, there seems little doubt but that higher shales might be utilized also, if necessary. No analysis from Beaver County can be given.

Analyses of clay and shale.

	1.	2.	3.	4.	5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica (total)	58.20	49.30	57.45	55.60	57.15
Alumina	22.47	24.00	21.06	24.34	20.26
Water (combined)	6.15	9.40	5.90	6.75	5.50
Oxide of iron	5.63	8.40	7.54	6.11	7.54
Lime	.62	.56	.29	.43	.90
Magnesia	.98	1.60	1.22	.77	1.62
Potash	3.08	3.91	3.27	3.00	3.05
Soda	.42	.19	.39	.09	.58
H_2O (Uncombined)	1.65	1.20	1.90	2.65	2.70
Total	99.20	98.54	99.02	99.74	99.30

No. 1. Shales and fire clays mixed, from the T. B. Townsend Brick Company, Zanesville, Freeport shales and Kittanning fire clays. Lord, analyst.

No. 2. Shale from Waynesburg Brick and Clay Manufacturing Company, from the Middle Kittanning (Darlington ?) horizon. Lord, analyst.

No. 3. Shale from the Ohio Paving Company, Columbus, Ohio, mined at Darlington, Ohio, on Lower Kittanning horizon, Average sample. Lord, analyst.

No. 4. Shale and fire-clay mixture, from the A. O. Jones Company, Zanesville, Ohio, from the Kittanning horizon. Lord, analyst.

No. 5. Shales used by Bucyrus Brick and Terra Cotta Company, mined at Glouster, Ohio, on horizon of Cambridge limestone. Average sample. Lord, analyst.

Conemaugh formation.—These rocks extend from the top of Upper Freeport coal to the base of Pittsburg coal, making an interval of about 510 feet. The base of this formation, which practically is the horizon of the Upper Freeport clay, lies 375 feet above Beaver River at Beaver Falls and dips southward to 275 feet above Ohio at Beaver, to 175 at Freedom, thence becoming lower toward Pittsburg. From 275 feet at Beaver, it drops westward to 265 at Vanport, 235 at Industry, 225 at Phillis Island, and then rises to 325 at State line. The river bluffs do not rise much above this elevation, and therefore catch only the lower portion of the Conemaugh formation, but it forms all of the high country back from the river and is exposed over most of Beaver County. Owing to lack of transportation facilities the clays of this formation are at a disadvantage, but, curiously, there are few, if any, beds of pure, nonconsolidated fire clay in the formation. Many of the conspicuous red clays and variegated shales, however, may be found valuable for brick purposes. Indeed, the analyses compare favorably with those of high-grade clays, and these clays and shales of the Barren Measures have, in fact, been used for paving brick and terra cotta at Glouster, Ohio (see No. 5 of analyses above). At Bellaire, Ohio, 20 feet of shale just under the Pittsburg coal is made into paving brick and sewer pipe.

General section of Conemaugh formation.

		Feet.
	Pittsburg coal at top.	
1.	Shale	25
2.	Limestone	3
3.	Shaly sandstone and shale	50
4.	Red shales	40
5.	Morgantown sandstone	65
6.	Elk Lick coal	Blossom.
7.	Variegated shale	40
8.	Ames limestone "Crinoidal"	2 to 5
9.	Coal (Platt?)	1
10.	Red shale	30
11.	Green shale	25
12.	Red shale	15
13.	Bakerstown coal, cannel	2 to 7
14.	Sandy shale and laminated sandstone	85
15.	Brush Creek limestone, dark	1
16.	Dark shale	20
17.	Brush Creek coal	Blossom.
18.	Shale	35
19.	Yellow and red caky shale	20
20.	Sandy shale	10
21.	Mahoning sandstone	30
	Upper Freeport coal.	

As seen from the section, most of the formation is composed of shales in such enormous quantities that the manufacture of brick can be carried on for centuries. Nearly all of the shales, the exceptions being the very arenaceous types, are well adapted to the manufacture of brick, and all show evidence of the presence of more or less iron, ferrous in the fresh shale and ferric in the weathered. The most common varieties are yellowish, drab, or bluish gray. Recently M. Lanz & Sons, of Pittsburg, have succeeded in making brick of good color and quality for building purposes from these shales.[a] Red shales are not very abundant, but where they do occur they generally have disintegrated to red residual clay.

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[a] Prof. Paper U. S. Geol. Survey No. 11, p. 233.

Of the 57 clay yards mentioned in Hopkins's report, over two-thirds use shale, wholly or in part, making a product chiefly of red brick, but also paving and pressed brick.

QUATERNARY CLAYS.

These clays are limited to the river terraces, of which three are well marked along Beaver and Ohio rivers. One lies 200 to 250 feet above river level, and is well exposed between Rochester and New Brighton and at Doctor Heights, but farther west on the Ohio, to State line, is represented only by very small remnants. Another terrace lies about 100 feet lower, and on this are built most of the river towns—New Brighton, Fallston, Beaver, Monaca, Shippingport, and Georgetown. A third terrace, 100 feet lower than the one just described, lies from 30 to 50 feet above river level, and usually is inundated by spring floods.

Of these three terraces, the highest and lowest produce clays which being generally impure and frequently sandy, are chiefly adapted to the manufacture of common brick, though pressed brick, and even crude pottery are made when the clays are fine and homogeneous. Often they are mixed with shale, producing excellent results. So far as known, clay deposits of value have not been discovered on the intermediate terrace. A terrace of the same elevation as the highest one mentioned above, and probably of the same age, occurs between Raccoon Creek and Logtown Run. New Sheffield is situated upon it. That this terrace might in depth also carry red-brick clays seems probable, but exploitation is hindered by lack of transportation facilities.

An important deposit has been worked on the highest terrace near New Brighton and Rochester. At the former place the deposit, which was used for terra cotta, and, by mixing with Lower Kittanning clay, for flower pots, shows the following composition:

Analyses of terrace clays.

	1.	2.
	Per cent.	*Per cent.*
SiO_2	46.160	67.780
Al_2O_3	26.976	16.290
Fe_2O_3	7.214	4.570
TiO_2	.740	.780
CaO	2.210	.600
MgO	1.520	.727
Alkalies	3.246	2.001
Water	11.220	6.340
Total	99.286	99.088

1. Mendenhall & Chamberlin Works.
2. Elverson & Sherwood Works.
Both analyses from Second Geol. Survey, Pennsylvania, Rept. MM, p. 257. A. S. McCreath, analyst.

Across the northern part of Beaver County lies the great terminal moraine of the Glacial epoch, which in Allegheny County and elsewhere often contains irregular beds of clay. But there is no record that such clay deposits have been found in Beaver County.

In other counties valuable "basin deposits" of glacial clays are worked. These were formed in local lakes produced by the glacier, and are consequently to be looked for just south of the terminal moraine. Like the morainal deposits, these "basin deposits," so far as known, have not been discovered in Beaver County. Such deposits must, from their origin, necessarily be impure and sandy, but screening and washing often produce a good quality of clay for red bricks, flower pots, and, if mixed with other clays, even for terra cotta.

CLAY INDUSTRIES.

General.—The clay industries along these two rivers may be classed according to products as follows: Pottery, tiles, sewer pipe, refractory materials, building materials, and paving materials. These will be briefly described in order.

Pottery.—The clays used for pottery are almost infinite in variety, according to the grade of ware desired. Earthenware is often made from very impure clay, which is sometimes glazed to conceal imperfections, and sometimes not, as in flower pots. Such material consists of impure fire clays, shales, or glacial clays, or mixtures of them. Stoneware is usually made from domestic fire clays, but porcelain and china ware require white clays, such as are not found in Beaver County. Small quantities of fire clay, however, may be mixed with the latter to obtain the proper degree of plasticity.

The first attempt at pottery making in the Beaver Valley, so far as can be ascertained, was about the year 1834, when Thomas Jackson started a small pottery at New Brighton. The panic of 1837, so disastrous to the business interests of the country, caused Mr. Jackson to suspend business. Perhaps the next venture was by Hamilton Bros. at West Bridgewater, but the exact date of their operations is not known. They obtained clay on the west side of Bradys Run near its confluence with Beaver River. Their chief products were crocks and jugs. The Mackenzie Bros., at possibly the same date, manufactured pottery at Vanport and procured their clay, it is reported, from the Beaver Valley.[a]

The present large pottery and kindred industries at New Brighton date from 1862, when Mr. Thomas Elverson began making Rockingham and yellow ware in a little pottery on the hillside above the present site of the New Brighton pottery. This little pottery, which was the nucleus of all of the large works now in the valley, continued opera-

[a] Hopkins, T. C., Clays and Clay Industries of Pennsylvania; Clays of Western Pennsylvania: Appendix to Ann. Rept. Penn. State College for 1897, 1898, p. 37.

tions under various firms until 1890, when it was absorbed by the Pittsburg Clay Manufacturing Company. This company still operates the works together with the New Brighton pottery, which is also an outgrowth of the small pottery started by Elverson.[a]

In 1878 and 1879 Sherwood Bros. laid the foundation of the present large pottery on Blockhouse Run. They started with one kiln and one small building, enlarging their facilities from time to time until now this company is one of the most progressive in Beaver County in the production of high-grade ware. Their specialties are glazed milk pans, stew pans, fruit jars, and Bristol ware. Since 1880 the following companies have been established: The Enterprise Pottery and the American Porcelain Company on Blockhouse Run, the Mayer Pottery Company at Beaver Falls, the Fallston Pottery Company on Bradys Run, and Keystone Pottery at Rochester. Their products are pitchers, toilet sets, plain and decorated table ware, bath tubs, sinks, jars, jugs, cuspidors, pots, etc. All of these companies use the Lower Kittanning clay in varying proportions, combined with imported clays of higher quality. Flower pots are manufactured from a mixture of Lower Kittanning and terrace clays at Oak Hill pottery, situated north of New Brighton, on the highest terrace.

Tiles.—The Beaver Falls Art Tile Company, which began operations in 1887, make chiefly decorative and glazed tile of great variety in size and color. Eighty-five per cent of the clay used is taken from the Lower Kittanning clay bed on Blockhouse Run. The rest of the clay is imported. The ware is all burned in saggers made from Lower Kittanning clay.[b]

Sewer pipe.—The manufacture of sewer pipe was begun in 1887 by the Pittsburg Sewer Pipe Company on Blockhouse Run. After many changes in the management this company was absorbed in 1890 by the Pittsburg Clay Manufacturing Company.[c] Sewer pipe requires a low-grade siliceous clay, such as is used for paving brick. This is obtained from the Lower Kittanning and Lower Freeport beds, though the latter is not now worked.

