CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1907, PART I.

C. W. HAYES AND WALDEMAR LINDGREN, *Geologists in charge.*

INTRODUCTION.

By C. W. HAYES, *Chief geologist.*

This bulletin is the sixth of a series, including Bulletins Nos. 213, 225, 260, 285, and 315, Contributions to Economic Geology for 1902, 1903, 1904, 1905, and 1906, respectively. These bulletins are prepared primarily with a view to securing prompt publication of the economic results of investigations made 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. By means of the bibliographies accompanying the several groups of papers they also serve as a guide to the economic publications, and 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 final reports.

The first two bulletins of this series included numerous papers relating to the economic geology of Alaska. In view of the rapid increase of economic work, both in Alaska and in the States, and the organization of a division of Alaskan mineral resources distinct from the division of geology, it was in 1905 considered advisable to exclude all papers relating to Alaska. These were brought together in a separate volume entitled "Report of progress of investigations of mineral resources of Alaska in 1904," Bulletin No. 259. A similar segregation of papers relating to Alaska was made in 1905 and 1906 (Bulletins Nos. 284 and 314), and will be made this year.

During 1906 a further change in the arrangement of the economic bulletin seemed desirable. The former section of iron ores and nonmetallic minerals was divided and M. R. Campbell was placed in charge of a new section devoted to the investigation of fuels. This change in Survey organization was used as a basis for a separation of the economic bulletin, based on subjects. The present bulletin is therefore restricted to the work of the Survey in 1907 in the metals, structural materials, and other nonmetals except coal. A separate bulletin will be issued later relating to Survey work on coal, lignite, and peat.

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.

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 serviceable to 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.

Material assistance in the preparation of this volume has been rendered by W. C. Phalen, and to him is largely due the promptness of its publication.

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.*—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, has been substituted.

2. *Bulletins.*—The bulletins of the Survey comprise a series of paper-covered octavo volumes, each containing usually 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.*—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 are the bulletins.

4. *Monographs.*—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.*—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 in some cases 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 complete lists of these folios, showing the locations of the quadrangle 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 since January 1, 1907, and in an advanced state of preparation, also the economic products discussed in the text of each, the products of greatest importance being printed in italic:

List of geologic folios issued since January 1, 1907, showing mineral resources described.

No.	Name of folio.	State.	Area in square miles.	Author.	Mineral products described as occurring in area of folio.
143	Nantahala	N. C.-Tenn	975	Keith, A	*Marble*, *talc*, kaolin, soapstone, mica, corundum, iron, gold.
144	Amity	Pa	228	Clapp, F. G	*Coal*, *oil*, *gas*, limestone, shale, sandstone.
145	Lancaster-Mineral Point.	Wis.-Iowa-Ill.	1,756	Grant, U. S.; Burchard, E. F.	*Zinc*, *lead*, cement, building stone, glass sand, clay.
146	Rogersville	Pa	229	Clapp, F. G	*Oil*, *gas*, coal, limestone, sandstone.

List of geologic folios issued since January 1, 1907, etc.—Continued.