Refractory materials.—These require a high-grade clay in point of fusibility. The Lower Kittanning clay, while of excellent refractory quality, can not be used alone for the most highly refractory products. To supply this need, flint clay is imported from Cambria, Clearfield, and Clarion counties. When this is mixed with the Lower Kittanning clay it gives a highly refractory material, sufficiently plastic to serve as a bond for the flint clay. The aim is to obtain a mixture as siliceous as possible, which will at the same time develop plasticity well, for the more siliceous a clay is the less it shrinks and the more refractory it becomes.

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[a] Hopkins, T. C., op. cit., p. 38. [b] Ibid, p. 47. [c] Ibid, p. 41.

Fire bricks were first made in this region by S. Barnes & Co., about a mile above Rochester, on Beaver River, as early as 1839, and this is said to be one of the oldest brick works in the State. At present this company manufactures fire brick and refractory materials of all kinds.

A. F. Smith & Co. began the manufacture of fire brick east of New Brighton in 1847. At one time they made both fire brick and building brick, besides shipping considerable raw clay. In the same year fire brick were produced on the south side of Ohio River opposite Beaver, where at present the works of the Stahl Fire Brick Company are situated. Twenty years later the Vanport Brick Company was established, and made some fire brick in connection with building and paving brick. Since then several brick works have been started, which make some fire brick, but the fire-brick industry has receded before the more profitable building and paving-brick industry.[a]

Building and paving materials.—Building materials are practically limited in this region to building and paving brick of two general classes, that made from the Lower Kittanning clay and that made from terrace clays. The former produces brick of various colors, depending upon the amount of iron present and the duration of firing; the latter always produces a deep red brick. The two clays are sometimes mixed to obtain various intermediate effects. These, too, are often obtained by mixing shale with Lower Kittanning clay.

Paving brick require a clay similar to that used in vitrified building brick and sewer pipe. The clay must be such as will thoroughly vitrify without melting out of shape, must be plastic for working into shape, and should contain iron for colors. The iron should not, however, be present in grains, as it then renders the brick blotchy and rough. Shales and impure fire clays mixed with each other or with terrace clay give satisfactory results.

Many of the companies already mentioned make building and paving brick, beside fire brick.

The Fallston Fire Clay Company is one of the most prosperous manufacturers of high-grade building brick of different shapes and sizes, and also of paving brick.

The red-brick industry began as early as 1852, when A. F. Smith began the manufacture of red brick from the terrace clay east of New Brighton. Levi Fish, A. Dewhirst, and T. Dewhirst have all operated extensively in this industry, and all used clay from the high terrace between New Brighton and Rochester.[b]

A brickyard owned by Mr. Agner, situated between the railroad and Ohio River at the upper part of Rochester, produces red brick from the alluvium of the river bank. The brick are burned in the ordinary open-top updraft kilns used in this industry. With this

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[a] Hopkins, T. C., op. cit., 65–67.

[b] Ibid., p. 120.

exception no other brick works now use clay from this terrace, though at Vanport, in connection with Lower Kittanning clay, it is reported once to have been used.

PRODUCTION.

In the clay industry of the United States Ohio ranks first, producing 19½ per cent of the total product, valued at over $34,000,000. Pennsylvania ranks second, with a product of over $17,000,000, which is 14 per cent of the total product of the United States.

Pennsylvania holds first place in the United States in the manufacture of fire brick and building brick, making one-half of the total product in fire brick and over one-seventh of the building brick. Ohio and New Jersey hold second and third place, respectively. The preeminence of Pennsylvania in the fire-brick industry is probably due to the extraordinary demand for refractory materials within the State itself, as it is the chief iron producer of the United States. Enormous quantities of fire brick, fire-clay cement, and other refractory products are used as linings for blast furnaces, crucibles, and other articles in the metallurgical processes and also as linings for coking ovens and house furnances.

Of the total Pennsylvania production, Beaver County supplies a considerable part. It produces 29 per cent of the Pennsylvania pottery, all within a radius of a mile and a half from New Brighton, 30 per cent of its paving brick, and 25 per cent of its fancy or ornamental brick; 16 per cent of the fire brick made in Pennsylvania, and about the same proportion of sewer pipe, fireproofing, and tile (not drain), come from Beaver County. But of building brick it supplies the least, 4 per cent of the total amount manufactured in the State. Of the total clay products of the State, Beaver County furnishes 5 per cent. This is a small percentage of what the county could produce if its clay deposits were developed in proportion to those in Ohio where the clay deposits are practically the same as those in Beaver County. Further development, however, is greatly impeded by lack of transportation facilities. This is especially true along Ohio River, west of Beaver River, where the valley affords but one single-track railroad with an embarrassing scarcity of cars, and a river unnavigable for a great part of the year.

GEOLOGICAL SURVEY PUBLICATIONS ON CLAYS, FULLER'S EARTH, ETC.

In addition to the papers listed below, references to clays will be found in the publications listed under the head of "Cements," on page 462.

BRANNER, J. C. Bibliography of clays and the ceramic arts. Bulletin No. 143, 114 pp. 1896.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin No. 213, p. 382–391. 1903.

GOLDING, W. Flint and feldspar. In Seventeenth Ann. Rept., pt. 3, pp. 838–841. 1896.

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1891, pp. 474–528.

——— Clay materials of the United States. In Mineral Resources U. S. for 1892, pp. 712–738. 1893.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp. 523–575. 1895.

——— The pottery industry of the United States. In Seventeenth Ann. Rept., pt. 3, pp. 842–880. 1896.

——— The clays of the United States east of the Mississippi River. Prof. Paper No. 11. 1903.

SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F. The glacial brick clays of Rhode Island and southeastern Massachusetts. In Seventeenth Ann. Rept., pt. 1, pp. 957–1004. 1896.

VAUGHAN, T. W. Fuller's earth deposits of Florida and Georgia. In Bulletin No. 213, p. 392–399. 1903.

WILBER, F. A. Clays of the United States. In Mineral Resources U. S. for 1882, pp. 465–475. 1883.

——— Clays of the United States. In Mineral Resources U. S. for 1883–1884, pp. 676–711. 1885.

SALT, GYPSUM, BORAX, AND SODA.

The mineral products grouped under the above heading, though applied to widely different uses, form a somewhat natural group so far as origin is concerned. Their close connection becomes obvious when their study in the field is attempted, for two or more of these salts will often be found in adjacent and closely related deposits. This is due to the mode of origin of such deposits. The materials here grouped include certain sulphates, chlorides, carbonates, or borates of lime, magnesium, sodium, or potassium; and deposits of commercial value are due in almost every case to the deposition of these salts, by evaporation, from the sea or lake water in which they were contained in solution.

The most important and fortunately the most widely diffused of these materials is common salt, whose uses, both in the preparation and preservation of food and in the chemical industries, are rapidly increasing. For a report on field work by the Survey, during 1903, on the Utah and California salt industry, see pages 488–495. Appended to this report are tables of analyses of rock salts, brines, and commercial salts from various United States and foreign localities. Several of the important districts were examined during 1903, while the remaining districts will be visited in 1904. A survey bulletin on the saline deposits of the United States will then be published.

The next in importance of these materials is gypsum. In addition to the report on Utah gypsum, presented in this bulletin, all the commercially important gypsum deposits of the United States are described in Bulletin No. 223, of the United States Geological Survey, now in press.

A report on the California borax deposits has recently been issued by the Survey. This, together with other Survey publications on the materials of this group, will be found listed on page 496.

ROCK GYPSUM AT NEPHI, UTAH.[a]

By J. M. BOUTWELL.

INTRODUCTION.

The more important known gypsum deposits in Utah occur in the central and southern portion of the State, in Juab County, east of Nephi; in San Pete and Sevier counties, near Salina; in Millard County, at White Mountain, near Fillmore; and in Wayne County, in South Wash. They are all of the rock gypsum type except the one near Fillmore, which is in the secondary form of unconsolidated crystalline and granular gypsum blown up from desiccated playas into dunes. Deposits are also known in Emery County, about 40 miles southeast of Richfield; in Kane County, near Kanab; in Grand County, between the Grand River and the La Sal Mountains; in San Pete County, near Gunnison; and in the eastern part of Washington County, between Duck Lake and Rockville, and recently large deposits of gypsum have been reported from Iron County, at points so far from lines of transportation, however, as to make their exploitation commercially impracticable at present.

In this paper the character, occurrence, and development of rock gypsum near Nephi, Utah, will be considered. In December, 1902, the writer visited these deposits and procured the data which form the basis for the following sketch. A heavy snowfall seriously interfered with thorough geologic field study, and entirely prevented careful investigation of certain important points. Brief descriptions of the general character, geologic relations, and economic development of the gypsum deposits near Salina, White Mountain, and South Wash are given in the complete paper.

CHARACTER OF DEPOSITS.

This immense deposit of rock gypsum is located in Juab County, 1 mile east of Nephi, on the south side of the entrance to Salt Creek Valley. It is the largest well-known deposit of rock gypsum in Utah,

[a]This abstract is a portion of a paper on "Gypsum deposits in Utah," which will appear in Bulletin No. 223 (now in press), on "Gypsum deposits in the United States." For information regarding the history and development of this deposit the writer is indebted to Mr. F. A. Hyde, manager, secretary, and treasurer of the Nephi Plaster Company, and to Mr. James Jackson, superintendent in charge of both quarry and mill, who also courteously afforded every facility for studying the occurrence and exploitation of this deposit.

and forms the entire mass of a prominent spur at the entrance to Salt Creek Valley, and outcrops from the level of the creek up the slope in a southeasterly direction in the form of a vertical bed or lens. The dimensions of the exposed portions of this body are 275–300 feet in thickness, 500 feet in height along the bedding, and at least 700 feet in length along the strike. The length depends upon whether the deposit thins out along the strike, is faulted, or continues unbroken. Owing to a thick blanket of snow, which covered the upper portion of the gypsum croppings to a depth of 2½ to 3 feet at time of visit, this could not be observed. The croppings are reported, however, to have been traced southeastward for several hundred feet to the main divide.

Although the entire thickness of the deposit is made up of gypsum, the character of the rock varies somewhat in different beds. This is shown in the following section from foot to hanging wall:

General section of the Nephi gypsum deposit.

	Feet.
Interbedded shale and gypsum, marl and gypsum dirt	30
Rock gypsum, "first-class"	65
Rock gypsum, fractured, occasional bands of disseminated calcareous particles, etc	75
Rock gypsum, "first-class"	55
Gypsum and shale, transition to shale	50

The second member affords all of the present output; the third, though gypsum and easily quarried owing to its fractured state, is not quite so pure; while the fourth is of excellent grade, and will probably be excavated in conjunction with the second by the open-cut method in the near future.

The first-class rock is massive, dense, lusterless, and light grayish brown in color. The chief variations are a mottled, whiter, harder phase, which occurs at the top of the main bed exploited, and "shaly" bands. The bands are zones in which small brown angular fragments are included in white and brown rock gypsum. These fragments prove on analysis to be more calcareous than the remainder of the rock.

An analysis by Dr. E. T. Allen, of the U. S. Geological Survey, of first-class gypsum from the second member, and also an analysis of shaly portions in waste rock from the third member, afford valuable data. From these analyses Doctor Allen determines that the first sample is made up of 76 per cent gypsum, 22.5 per cent anhydrite, and 1.5 per cent calcium carbonate (limestone?); and that the second is composed of 60.5 per cent gypsum, 22 per cent anhydrite, 17 per cent calcium carbonate (limestone?), and 0.5 per cent magnesium carbonate (dolomite?).

Perhaps the most important feature brought out by these results, next to showing a high gypsum content, is that the first-class rock, as well as the "waste" rock, includes between 22 and 23 per cent of anhydrite. The significance of this fact lies in the practical influence of the anhydrous material upon the action of the combined product; for, although when gypsum is calcined the largest portion of water is driven off, it is generally regarded essential for its suitability for plaster that some of its water be left. "When it is heated to 100–120° it gives up three-fourths of its water very quickly, but it requires a temperature of from 200–250° to expel the remainder." "If gypsum has been heated to a little over 200°, thus being deprived of all of its water, it becomes dead burnt, and takes up water very slowly and without hardening."[a]

It would seem, therefore, that in so far as natural anhydrous calcium sulphate (anhydrite) is like artificially dehydrated gypsum in actual practice, the presence of anhydrite would at least retard "setting." In the manufacture of patent cements, however, heating to 600–700° F., while mixing it with sulphuric acid, borax, cream of tartar, etc., is stated to give a product, which, after setting very slowly, becomes exceedingly firm and hard.[b]

It is highly probable that anhydrite occurs in a large per cent of the gypsum deposits, so that further reliable analyses of other gypsums which have proved to afford plaster of good setting quality are much to be desired.

The presence of calcium carbonate (limestone) to the extent of 17 per cent in the rock, which is sorted out for rejection, may be advantageous for special uses, for in the preparation of certain hydraulic cements limestone is considered a valuable constituent. The significance of the content of potassium, magnesium, and sodium is considered hereafter in connection with the discussion of the origin of these deposits.

Several other deposits of value are known in Salt Creek Valley east of the main body, the most important of which is on the north side of the creek, about one-half mile east of the Nephi plaster mill. They include rock gypsum of good grade and impure transitions. In many localities they would be exploited, but being in such close proximity to the great body at the mouth of the valley, these are left idle.

GEOLOGIC OCCURRENCE.

The geologic structure of this region is exceedingly complicated and only its broadest characteristics can now be stated. The Nebo massif to the north, composed of Paleozoic rocks, appears to have been elevated above the tract of Jurassic and Tertiary rocks to the south and east by faulting along a northeast-southwest zone. The tract on

[a] Thorp, T. E., Dictionary of Applied Chemistry, vol. 1, p. 406.
[b] Wilder, F. A., Iowa Geological Survey, vol. 12, p. 157.

the southeast side of this possible fracture zone includes a considerable thickness of olive and gray calcareous shales, buff limestone, black paper shales with massive interbedded members, gray sandstone, reddish conglomerate, and a heavy series of grayish-brown sandstone. The general eastward dip is frequently lost in excessively folded and tilted structures. The geologists of the Wheeler Survey were of the opinion that an unconformity between the Tertiary and Paleozoic rocks appears in this valley.

The area in the immediate vicinity of the main gypsum deposit lies on the southeast side of the possible zone of fracture, and the beds are extremely deformed. On the north side of the mouth of Salt Creek Valley gray and black shales stand vertical and strike northeast, farther east they swing into east and southeast strikes and dip northward, thus forming the nose of an anticline which plunges steeply northward. The gypsum bed lies on the south side in a series of buff limestones and gray and buff calcareous shales. The strike of this series is northwest-southeast, and the general dip is vertical or steeply to the southwest, except that there are local variations adjacent to fissures or to closely appressed folds. The gypsum body stands nearly vertical, dipping locally 85° southwest, between shale walls, and strikes southeastward. Owing to the snow which covered the ground at the time of visit, neither the upper nor lower contact, nor either limit along the strike were observed, so the precise nature of the occurrence can not be positively stated. It appears, however, to be in the form of a bed deposited contemporaneously with inclosing sediments, and it is probably either a thick lens which pinches rapidly along the strike or a bed which has been terminated in either direction along the strike by faulting.

Although the study of the region was too hasty to obtain sufficient data for a complete explanation of the origin of the deposit, general observations and facts brought out by the analyses afford accordant evidence for an opinion. The bedded structure of the gypsum, the agreement of this bedding with that of the country rock, the interbedding of the wall rock and gypsum, and the occurrence, in the same series in this neighborhood, of rock salt, common salt, and gypsum of various degrees of impurity, tend to indicate a sedimentary origin; and the analyses, showing the presence of about 17 per cent calcium carbonate, one-half of 1 per cent of magnesian carbonate, and minor amounts of potassium and sodium salts, afford additional basis for the belief that this gypsum is the product of deposition from inland water bodies, such as lakes, lagoons, or bayous.

The geologic date of this deposition can not be settled until further paleontological evidence has been obtained. The rocks of the region are indicated on the geological map of the Wheeler Survey as Jurassic, and in the report it is stated that "the Jurassic rocks are everywhere found to be very gypsiferous, and in some places good workable beds of gypsum are seen. One of these beds occurs at Salt Creek, near Nephi."

HISTORY AND DEVELOPMENT.

This is the only gypsum deposit in Utah which is now being exploited to any considerable extent. It was known before the town of Nephi was settled, and has probably been known to the whites for nearly eighty years. About thirty-five years ago a claim 600 by 1,500 feet in dimensions was formally located, and in 1882 this was patented by John Hague and others under the name of the Juab Plaster and Mining Claim. After small intermittent shipments to Salt Lake City, in 1887, under the management of Messrs. Hyde, Hague, and Whitmore, rock gypsum was quarried, and burned in sorghum pans for local consumption. During the following year, encouraged by the rapidly increasing demand, these parties incorporated their company and erected the nucleus of the present efficient plant.

The rock is now obtained by blasting from an extensive open cut, and is trammed thence by gravity to the works. The present plant, which is the product of repeated enlargement, though not extensive, is very complete. It includes (1) a mill, which is fitted with one nipper, steel grinder, round buhrs, 3 chain elevators, 2 two-flue, 8-foot calcining kettles, a mixing plant, etc.; (2) a complete cooperage, and (3) a storehouse. Ample power is supplied by a turbine driven by water taken from Salt Creek, 3,500 feet upstream from the mill.

The output averages 36 tons of plaster a day, and between 7,500 and 10,000 tons a year. This includes dental, casting, finishing, land, and hard plaster, each appropriately prepared for its special uses. A large and increasing demand is supplied throughout the great basin region, and shipments are made as far as Grand Junction on the east, Los Angeles and Hawaii on the south and west, and Victoria on the north.

THE SALT INDUSTRY IN UTAH AND CALIFORNIA.

By Edwin C. Eckel.

During the field season of 1903 the writer was enabled to spend a few days in the study of the salt industry near Great Salt Lake, Utah, and on San Francisco Bay, California. A brief description of the practice at these two localities is presented in this paper. A more detailed discussion will appear later in a Survey bulletin on the saline deposits of the United States.

The writer's acknowledgments are due to the officers of the Inland Crystal Salt Company, the California Salt Company, and the Carmen Island Salt Company, to all of whom he is indebted for valuable data and courtesies received at the works.

The two salt-producing areas to be described in the present paper are of peculiar interest, for they contain the largest solar-evaporation plants in the United States. While thus agreeing in method of treatment, the practice in the two districts differs because of differences in the degree of concentration of the brine. The brine pumped from Salt Lake, Utah, is highly concentrated, carrying over 20 per cent of saline matters, and being, therefore, free from calcium sulphate, which has been deposited naturally at an earlier stage in the evaporation of the lake water. The water of San Francisco Bay, on the other hand, is rather less salt than that of the open sea, and its gypsum must be precipitated at the works.

SALT INDUSTRY IN UTAH.

Though a certain small amount of salt is still made from salt ponds in other portions of the State, all the product which enters the market is manufactured by solar evaporation at various points along the border of Great Salt Lake.

As is well known, Great Salt Lake is but the remnant of an immensely greater body of water. This earlier body, called Lake Bonneville, was reduced by evaporation to its present size, while at the same time it became a highly concentrated solution.

Specific gravity and total solid content.—As shown in the table below, the water of Great Salt Lake has varied considerably in its degree of concentration even during the comparatively short period which has elapsed since the settlement of Utah. If the records can be relied upon, it was at its point of maximum concentration when sampled by Stansbury in 1850. From that date until some time in the seventies the lake gradually became fresher, reaching its recorded least concentration in 1873. A reverse process then set in, and the lake has now almost reached the concentration point of 1850.

Specific gravity and solid contents of water of Great Salt Lake.[a]

Date of collection.	Specific gravity.	Solids.	Authority.
		Per cent.	
1850	1.170	22.282	L. D. Gale.
1869. Summer	1.111	14.9934	O. D. Allen.
1873. August	1.102	13.42	H. Bassett.
1885. December	1.2225	16.7162	J. E. Talmage.
1888. February	1.1261	....	Do.
1889. June	1.148	....	Do.
1889. August	1.1569	19.5576	Do.
1892. August	1.156	20.51	E. Waller.
1892. September	1.1679	21.47	J. E. Talmage.
1893	....	20.05	J. T. Kingsbury.
1894. December	1.1538	21.16	J. E. Talmage.
1895. May	1.1583	21.39	Do.
1900. June	1.1576	20.90	H. McCoy and T. Hadley.

[a]This table is reprinted from the valuable booklet on "The Great Salt Lake," by Dr. J. E. Talmage, published in Salt Lake City, 1900.