No.	Name of folio.	State.	Area in square miles.	Author.	Mineral products described as occurring in area of folio.
147	Pisgah	N. C.-S. C		Keith, A	*Mica, corundum, soapstone,* talc, kaolin, gold, graphite, copper, building stone, lime, clay.
148	Joplin district	Mo.-Kans	476	Smith, W. S. T.; Siebenthal, C. E.	*Zinc, lead,* lime, barite, coal, bitumen, oil, building stone, clay, underground water.
149	Penobscot Bay	Me	857	Smith, G. O.; Bastin, E. S.; Brown, C. W.	*Granite,* limestone, building stone, copper, clay.
150	Devils Tower	Wyo	849	Darton, N. H.; O'Harra, C. C.	Coal, building stone, clay, gypsum, *underground water.*
151	Roan Mountain	Tenn.-N. C	963	Keith, A	*Iron, mica,* lime, talc, soapstone, building stone, road material, clay.
152	Patuxent	Md.-D. C	932	Shattuck, G. B.; Miller, B. L.	Clay, sand, gravel, *building stone,* marl, *diatomaceous earth, underground water.*
153	Ouray	Colo	236	Cross, W.; Howe, E.; Irving, J. D.	*Silver, gold,* building stone, lime.
154	Winslow	Ark	969	Purdue, A. H.; Adams, G. I.	Lime, clay, coal, underground water.
155	Ann Arbor	Mich	885	Russell, I. C.; Leverett, F.	Road material, building stone, clay, *cement material,* marl, peat, *underground water.*
156	Elk Point	S.Dak.-Nebr.-Iowa.	878	Todd, J. E	Clay, sand, gravel, cement material, volcanic ash, lignite, *underground water.*
157	Passaic	N. J.-N. Y	906	Darton, N. H.; Bayley, W. S.; Salisbury, R. D.; Kümmel, H. B.	*Iron,* building stone, road material, *pottery clay,* brick clay, graphite, peat, underground water.
158	Rockland	Me	215	Bastin, E. S	*Lime, granite, clay,* peat, road material, gravel, underground water.

List of geologic folios in preparation.

Name of folio.	State.	Area in square miles.	Author.	Mineral products described as occurring in area of folio.
Aberdeen-Redfield	S. Dak	3,383	Todd, J. E	Lignite, clay, sand, gravel, salt, gas, *underground water.*
Accident-Grantsville	Md.-Pa.-W. Va.	460	Martin, G. C	*Coal,* fire clay, lime, building stone, road material.
Bellefourche	S. Dak	849	O'Harra, C. C.; Darton, N. H.	Gypsum, lime, clay, building stone, bentonite, *underground water.*
El Paso	Tex	889	Richardson, G. B	Tin, *clay, cement,* flux, lime, sand, gravel, *underground water.*
Franklin Furnace	N. J	226	Wolff, J. E.; Spencer, A. C.; Palache, Charles; Salisbury, R. D.; Kümmel, H. B.	*Lime, flux,* road material, graphite, *iron, zinc,* manganese, building stone.
Independence	Kans	950	Schrader, F. C	*Oil, gas,* coal, building stone, road material, lime, glass sand, *cement material,* clay, underground water.

List of geologic folios in preparation—Continued.

Name of folio.	State.	Area in square miles.	Author.	Mineral products described as occurring in area of folio.
Mercersburg-Chambersburg.	Pa	458	Stose, G. W	*Iron*, manganese, white clay, barite, *lime*, cement material, sand, clay, building stone, marble, road material, underground water.
Philadelphia	Pa.-N. J	915	Bascom, F.; Darton, N. H.; Clark, W. B.; Kümmel, H. B.; Salisbury, R. D.	Building stone, *road material*, *lime*, magnesium carbonate, soapstone, iron, gravel, sand, *pottery clay*, *feldspar*, *brick clay*, marl.
Santa Cruz	Cal	950	Branner, J. C.; Newsome, J. F.; Arnold, R.	Gold, *bituminous rock*, *petroleum*, building stone, road material, lime, cement material, diatomaceous shale, sand, underground water.
Trenton	N. J.-Pa	912	Bascom, F.; Darton, N. H.; Clark, W. B.; Kümmel, H. B.; Salisbury, R. D.	*Pottery clay*, brick clay, *molding sand*, building sand, gravel, *marl*, building stone, road material, lime, copper, barite.
Watkins Glen-Catatonk.	N. Y	1,770	Williams, H. S.; Tarr, R. S.; Kindle, E. M.	Sand, gravel, clay, underground water.

6. *Mineral Resources.*—From 1883 to 1894, inclusive, an octavo cloth-bound volume bearing the above title was issued annually, except that the reports for the years 1883–84 and 1889–90 were 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 thereafter the statistical 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 seven volumes of the new series, Mineral Resources of the United States for 1900, for 1901, for 1902, for 1903, for 1904, for 1905, and for 1906, 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 short papers on economic geology when these are necessary to account for the new developments.