Chemical composition of Great Salt Lake water.—The composition of the water of Great Salt Lake is subject to seasonal and other variations, but the following five analyses will serve to show its range. It is a naturally highly concentrated brine, and therefore carries practically no gypsum or carbonates, as these have already been precipitated along the shores and at the bottom of the lake.

Analyses of water of Great Salt Lake.

	Analyst.				
	L. D. Gale.	O. D. Allen.	H. Bassett.	J. E. Talmage.	
Sodium chloride (NaCl)	20.20	11.86	8.85	13.59	15.74
Potassium chloride (KCl)	....	....	1.89	....	....
Magnesium chloride ($MgCl_2$)	.25	1.49	1.19	1.13	2.01
Sodium sulphate (Na_2SO_4)	1.83	.93	1.09	1.42	1.05
Potassium sulphate (K_2SO_4)	....	.53	....	.43	.47
Calcium sulphate ($CaSO_4$)	....	.09	.20	.15	.28
Total solid contents	22.42	14.82	13.67	16.72	19.55
Specific gravity	1.170	1.111	1.102	1.122	1.157
Date of collection	1850	1869	1873	1885	1889

If water from Great Salt Lake be evaporated to the points where various salts crystallize out, the results of such fractional crystallization, while following approximately the results obtained by evaporating sea water, will present certain interesting differences. These differences are due in part to the difference in composition between Great Salt Lake water and sea water, and in part to the fact that at Great Salt Lake certain critical temperatures are reached naturally in the course of the year.

Salt ponds.—The harvesting ponds of the Inland Crystal Salt Company are each about 800 feet wide and 1,000 feet long. A number of them are set side by side next to a larger "stock" or "settling" pond. About May 1 the pumping season commences. The stock pond is pumped full of water from the lake, and this brine is allowed to stand there until a reddish precipitate of iron oxide, etc., has settled. It is then allowed to flow into the harvesting ponds, which are usually kept with about 6 inches depth of water in them. In a normal season the evaporation of water in these harvesting ponds will amount to about 2 inches a day, which must be replaced from the stock pond, while this is in turn kept full by pumping from the lake. The brine thus treated would not give a product containing much over 96 per cent NaCl if it were not for the fact that the mother liquor (containing part of the magnesium and sodium sulphates and practically all of the magnesium and lime chlorides) is not allowed to evaporate, but is returned at intervals to the lake. A further purification is effected by the fact that the sodium sulphate, which floats when formed, is driven by the wind into the leeward ponds and against the sides of the ponds. The material from such ponds is therefore marketed for cattle and silver-mill use, while that from the windward ponds is a very pure salt, and is shipped to the mill for further treatment.

Until about September 1 the ponds are kept full of water, after which time they are allowed to evaporate completely, with the exception, as before noted, of the lighter brines containing the bulk of the impurities. In an average season about 3 inches of salt will be obtained, though 6-inch crops have been reported in exceptionally favorable years.

In harvesting the salt, after the contents of the ponds have entirely evaporated, the salt is shoveled up into wheelbarrows and heaped into large stacks. The removal of any adhering mother liquors is effected by the rain, and the salt is then ready for the refining mill or for market if it is to be sold crude.

Salt milling.—The mill of the Inland Crystal Salt Company is constructed in two duplicate sections, each containing one drier and six sets of rolls, fans, shaking sieves, etc. Each of these sections is operated as follows:

The crude salt arrives at the mill in standard-size cars over a switch from the tracks of the Saltair Railway. The salt first passes through a Hersey rotary drier. This consists of two concentric cylinders clamped together and rotating on bearings which support the outer cylinder. The inner cylinder, or steam drum, is about 3 feet in diameter, and is fed with steam from the boiler. The outer cylinder is 6 feet in diameter and 45 feet long. Angle irons are fixed at intervals around its inner circumference. The drier is set at a slight inclination, say about one-half inch to the foot. The salt is fed into the space between the two cylinders at the upper end of the drier, and as the drier revolves the salt travels slowly toward its lower end, where it is discharged into a conveyer. This carries it to the second floor of the mill, from which it falls through a chute to the first set of a series of six rolls. After passing through the first set of rolls the crushed material is again elevated to the second floor and sent over a shaking sieve, which acts as a separator, allowing the fine stuff to go to the bagging room, while the coarser material is again dropped through a chute to the second pair of rolls, which are set closer than the first set and therefore give a finer product. This is again sieved, separated, and crushed in still finer rolls, the process continuing until the material has passed through six sets of rolls of increasing closeness, passing over sieves after each crushing. The sieves are of 40 mesh at their upper end and 30 mesh at the lower end, and feed into different bins. Fans are placed over the top of each sieve and also in the rolls and driers. These fans take off the very lightest and finest material, and their product is conveyed into a room where it is pressed for cattle feed. As the magnesium and sodium sulphates are considerably lighter than the sodium chloride, the use of these fans takes out much of the sulphates and purifies the salt very appreciably, as shown by the analyses below. This fine material, relatively high in sulphates, is mixed with 0.5 to 2 per cent of powdered sulphur, dampened slightly, and pressed into boxes or blocks. These are loaded on little trucks and run into a drying tunnel, where they are baked by direct heat.

That such a device would effectively accomplish the separation of the sulphates from the salt might perhaps be doubted, but the efficiency of the fans is abundantly demonstrated by comparison of analyses of crude and of refined salt. A more striking proof, perhaps, is afforded by the following analysis. This represents the composition of a specimen, collected by the writer, of the separated material which had caked on the drier. The analysis was made by Mr. W. T. Schaller, in the laboratory of the United States Geological Survey.

Analysis of separated material caked on drier.

	Per cent.
Silica (SiO_2)	0.31
Alumina (Al_2O_3) } Iron oxide (Fe_2O_3) }	.10
Lime (CaO)	.67
Magnesia (MgO)	4.66
Potash (K_2O)	2.41
Soda (Na_2O)	27.41
Sulphur trioxide (SO_3)	13.11
Chlorine (Cl)	43.05
Water of combination	7.03
Moisture	1.58
Total	100.33

When these constituents are combined in the most probable manner, it will be seen that this separated material contains about 70 per cent of sodium chloride and 14 per cent of magnesium sulphate, with lesser amounts of potassium sulphate, etc.

Composition of commercial salt.—The following are analyses of salt manufactured from brine of Great Salt Lake:

Analyses of commercial salts, Utah.

	1.	2.	3.	4.	5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica (SiO_2), etc	0.214	0.472	0.201	0.102	0.007
Sodium chloride (NaCl)	98.101	98.300	98.121	98.407	99.927
Calcium chloride ($CaCl_2$)	.322	.345	.311	.371	Tr.
Magnesium chloride ($MgCl_2$)	.000	.000	.000	.000	Tr.
Calcium sulphate ($CaSO_4$)	.364	.680	.422	.650	.058
Magnesium sulphate ($MgSO_4$)	.021	.042	.022	.030	.000
Water	.952	.158	.911	.442	.008

1. Coarse salt, Jeremy Salt Company. J. E. Talmage, analyst.
2. Table salt, Jeremy Salt Company. J. E. Talmage, analyst.
3. Crude salt, Inland Crystal Salt Company. J. E. Talmage, analyst.
4. Salt, Inland Crystal Salt Company. J. E. Talmage, analyst.
5. Table salt (refined), Inland Crystal Salt Company. H. Harms, analyst.

Early history of the industry.[a]—The history of salt manufacture from the waters of Great Salt Lake begins immediately upon the arrival of the Mormons in Utah in 1847. In the earlier years of the industry the only salt harvested was that obtained from the evaporation, during summer, of the water contained in little lagoons or natural basins along the shore of the lake.

The early settlers were supplied in this way until about 1860, when the idea was conceived of making dams which would hold large quantities of water in low places, for evaporation. These ponds were flooded in the spring and the salt deposited dur-

[a] A more detailed discussion will be found in the Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, pp. 608–609.

ing the summer by solar evaporation was gathered into piles along the banks and carried over from one year to another. About this time the chlorination process for the reduction of silver ores was discovered. Probably the first use of Utah salt for this purpose was at the Alice mill, located at Butte, Mont. It was before the days of railroads, and the salt was packed to Butte on the backs of mules, at a cost of about $200 per ton. As the chlorination process became better known, other mills put in the system, including the Ontario, located at Park City, Utah.

The salt for this mill was hauled in wagons from the shores of the lake to Park City, at a cost of $15 per ton. The rapidly increasing demand for salt caused further outlays in its production, and salt fields were made on high ground and the brine was pumped to them, the average height above the lake being about 20 feet. This was found to be greatly preferable to the plan of depending on the spring overflow into low places, as the natural overflow was uncertain, while with pumps as much water could be raised as was desired. The increase in the demand was very rapid, especially for milling salt, and the output for all purposes reached a total of 50,000 tons in 1890, whereas not over 500 to 1,000 pounds were gathered in 1848.

Utah salt production.—Utah at present ranks sixth among the States as a salt producer, so far as quantity is concerned, and fifth if the value of the product be considered. This is shown in the following table:

Rank of various States as salt producers, 1902.

Rank.	Quantity.	Value.
1	New York	New York.
2	Michigan	Michigan.
3	Kansas	Ohio.
4	Ohio	Kansas.
5	California	Utah.
6	Utah	California.

The amount of salt produced in Utah for each year since 1882, as compared with the total production of the United States for the same years, is given in the following table, the data for which have been compiled from various volumes of the Mineral Resources of the United States:

Salt production of Utah and entire United States, 1880–1902.

Year.	Utah.	United States.
	Barrels.	*Barrels.*
1880	96,760	5,961,060
1882	92,820	6,412,373
1883	107,143	6,192,231
1884	114,285	6,514,937
1885	107,140	7,038,653
1886	164,285	7,707,081
1887	325,000	8,003,962

Salt production of Utah and entire United States, 1880–1902—Continued.

Year.	Utah.	United States.
	Barrels.	*Barrels.*
1888	151,785	8,055,881
1889	200,000	8,005,565
1890	427,500	8,876,991
1891	969,000	9,987,945
1892	1,292,471	11,698,890
1893	189,006	11,897,208
1894	268,186	12,967,147
1895	294,485	13,669,649
1896	279,800	13,850,726
1897	405,179	15,973,202
1898	266,250	17,612,634
1899	236,135	19,708,614
1900	249,128	20,869,342
1901	334,484	20,566,661
1902	417,501	23,849,221

SALT INDUSTRY IN CALIFORNIA.