INVESTIGATIONS RELATING TO NONMETALLIC MINERAL RESOURCES.

By C. W. Hayes, *Chief Geologist.*

PUBLICATIONS ISSUED AND IN PREPARATION.

During the year 1907 the following publications, consisting wholly or in part of the results of investigations on the nonmetallic mineral resources of the United States, were issued by the Survey. Publications relating to coal, lignite, peat, etc., except folios, are not included in this list.

Bulletins:

No. 279. Economic geology of the Kittanning and Rural Valley quadrangles, Pennsylvania, by Charles Butts.

No. 296. Economic geology of the Independence quadrangle, Kansas, by F. C. Schrader and E. Haworth.

No. 300. Economic geology of the Amity quadrangle, eastern Washington County, Pennsylvania, by F. G. Clapp.

No. 304. Oil and gas fields of Greene County, Pennsylvania, by R. W. Stone and F. G. Clapp.

No. 309. The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California, by G. H. Eldridge and Ralph Arnold.

No. 313. The granites of Maine, by T. Nelson Dale, with an introduction by George Otis Smith.

No. 317. Preliminary report on the Santa Maria oil district, Santa Barbara County, California, by Ralph Arnold and Robert Anderson.

No. 318. Geology of oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, West Virginia, and Pennsylvania, by W. T. Griswold and M. J. Munn.

No. 321. Geology and oil resources of the Summerland district, Santa Barbara County, California, by Ralph Arnold.

No. 322. Geology and oil resources of the Santa Maria oil district, Santa Barbara County, California, by Ralph Arnold and Robert Anderson.

No. 324. The San Francisco earthquake and fire of April 18, 1906, and their effects on structures and structural materials, by G. K. Gilbert, R. L. Humphrey, J. S. Sewell, and Frank Soulé.

The following folios are those in which nonmetallic products of considerable importance are described. The substances printed in italics are of most importance.

Folios.

No. 143. Nantahala (North Carolina-Tennessee), by A. Keith. *Marble, talc,* kaolin, soapstone, mica, corundum, iron.

No. 144. Amity (Pennsylvania), by F. G. Clapp. *Coal, oil, gas,* limestone, shale, sandstone.

No. 145. Lancaster-Mineral Point (Wisconsin-Iowa-Illinois), by U. S. Grant and E. F. Burchard. Cement, building stone, glass sand, clay.

No. 146. Rogersville (Pennsylvania), by F. G. Clapp. *Oil, gas,* coal, limestone, sandstone.

No. 147. Pisgah (North Carolina-South Carolina), by A. Keith. *Mica, corundum, soapstone,* talc, kaolin, graphite, building stone, lime, clay.

No. 148. Joplin district (Missouri-Kansas), by W. S. T. Smith and C. E. Siebenthal. Lime, barite, coal, bitumen, oil, building stone, clay, underground water.

No. 149. Penobscot Bay (Maine), by G. O. Smith, E. S. Bastin, and C. W. Brown. *Granite,* limestone, building stone, clay.

No. 150. Devils Tower (Wyoming), by N. H. Darton and C. C. O'Harra. Coal, building stone, clay, gypsum, *underground water.*

No. 151. Roan Mountain (North Carolina-Tennessee), by A. Keith. *Iron, mica,* lime, talc, soapstone, building stone, road material, clay.

No. 152. Patuxent (Maryland-District of Columbia), by G. B. Shattuck and B. L. Miller. Clay, sand, gravel, *building stone,* marl, *diatomaceous earth, underground water.*

No. 153. Ouray (Colorado), by W. Cross and E. Howe. Building stone, lime.

No. 154. Winslow (Arkansas), by A. H. Purdue and G. I. Adams. Lime, clay, coal, underground water.