Rock salt or brine from springs and lakes is utilized in several California counties, but the greater part of the salt production of the State still comes from the solar-evaporation plants, working on sea water, in the counties of Alameda and San Diego. In recent years almost 90 per cent of the total production has come from Alameda County alone.

Most of the "bay salt" plants are located on the eastern side of San Francisco Bay, near its southern end in the vicinity of Alvarado, Newark, and Mount Eden. Attempts have been made to manufacture salt on the west side of the bay, but the water there is said to contain more iron. For some reason, at any rate, the plants on the west side have never proved successful.

Chemical composition of sea water.—While differing slightly in various parts of the ocean, the chemical composition of sea water is fairly uniform. The following average, given by Dittmar, is usually accepted as representative:

Average composition of the solid matter of sea water.

	Per cent.
Sodium chloride ($NaCl$)	77.758
Magnesium chloride ($MgCl_2$)	10.878
Magnesium sulphate ($MgSO_4$)	4.737
Calcium sulphate ($CaSO_4$)	3.600
Potassium sulphate (K_2SO_4)	2.465
Magnesium bromide ($MgBr$)	.217
Calcium carbonate ($CaCO_3$)	.345

Sea water contains, on the average, about 3½ per cent of such solid matter.

Manufacturing methods.—While the processes of evaporating and milling, as carried out at the best equipped California plants, closely resemble those already described as in use in Utah, a few differences are worthy of note.

The most important of these differences of practice arises from the difference in strength of brine. The water of Great Salt Lake carries 20 per cent or more of salts, and has therefore deposited practically all of its lime carbonate and gypsum. The water of San Francisco Bay, on the other hand, is a relatively weak brine, carrying probably about 3 per cent of salts. In evaporating, it is therefore necessary to provide for the precipitation of the iron oxide, lime carbonate, and gypsum.

Analyses of commercial salts, California.

	1.	2.
	Per cent.	*Per cent.*
Sodium chloride (NaCl)	97.31	99.655
Lime (CaO)	.10	.125
Magnesia (MgO)	.48	Tr.
Sulphur trioxide (SO_3)	.36	.17
Water	1.55	.05

1. Crude salt, first evaporation, 1903 crop. California Salt Company, Alvarado. L. Falkenau, analyst.
2. Table salt, refined. Coward mill, Oakland (not now in operation). L. Falkenau, analyst.

GEOLOGICAL SURVEY PUBLICATIONS ON GYPSUM, SALT, BORAX, AND SODA.

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——— Borax deposits of eastern California. In Bulletin No. 213. pp. 401–405. 1903.

Chatard, T. M. Salt-making processes in the United States. In Seventh Ann. Rept., pp. 491–535. 1888.

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Eckel, E. C. Salt and gypsum deposits of southwestern Virginia. In Bulletin No. 213. pp. 406–416. 1903.

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SULPHUR, PYRITE, AND ALUM.

The following paper, by Mr. G. I. Adams, contains a description of the sulphur mines of northwestern Nevada, and in this connection there is also presented a brief report by Mr. J. E. Spurr, on a deposit of sulphur and alum near Silver Peak, Nev.

THE RABBIT HOLE SULPHUR MINES NEAR HUMBOLDT HOUSE, NEV.

By George I. Adams.

Location of the mines.—The Rabbit Hole sulphur mines are in northwestern Nevada, at the western base of the Kamma Mountains, on the border of Black Rock Desert, about 35 miles northwest of Humboldt House, a station on the Southern Pacific Railroad, from which they may be reached by a wagon road having moderately easy grades. The mines derive their name from Rabbit Hole Springs, near which they are located.

Economic development.—The geology of this portion of Nevada is described in the reports of the Geological Exploration of the Fortieth Parallel, but at the time those reports were made the sulphur mines had not been developed. The sulphur deposit was discovered about thirty-five years ago by an Indian, who sold his claim for a horse and saddle, which he never received. It was first worked in 1874 in a small way. Mr. I. C. Russell visited the locality and described the occurrence of sulphur in the Transactions of the New York Academy of Sciences for 1882 (p. 173). He reported that at that time the mines were producing about 6 tons of sulphur a day. They are now worked by the Nevada Sulphur Company, of San Francisco, which assumed control of them in 1900. The equipment consists of two retorts, which receive about 2½ tons at each charge.

The rock containing the sulphur is assorted at the mines and pits, and at the mill is dumped over a "grizzly," from which it goes into the retorts. After the retorts are charged, they are closed, and live steam is turned into them at a pressure of about 70 pounds to the square inch, but as the sulphur melts the pressure is decreased somewhat—to about 60 or even 50 pounds. The melted sulphur sinks through a grate into the kettle-like bottom of the retort. From the retort it is drawn off into a settling pan, in which it is kept at a temperature sufficiently high to maintain it in a liquid condition. From the settling pan the sulphur is run into cast-iron molds, which have a capacity of about 250 pounds each, and are in the form of a frustum of a cone. In these molds the sulphur is allowed to stand from thirty-six to forty-eight hours. When it is cooled the sulphur is dumped out and broken up into small pieces. It is then put through a crusher, which reduces it to what is called pea size. The sulphur is placed on the market in this form in sacks containing 100 pounds, or it is ground by buhrstones to flour sulphur and put up into sacks containing 110 pounds.

In this region the question of fuel is important. The use of coal would necessitate its transportation from a long distance. Fortunately, however, on some of the mountains in the neighborhood of the mines there is a sufficient growth of wood to supply fuel as well as timbers for the mines.

Geology of the region.—The writer attempted an examination of only the region immediately near the sulphur mines. His route of travel to them was from Mill City, the first station northeast of Humboldt House, along the wagon road from this place which joins the one from Humboldt House in the valley of Humboldt River. As is commonly the case in this portion of Nevada, the country presents two types of topography—desert valleys and barren mountain ranges. Humboldt River usually has but small volume where it is crossed. It is bordered by a sagebrush desert about 10 miles wide. The mountains west of the river in the vicinity of Humboldt House are known as the Montezuma Range. The wagon road crosses a low divide in them and descends into a narrow valley, to the west of which are the Kamma Mountains, in which are the sulphur mines. The Kamma Mountains form a crescentic mass, the curve opening to the west. They are divided into three groups, which may be denominated the southwestern, middle, and northern groups. The wagon road over which the sulphur is hauled from the mines passes between the central and northern groups.

The rocks which constitute the northern group, as shown on the maps of the fortieth parallel, consist of a mass of rhyolite, forming the main mountains. Along their western border, on the lower slopes, there is an irregular area of water-laid deposits of Tertiary age. These Tertiary rocks, in which the sulphur deposits occur, consist of fragments of volcanics and beds of tuffs which in places have been largely altered since their deposition. These are regarded as part of the Truckee Miocene, which is found at numerous localities in that portion of Nevada. At the sulphur mines the rocks are very siliceous and are cemented by quartz and chalcedony, and in some instances carry globular masses of hyalite or are coated with a layer of that mineral, a transparent, glassy variety of opal or amorphous silica. There is little evidence of bedding in the sulphur pits and mines. The rocks have apparently been leached by hot waters, and the excavations are made in loose, siliceous material which has a harsh feeling and contains considerable pulverulent matter. At the mouth of a dry watercourse leading from the mines to the border of the desert the beds are stratified in regular nearly horizontal layers. The brecciated material is cemented into quartzite-like beds. In another watercourse, about half a mile southwest of the mines, there are exposures of variously colored beds of tuffs and crumbling material. Rocks of the same nature as those found at the sulphur mines occur in a belt running parallel with the border of the desert for a distance of 2 or 3 miles. Numerous pits that have been dug in the search for sulphur serve to expose the formation, which, on account of the large amount of detrital material on the slopes of the mountains, would otherwise be concealed.

Mode of occurrence of the sulphur.—The sulphur is obtained from open pits, tunnels, and underground chambers. In many cases the sulphur may be seen from the surface workings. In its more beautiful form it occurs as masses of crystals depending from the walls of irregular cavities and incrusting free surfaces. It has the beautiful yellow color of crystallized sulphur, with here and there a reddish tinge due to the occurrence of a small amount of cinnabar deposited on its surface. The most important mass of sulphur found is, however, of a different type. It is seen in large underground chambers, and has the appearance of a flow of molten sulphur which, welling up, has filled open channels in the rocks. It contains occasional fragments of rocks, but is remarkably pure. Its color is a dark resinous yellow.

Origin of the sulphur.—It is probable that the sulphur at the Rabbit Hole mines has been derived from a greath depth and deposited as a result of solfataric action. It may have had as its source a molten magma, from which it ascended in the form of vapor, and cooled in the fissures and interspaces of the rocks near the surface. Portions of the deposit appear to have flowed into channels and cavities in the rocks in liquid form.

Sulphur gases may have accompanied ascending waters. The condition of the country rock indicates that it has been subject to the action of thermal waters, since in certain places it has a leached appearance and in others it is cemented with siliceous material. The existence of hot springs in Nevada at the present time, and especially in former periods, is well known. Perhaps the most familiar hot springs locality is Steamboat Springs, where hot water is now issuing from a mass of siliceous sinter which has been built up by the springs. There are masses of siliceous sinter attesting the former action of hot waters at a number of places in northwestern Nevada, and just south of Humboldt House there are minor occurrences of sulphur in the craters of extinct hot springs. If a deposit of siliceous sinter was formed at the Rabbit Hole sulphur mines it has been removed by erosion. Evidence of the action of thermal springs may now be seen in the altered rocks through which the waters ascended.

Mr. Russell, in discussing the Rabbit Hole deposits, expressed the opinion that the mines lie along a fault, but no direct evidence of a fault at the locality can be found. Faulting, however, is common in the region, and the fracturing accompanying displacement would allow deep-seated waters and sulphurous gases to ascend. In this region, where volcanic activity has been so important, we may reasonably presume that it is the cause of the sulphur deposits. The escape of sulphurous gases may have been contemporaneous with the action of the springs or may have occurred subsequent to their activity.

Associated minerals.—In the cavities of the rock formations carrying sulphur deposits there is found a considerable amount of white pulverulent material, which on chemical examination proves to be alunite. This is a hydrous sulphate of aluminum and potash, a mineral which is thought to be formed in many cases by the reaction of sulphurous vapors on rocks, especially on feldspars that carry aluminum and potash. It usually occurs at places where solfataric action is known to have taken place, and the fact that alunite is found at the Rabbit Hole sulphur mines may be regarded as supplementary proof of the mode of origin of the sulphur. Alunite, when it occurs in sufficient quantities, may be used as the source of alum, its chemical composition being similar to kalinite, or native alum.

The occurrence of a small amount of cinnabar on the surfaces of the rocks and the sulphur has already been noted. This mineral, which is mercuric sulphide, is commonly formed by solfataric action, and its presence is an additional evidence of the mode of origin ascribed to the sulphur deposits.

Some crystals of gypsum were seen in the mines. This mineral, which is sulphate of lime, may be formed by the reaction of sulphuric acid on the calcareous material of the rocks, and it is probably of late origin.

Production.—The output of the Rabbit Hole sulphur mines is included in the statistics published in Mineral Resources of the United States for 1902 by the U. S. Geological Survey, in which the total production of the country is stated to be 8,336 short tons, valued at $220,560. This was all derived from Louisiana, Nevada, and Utah, named in the order of their importance. The output for that year is the largest yet recorded. The amount of sulphur imported during the year was 174,939 long tons, which shows that the percentage produced in the United States is but a small amount of the annual consumption. In spite of the disadvantage of location with respect to the market and the absence of duty on imported sulphur, the domestic industry promises to increase.

ALUM DEPOSIT NEAR SILVER PEAK, ESMERALDA COUNTY, NEV.

By J. E. Spurr.

Locality.—About 10 miles north of Silver Peak, Nevada, there lies, by the roadside, a deposit of alum and sulphur. This has been many times located and prospected as a sulphur mine, but not until recently has the relatively important amount of alum in it been recognized. No important work has yet been done on the deposit.

Mode of occurrence.—At the locality mentioned there is an elongated dike-like or neck-like mass of rhyolite, having all the appearance of being intrusive into gently folded white and red sedimentary rhyolitic tuffs of Tertiary age. In parts the rhyolite is easily recognizable as such; in other portions it is decomposed to a white powdery variety. This is especially true of two portions examined, about 600 feet apart; one some 200 feet in diameter, the other about 30 feet. The former, at the south end of the area, contains the chief alum and sulphur deposits. The latter contains sulphur, but no alum.

In the larger area the decomposed rhyolite shows sulphur throughout, coating all cracks and crevices, but generally not over a fraction of an inch thick. With the sulphur is closely associated pure alum, which has a different habit, forming veins, some of them several inches thick, that split and ramify irregularly throughout the broken masses of altered rhyolite. Analysis in the chemical laboratory of the United States Geological Survey shows it to be an ordinary potassium alum (kalinite). There are also occasional gypsum seams, of the same habit as the alum, but much less abundant. Bright-red stains are associated with the sulphur and alum, which were thought in the field possibly to be cinnabar. The small quantity represented by these spots is not suitable for chemical examination. During the past summer, however, Dr. George I. Adams has investigated the Rabbit Hole sulphur mine, in northern Nevada, near Humboldt House station, on the Southern Pacific Railway, where the geology appears to be not greatly different from that of the place being described, and has found there similar bright-red stains. Analysis of these shows them to be really cinnabar (sulphide of mercury), and there can be little question that the stains of the deposit near Silver Peak are of the same material.

The smaller area above noted, north of the principal deposit, shows sulphur in crevices, in moderately large, perfect crystals, nearly or quite isolated.

When exposed to the air the alum rapidly dehydrates and crumbles to a white powder, so that it is not conspicuous in the outcrop, and the real amount of it present is visible only when it has been freshly taken out.

Manner of formation.—These areas are evidently pipes or chimneys through which sulphurous volcanic gases have ascended. Since the rhyolite bodies are probably intrusive, the gases seem to have directly followed the intrusion. This action is familiar around recently active volcanoes, and is called solfataric action, from the fact that sulphur (Italian *solfo*) is deposited by it. For this reason the volcanoes of Italy, Mexico, and other places yield a large amount of the world's sulphur. The formation of alum by the escaping steam and gases of these solfataras is also known to occur in many localities. While the sulphur is a direct sublimate from the sulphurous gases, as its occurrence just described in the Silver Peak deposits indicates, the alum, which is a hydrous sulphate of aluminum and potassium, is formed by a combination of the steam and the sulphuric acid emitted from the solfataras with the potash and aluminum contained in the rhyolite. This combination is rendered possible by a preliminary decomposition of the rhyolite by the escaping gases. The presence of cinnabar is also interesting, since this mineral is one of those which has been found as a sublimate on the walls of crevices in volcanoes, as, for example, at Vesuvius, where it has been deposited by jets of escaping gases. The deposit of cinnabar at Steamboat Springs, some distance north of here and just north of Carson, is also significant.

Commercial aspects.—Though the alum in these prospects is present in far larger quantity than the sulphur, it is somewhat more localized. It forms an irregular network of veinlets, and yet from the manner of formation the chimney undoubtedly continues downward. The decomposed rhyolite is so friable that the material could easily be worked on a large scale. The rhyolite itself, in the alum locality, has been found by analysis to contain a large percentage of alum. The whole deposit, therefore, would have to be worked together, and the sulphur could also be collected as a by-product.

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PUBLICATIONS ON PHOSPHATES AND OTHER FERTILIZERS.

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MISCELLANEOUS NONMETALLIC PRODUCTS.

FLUORSPAR DEPOSITS OF SOUTHERN ILLINOIS.

By H. Foster Bain.

INTRODUCTION.

Location.—The fluorspar mines which are the subject of this sketch occur in Pope and Hardin counties, in the extreme southern portion of Illinois. The principal mines are near Rosiclare, Elizabethtown, and Cave in Rock, small towns on the Ohio River, in Hardin County. An important group of prospects is located in the northwest part of Hardin County and the northeast part of Pope County, and there are minor occurrences at various other points in these counties, as well as in Saline and Johnson counties. The area forms the northern part of the Kentucky-Illinois district, the southern part of which has been described by E. O. Ulrich and W. S. Tangier Smith.[a] The Illinois mines have been briefly described in the State survey reports[b] and by S. F. Emmons, who some years since spent a few days in the area.[c]

History of development.—The Illinois mines were first developed in 1842, and were for many years worked intermittently for lead. At a later period the dumps which had accumulated in the course of the lead mining were reworked for fluorspar, and still more recently mining has been directed mainly to the production of the latter mineral. For many years the Rosiclare mine was almost the only producer, the Empire, Fairview, and others being idle much of the time. The rise in the price of zinc in 1899 attracted attention to the district, since zinc ores occur sparingly in it. A great deal of prospecting has since been carried on in the hope of finding bodies of that mineral. The general failure to find important deposits of zinc ore on the north side of the river has directed renewed attention to the fluor spar, and a determined effort is now being made to enlarge the market for this product.

[a] Contributions to economic geology, 1902: Bull. U. S. Geol. Survey No. 213, 1903, pp. 205-213.
[b] Geol. Survey Illinois, vol. 1, 1866, pp. 350-375.
[c] Trans. Am. Inst. Min. Eng., vol. 21, pp. 31-53, 1893.

Economic importance.—The Kentucky-Illinois district is not only the main American source of fluorspar, but is the only one from which it reaches the general market. Since 1882 the district has produced 218,135 tons of spar, of a total value of $1,309,469. There are no data for determining the production of the Illinois mines separately, but since 1899 the production has been about equal from the two States. Before that date it is probable that considerably more than half the output came from the north side of the Ohio.

The spar is shipped in part by the Illinois Central Railway and in part on the Ohio River. Prices are fixed by Pittsburg quotations, less freight and commissions. At Pittsburg the American spar comes into competition with English and German material imported through New York. The American mines supply the Western trade and about half of the Pittsburg demand. The importers control the Eastern trade and determine prices at Pittsburg.

There are three main uses for fluorspar. The highest grade, running less than 1 per cent of silica, and white in color, is sold either ground or in lump, for use in the enameling, chemical, and glass trades. It brings the highest price, recent New York quotations being $8 to $10 a ton unground and $11.50 to $13.50 ground. The price at the Western mines is about a dollar less per ton than the New York price, to offset differences in freight rates to competing territory. There is a limited market for this grade of spar, and it probably would not be extended much even at lower prices, since the amount used is determined by conditions wholly outside the cost of the spar.

The second grade of spar is used in steel making, and is sold unground as lump or gravel. It includes colored spar and may run as high as 4 per cent silica, though mostly sold with a 3 per cent guaranty. It is demanded for open-hearth work because of the great fluidity which it gives the slag. At present about 20,000 tons are used annually in this work, at a cost to the user of from $6 to $8 per ton. Importers have now a slight advantage in the Pittsburg market on this grade of ore. It is probable that if a steady supply of fluorspar at the present or slightly lower prices can be guaranteed in steel making centers, the market can rapidly be expanded.

The lowest grade of spar, including all running over 4 per cent silica, or spar mixed with calcite, can be used in foundry work, and while the price is and always must be low, there is possible an almost unlimited market. It is probable that systematic efforts to introduce the low-grade material into this trade would be highly beneficial to the industry as a whole. While there would be little profit in mining foundry spar, it would allow the production of No. 2 spar in quantity and at prices demanded by steel makers. With the exhaustion of bessemer grades of iron, there will be an increased demand for fluorspar, though even now demand is ahead of supply for steel-making grades, remembering always that at any increase in prices it becomes cheaper to use less efficient fluxes. It follows that while the output can be increased, prices probably can not be much changed.

With these facts in mind it is seen that the fluorspar mines of the Kentucky-Illinois district will have for many years an important and growing market to supply. Their only competitors are the importers, and competition with them is mainly a matter of transportation costs. Mines in the Rocky Mountain region and other Western States can not be expected to disturb the fluorspar market. Such fluorspar as occurs in connection with the ores of that region will probably always have a sufficient local market. The quantity present is not important in any western district yet described, and local smelters make an allowance for lime which, entirely aside from the cost of transportation, is likely to prevent shipments of spar to the east.

GEOLOGY OF THE DISTRICT.

General statement.—The geology of the Kentucky portion of the district was studied in 1889 and 1890, and again in 1902 by Mr. Ulrich. In 1903 the Illinois area was studied by the writer, in cooperation with Mr. Ulrich and with the assistance of Mr. A. F. Crider. A report is now in preparation. The formations on the two sides of the river are equivalent, except that in Illinois certain lower beds come to the surface and there is apparently a slightly greater variety in the igneous rocks.

Sedimentary deposits.—The section as made out by Mr. Ulrich from a study of the Kentucky area, consists of the following formations: At the top is the coarse sandstone and conglomerate forming the base of the coal measures of the Pennsylvanian series. Next below it are the sandstones, shales, and limestones, together forming the Chester group, and having a total thickness of about 700 feet. Underlying the Chester is what was called the Princeton limestone,[a] but to which the name Ste. Genevieve is now applied. This is 200 to 250 feet thick, the lower two-thirds oolitic, and the upper somewhat shaly. It in turn rests on the well-known St. Louis limestone, which, in the area under consideration, is very commonly cherty.

In the northwestern portion of Hardin County, Ill., there is a small structural dome which brings up beds below the St. Louis. The first to appear from below the latter is a siliceous limestone, somewhat similar in general appearance to the St. Louis, but gradually changing toward the base into sandy shales. This was recognized by Mr. Ulrich as the equivalent of the Tullahoma formation of central Tennessee. It occupies the position in the general section filled by the Keokuk, Burlington, and Kinderhook formations, farther north. Below it is the black shale of the Chattanooga formation, the well-known Devonian

[a] Bull. U. S. Geol. Survey No. 213, 1903, p. 207.

slate of the interior. As exposed in Hardin County, this formation is at least 100 feet thick. There are no opportunities to determine either the total thickness of the formation or the nature of the beds below it.

Igneous rocks.—In both Pope and Hardin counties there are several dikes of dark-colored, holocrystalline, igneous material. For the most part they are mica-peridotite, similar to that described by J. S. Diller,[a] from the adjacent portion of Kentucky. In the high hill known as Downeys Bluff, at Rosiclare, there is a dike and a small intrusive sheet of rock consisting mainly of biotite, augite, and magnetite, and probably somewhat different from the mica-peridotite. Pieces of ordinary diabase, said to have been encountered in sinking a well in Rosiclare, possibly represent another dike. Certain other much-altered igneous rocks occur in the district, but these have not yet been studied in sufficient detail to determine their nature. In all, seven different dikes have so far been located—two in Pope and five in Hardin counties. Their intrusion was not marked by any notable metamorphism of the surrounding rocks.

Geological structure.—In a broad way the district represents a truncated dome, circled to the north and east by an escarpment formed by the basal formation of the coal measures of the Pennsylvanian series, and cut off on the west by the Mesozoic and Tertiary deposits of the Mississippi embayment. The central portion of the dome consists in the main of the rocks of the Mississippian series. Involved with them are certain fault blocks of Pennsylvanian, and the small area, previously noted, of Devonian shales. The whole dome, up to the bounding escarpment, has been planed down to a moderately smooth plain now forming the upland, and passing at its western edge under a deposit of gravels, probably of Tertiary age.

The area is one within which there are a very large number of faults. These are, so far as has been observed, normal, and follow a great variety of directions. The fault planes divide the area into a series of very irregular but always sharp-sided polygons. The amount of faulting varies from a few inches to 600 feet and perhaps more. Individual fault planes may be traced a mile or more, and lines or zones along which faulting has occurred may be traced several times as far. There is little, if any, folding present. The small dome in which the Devonian shale outcrops is itself bounded by normal fault planes, and the bending seems to be incidental to the more important phenomena of fracturing. The region is seemingly one in which vertical uplift has been more important than horizontal compression. The dikes occupy crevices along which, so far as observation goes, there has been no faulting. There are in Illinois no conclusive data as to the relations of the intrusion to the faulting, though the sill found in Downey's Bluff is apparently cut off to the north by a fault. If this interpretation be

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[a] Am. Jour. Sci., 3d series, vol. 44, 1892, p. 288.

correct, the intrusion is older than some of the faulting, and it seems not unlikely that the two were approximately contemporaneous, and occurred somewhere after the close of the Carboniferous and before the formation of the presumably Tertiary peneplain.

THE ORE DEPOSITS.

Character of the ores.—The ores are essentially made up of fluorspar, with calcite as the most abundant gangue mineral. Associated with these are subordinate amounts of lead and zinc sulphides, of stibnite, and possibly other sulphides, barium sulphate, and occasional traces of copper. In the same area are iron deposits (limonite) of some size, but not at present of commercial importance. Fluorspar is the most abundant mineral, and is the only ore now shipped in quantity. The lead occurs as galena intimately associated with the fluorspar, and its production is incidental to the preparation of the spar for the market. In contrast with the galena found elsewhere in the Mississippi Valley, this is argentiferous, seemingly reliable assays indicating the constant presence of silver running up to 9 ounces to the ton. Gold has also been reported to have been found, though not with the same degree of reliability. These facts, with the occasional occurrence of stibnite, are of considerable importance in indicating for the ores of the district a different genesis from that of the other lead and zinc ores of the Mississippi Valley.

Form of the ore bodies.—The ore bodies are of the type known as fissure veins, tabular deposits filling fissures. Together with the process of fissure filling there has been considerable replacement of the country rock, and this in places gives irregular form to the ore bodies. As a general thing, however, the veins are tabular bodies of ore having marked longitudinal direction, occurring in vertical position or cutting across the strata at high angles. They usually occupy fault planes, though the faulting is not in every case of great amount. The largest ore bodies so far developed have been found along or near fault planes which have brought sandstone and limestone into contact. In these cases the limestone near the ore body is usually recrystallized as calcite and the sandstone has been indurated to a quartzite. A very common phenomenon is fissuring parallel to the vein, particularly in the sandstone. The result of the processes of fissuring and induration is the production of hard quartzite ridges, dike like in form, traversing the country parallel to the vein. They are the most common and most reliable of the indications followed by the prospector.

Size of the ore bodies.—The ore bodies are of rather unusual size. In the Fairview and Rosiclare mines a continuous body of ore has been worked for a distance of nearly a mile. The workings now extend to a depth of 300 feet and stopes 12 to 20 feet wide have been the rule rather than the exception in the ground so far mined. Since only the clearest fluorspar can be mined, the total size of the zone of mineralization is much larger. In one case a thickness of 14 feet of calcite mingled with some fluorspar is known to be present in the foot wall. None of the other mines in Illinois has yet been developed enough to warrant a statement as to the size of the ore body, but several show at the present stage well-defined veins of mineral of a thickness of 4 to 6 feet.

Genesis of the ores.—Studies of the genesis of the ores are now being made, but are not yet complete. There are two broadly contrasted hypotheses: (1) Since the lead and zinc deposits of the Mississippi Valley have been shown by repeated investigations to represent segregations from the surrounding rock produced by the action of ordinary underground waters, these deposits, which carry some lead and some zinc, have been held to belong to the same category; (2) the presence in quantity of minerals either entirely absent or only found under exceptional conditions in the Mississippi Valley, the structural features of the ore bodies, not found elsewhere in the ores of the valley, and the presence of igneous rocks in the vicinity, have suggested a genetic relation between the ores and the igneous rocks.

In this connection it is to be noted that the eruptives occurring here are of the same type as those found in connection with the great fluorspar deposits of the north of England, and that the two districts include the largest known bodies of fluorspar. In the second place, microscopic examination shows the presence in the igneous rocks of unusual quantities of apatite, an undoubtedly primary constituent, which might have afforded the fluorine necessary to the formation of these ores. No attempt will be made at this place to determine finally between the two hypotheses advanced, but it may be stated that in the author's opinion the latter is probably correct in so far as a general genetic relationship between the ores and the igneous rocks is postulated. It is not intended to convey the idea that each ore body is related to a particular dike. There is strong field evidence against this, but the widespread presence of the dikes, together with the structural features mentioned, indicate in his judgment the derivation of the material from some mass of igneous rock beneath the surface yet within reach of underground waters and contributing to them.

Future production.—The opinion just given as to the genesis of the ores indicates the belief of the author that they will prove permanent in depth to horizons below which they can not be worked because of increasing cost. The low value of the ore places a somewhat severe limitation upon the future depth of mining, and it is possible that this feature alone will in most situations preclude work to depth greater than 1,000 feet. It is also possible that changes in the character of the country rock may influence disastrously the size and character of the ore bodies. It has been impossible to get any data on the character of the rock which occurs in this area beneath the Chattanooga shale. Normally a considerable thickness of dolomites and limestones would be expected to be present, but they may be absent, and it would not be impossible that the supposed igneous mass should occur below the shale. In all the mines so far located in Illinois, the shale lies 500 to 1,000 feet or more below present workings.

There are no data at hand for predictions as to change in character and richness of the ores with depth. Changes in the country rock may be expected to have an important influence, and so far the Ste. Genevieve and Chester formations have proved most favorable. In the Illinois mines nothing suggesting rearrangement of the ores and secondary enrichment coincident with degradation of the surface was observed. The Fairview and Rosiclare mines are now working well below ground-water level, and neither increase or decrease in amount nor change in character of the sulphides with depth was observed. At the Empire mine carbonates gave place to sulphides within the first hundred feet, and below that level no change was observed.

In the Kentucky mines a number of deposits of first-grade fluorspar are said to have given out or lost grade with depth. The significance of this fact is uncertain. Whether it is to be correlated with change in wall rock, or indicates only the usual irregular distribution of ore in depth as well as along a vein, is not clear. In no case was development carried on to determine whether the ore would come in again at lower levels. If it be true that the diminution in size of the ore bodies was related to topography rather than stratigraphy, it can only be stated that the best obtainable evidence in Illinois does not warrant the belief that the rule is universal. The character and size of the ore bodies certainly do not bear any constant relation to the present land surface.

In the light of these facts and the wide prospecting which has been going on in the district, little encouragement is offered to the hope of finding important bodies of lead and zinc on the northern side of the river, but it is believed that the fluorspar deposits afford the basis for an important and growing industry.

GRAPHITE IN THE EASTERN ADIRONDACKS, N. Y.

By J. F. Kemp.

General remarks.—Graphite is now attracting much interest in the region of Lake George and southern Lake Champlain, New York, and as important observations have been made in connection with the field work for a folio now in preparation, a brief sketch of the deposits is here given.

In this region graphite occurs solely in Algonkian strata. The deposits are found in four kinds of rock: (1) Pegmatite veins, (2) veinlets of graphite, (3) quartzites, (4) crystalline limestones with associated gneissoid strata. All four have been, or are, the objects of serious mining.

1. *Pegmatite veins.*—In the pegmatites the graphite is coarsely crystalline and in its outcrops it creates the impression of great richness, but it is difficult to find enough to make an extended opening a probable source of profit. Not a few prospects have attracted attention, but the pockety and uncertain nature of the deposits has made all attempts to work them practical failures except at the old and now abandoned workings on Chilson Hill, Ticonderoga, details concerning which will be given below.

The pegmatites contain coarse bunches of the mineral which can be cobbed down by hand and do not demand mechanical concentration to the extent needed by the quartzites or limestones. At the same time when one compares their possible yield with the tonnage demanded by the mills working on the quartzite, it is at once realized that in most cases they would be exhausted in a very short time.

In the pegmatites the graphite is more especially associated with quartz, but it is also involved with feldspar, pyroxene, hornblende, mica, calcite, scapolite, apatite, sphene, and other less common minerals.

2. *Veinlets of graphite.*—In a few places, as at Split Rock, near Essex, on Lake Champlain, narrow veins or veinlets of graphite have been found crossing the gneisses, and filling fissures up to an inch in width. The graphite is in rather coarse leaves, and stands at an angle, somewhat less than a right angle, to the wall rock. Considerable vein quartz is mingled with it, and it is not so pure as one would

infer at first sight. A large deposit of this sort would be the richest and most desirable of all, but veins have not yet been found crossing the gneisses in sufficient abundance to justify mining.

3. *Graphitic quartzites.*—The deposits of this type are much the most persistent and reliable of all. They form regularly stratified members of the sedimentary series, and in the two cases near Hague, where they have been mined, they are associated with garnetiferous sillimanite-gneiss, a very interesting type of rock. The quartzites are rather feldspathic as quartzites go, but nevertheless exhibit all the characteristics of fragmental rocks. There is a little pyrite associated with the graphite, and from the tailings of the mills some interesting concentrates of heavy minerals can be obtained by panning. The graphite appears in scales of various fineness interleaving the fragmental minerals of the quartzite. It is never so coarse as in the pegmatites and veins, but its quantity is much greater. In actual amount it varies from 5 to 15 per cent of the rock as roughly estimated. It often shows slickensides and evidence of rubbing, caused by the movement of the individual beds of the quartzite upon one another as the result of compression. The beds, too, pinch and swell more or less, and while their dip is flat they have evidently passed through severe dynamic processes.

The quartzites which are used in the two mills at Hague are differently treated. In the more westerly mill, at Graphite, they are concentrated by a wet process, being first stamped in California drop stamps and then washed in buddles to a state of considerable purity. The final process of concentration is, however, kept secret. In the Lakeside mill at Hague the rock is crushed without water and then carefully dried to remove all moisture. The concentration is then performed by Hooper air jigs.

The whole problem of the concentration of the graphite is in great contrast to that of metallic ores, in that in the former case we seek to save the light mineral and reject the heavy, while in the latter case the reverse is true. Graphite has a specific gravity of only 2.25–2.27, and its scaly nature makes it very prone to float in moving water. One mineral which would furnish a great drawback in the treatment of a graphitic quartzite is mica. Although it has a higher specific gravity, its scaly nature would make it remain in suspension and occasion great difficulty.

The graphitic quartzites have thus far been discovered chiefly in the town of Hague, on the western side of Lake George, and in the towns of Dresden and Whitehall on both sides of South Bay, Lake Champlain. Indications and poorly exposed outcrops have also been observed in the mountains west of Silver Bay, Lake George, and on the east side of the lake as well. The rocks also occur along Lake Champlain south of the village of Putnam.

There is no doubt that the quartzites form a definite member of the metamorphosed sediments in this general area, but the region is so badly broken by faults and the outcrops are so often buried in the woods that it is impossible to say whether the quartzite appears at one or more horizons. In its original and unmetamorphosed condition it was probably a very bituminous shale. By the metamorphism of such a deposit the abundant feldspar might easily have resulted and the graphite have been produced.

4. *Graphite in the crystalline limestones.*—The Algonkian strata of the Adirondacks contain many lenticular beds of limestone, which vary from a maximum of about 100 feet thick down to a few inches. They are now coarsely crystalline aggregates of calcite or dolomite, often with richly disseminated crystals of pyroxene, and not infrequently with scales of graphite more or less abundantly scattered through the mass. The crystalline limestones have never been utilized as a commercial source of the mineral, but they have certain advantages of their own and are worthy of serious consideration. The limestone is a soft rock, easily crushed, and in separation would free itself from the graphite. The presence of the mica (phlogopite) should be considered, since it also is found in the limestones and would present difficulties in the separation. The limestones also have irregular bunches of coarsely crystalline silicates scattered through them, in which large scales of graphite are common. The graphite even presents good hexagonal outlines, each an inch in diameter.

The mineral graphite is extremely useful and of increasing importance as time goes on. It often passes by the name of plumbago, or "black lead." A "lead mine" in the usage of the eastern Adirondacks means a graphite mine.

In the trade the quality of the mineral depends partly on the size of the scales, and partly on its adaptability for crucibles. If the size of the scales is small the price falls and the difficulties of concentration are increased.

Contrary to the general impression only a very small part of the graphite produced goes into lead pencils, and practically all of this is obtained from Sonora, Mexico. Crucibles for the manufacture of crucible steel take perhaps most of the product, and not every graphite can be used for them. The remainder is used as lubricants, stove polish, paints, and a few other purposes.

BARITE IN SOUTHERN PENNSYLVANIA AND PURE LIMESTONE IN BERKELEY COUNTY, W. VA.

By George W. Stose.

Scattered deposits of barite occur on the eastern side of the Cumberland Valley in southern Pennsylvania, in the vicinity of Waynesboro. The lower Cambrian quartzite, forming the South Mountain to the east, dips beneath the limestone series of the valley, which is here divisible into three formations. The lower 2,000 ± feet consists of dark-gray and mottled, massive limestone, in part siliceous, with purple shale and thin sandstone, bearing lower Cambrian fossils at the top; the middle 2,000 ± feet consists of light-gray, siliceous, massive, and thin-bedded, dolomitic limestone, almost barren of fossils, with calcareous sandstone and cherty beds at the top; and the upper 1,500 ± feet is composed of light-gray dolomitic limestone with numerous thin, cherty bands, containing a fauna of upper Cambrian age, grading up into pure limestones, in part crystalline, becoming carbonaceous and shaly at the top and containing Trenton fossils. To the west this is overlain by the Hudson shale.

The region is extensively folded. In general the mountains strike northeast-southwest and the valley structures are parallel, but in the vicinity of Waynesboro there are local pitching folds, which cause the mountain to be offset into the valley. East of the town the quartzite mountain is cut off abruptly by a fault, and the front of the mountains offset to the east several miles. Northeast of the town there is a syncline and a plunging anticline, giving rise to two right-angle bends in the mountain. The valley rocks follow these sinuosities only in an accentuated form. The sandstone at the top of the lower division of the limestone forms a ridge, which parallels the mountain at a distance of about 1½ miles. About 5 miles north of Waynesboro there is another sharp fold in the limestone. These folds have important relations to the deposits.

The barite is associated with the limestones and sandy layers of the lower division of the limestone series, and is usually found in the red-clay residuum. Such deposits are discovered in plowing, and after the available material has been removed the hole is filled and farmed over. Several tons have been shipped from each of the openings which were visited, but no extensive deposits were seen. In the residual deposits the masses average 6 to 8 inches in diameter, are rough in outline bearing casts of dissolved angular fragments of limestone, and are considerably weathered. Two of the openings visited are in bed rock. Here the barite is chiefly massive, banded, subcrystalline or granular, and milky, resembling chert, but is in part clear and crystalline. It occurs as a vein filling in the brecciated limestone. Such deposits are not profitable, as the ore must be crushed and separated from the rock; consequently they have been but little developed.

The deposits occur in the folded and brecciated portions of the limestone, and, in one case at least, in the arch of a plunging anticline associated with the hard sandstone at the top of the lower division, a favorable position for the brecciation of the limestone. Barite was deposited in the crevices of the breccia and has cemented it together. Being restricted in occurrence to the upper part of the lower division of the limestone series, the deposit, it appears, is due to local segregation of disseminated barite from the adjacent limestone. Vein quartz with comb structure, which occurs frequently in strata just below this horizon, also seems to be due to local segregation.

The barite deposits visited are as follows: Snowbarger's prospect, vein deposit top of hill 2 miles northeast of Waynesboro; Trimp Riley's deposit on the northern slope of the same hill, probably derived from the former vein; Bonebrake's deposit, 3½ miles east of town; and two openings by Mr. Stamey, 4½ miles north of town—one a vein, the other an associated residuum deposit.

In the same general region, but on the west side of Cumberland Valley, very pure limestone beds occur in the top of the Cambro-Ordovician limestone series. No great thickness of this pure limestone was observed in this immediate region, but southward along the same belt at Martinsburg, W. Va., this limestone is exceptionally pure and very thick. It has been quarried there on a vast scale by the Standard Lime and Stone Company for use as flux in the iron furnaces about Pittsburg.

The limestone outcrops in a belt extending southward from the town. On the east side is a low ridge of Hudson shale containing graptolites of Utica age near the base. Dipping at an angle of 20 degrees under these beds are 90 feet of dark, compact, crystalline and shaly limestones bearing fossils of Trenton age. Below this are three or four heavy beds of pure limestone averaging 15 to 20 feet in thickness, with a total of about 80 feet. This is the deposit that is quarried. The upper bed is a very massive, compact, light-gray limestone, weathering chalky white on the surface, with smooth fracture and but slight indications of bedding. The lower beds are darker, coarser grained, not so homogeneous, and have a rough fracture, and at the base are thinner bedded. The only fossils observed in these beds are a few *Leperditia* found in the upper layers, indicating Lowville (Birdseye) age.

The whole of this mass is quarried, and is stated to average 98 per cent carbonate of lime. The two samples tested by the Geological Survey contained 96.2 and 97 7 per cent. The limestone is quarried in an open cut 200 to 250 feet wide and 80 to 100 feet deep, the workable depth depending upon the amount of stripping that is profitable. The open cut extends for over 1½ miles along the strike and is being worked along its entire length. The same beds apparently continue beyond, to the south, and there is every reason to believe that they also occur along the strike north of the town. The rock is taken out on tram cars, is crushed to 5-inch size, and is loaded directly into the railway cars on the track. The reason that the stone can be profitably shipped such a distance is that the cars which transport the coal from the Pennsylvania mines to the south return loaded with limestone, thus avoiding an empty return run and the freight rates are reduced to a minimum. It is reported that from 20 to 50 carloads a day of the crushed rock are shipped. With a quarry face of 80 feet and the dip of the rocks 20 degrees, the estimated output of the quarry per mile is about 3,000,000 tons.

PUBLICATIONS ON MICA, GRAPHITE, ABRASIVE MATERIALS, ETC.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various nonmetalliferous mineral products not treated separately in the present bulletin:

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FULLER, M. L. Crushed quartz and its source. In Stone, vol. 18, pp. 1–4. 1898.

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