No. 155. Ann Arbor (Michigan), by I. C. Russell and F. Leverett. Road material, building stone, clay, *cement material,* marl, peat, *underground water.*

No. 156. Elk Point (South Dakota-Nebraska-Iowa), by J. E. Todd. Clay, sand, gravel, cement material, volcanic ash, lignite, *underground water.*

No. 157. Passaic (New Jersey-New York), by N. H. Darton, W. S. Bayley, R. D. Salisbury, and H. B. Kümmel. *Iron,* building stone, road material, *pottery clay,* brick clay, graphite, peat, underground water.

No. 158. Rockland (Maine), by E. S. Bastin. *Lime, granite, clay,* peat, road material, gravel, underground water.

Reports for which the field work has been completed and which are in an advanced state of preparation are the following:

Iron.

The iron ores and iron industry of the Birmingham district, Alabama, by E. C. Eckel, E. F. Burchard, and Charles Butts.

The iron ores of the Iron Springs district, Utah, by C. K. Leith and E. C. Harder. (Bulletin No. 338.)

Magnetite deposits of the Cornwall type in Pennsylvania, by A. C. Spencer.

Petroleum and natural gas.

Geology and oil resources of the Coalinga district, California, by Ralph Arnold and Robert Anderson.

Systematic comparison of the crude petroleum in the United States, by D. T. Day.

Geology of the Rangely oil field, Rio Blanco County, Colorado, by Hoyt S. Gale. (Bulletin No. 350.)

Structure of the Berea oil sand in Flushing quadrangle, Harrison, Belmont, and Guernsey counties, Ohio, by W. T. Griswold. (Bulletin No. 346.)

Oil and gas in the Sewickley, Carnegie, and Clarion quadrangles, Pennsylvania, by M. J. Munn.

Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil, by A. C. Veatch. (Professional Paper No. 56.)

Building stones, road metal, etc.

The road materials of Maine, by E. S. Bastin.[a]

Commercially important granites of Massachusetts, New Hampshire, and Rhode Island, by T. Nelson Dale. (Bulletin No. 354.)

Commercially important granites of Vermont, by T. Nelson Dale.

Cement and concrete materials.

Concrete materials produced in the Chicago district, by E. F. Burchard.

The structural materials in the District of Columbia region, by N. H. Darton.

The structural materials in the vicinity of Portland, Oreg., and Seattle, Wash., by N. H. Darton.

Portland cement mortars and their constituent materials, by R. L. Humphrey. (Bulletin No. 331. Published in March, 1908.)

Clays.

The clays of Arkansas, by J. C. Branner. (Bulletin No. 351.)

Economic geology of the Kenova quadrangle, northeastern Kentucky, and adjacent portions of Ohio and West Virginia, by W. C. Phalen. (Coal, clay, iron ore, petroleum, and natural gas, etc.) (Bulletin No. 349.)

Gypsum and magnesite.

Gypsum deposits of California, by F. L. Hess.

Magnesite deposits of California, by F. L. Hess. (Bulletin No. 355.)

Miscellaneous.

The pegmatites of Maine, by E. S. Bastin.

The occurrence of diamonds in the United States and elsewhere, by G. F. Kunz.

FIELD WORK.

As in previous years, a large part of the work on nonmetalliferous minerals during 1907 was carried on in connection with other investigations, chiefly areal surveys. By reason of the character of these deposits they can not generally be studied with advantage in advance

[a] To be published by the Department of Agriculture.

of detailed topographic mapping, and their relations to the areal distribution of the rock formations are such that detailed areal geologic surveys are also generally necessary.

Iron, manganese, and aluminum ores.—The investigation of iron ores of the Cornwall type in eastern Pennsylvania has been completed by A. C. Spencer, and a report is in preparation which gives the relations of these ores to the associated rocks in detail and points out the directions in which prospecting may be carried on with the expectation of locating other ore bodies in addition to those now known. The directing of exploration to the most favorable localities, whether additional ore bodies are found or not, will certainly effect great economies in future prospecting.

The study of the iron ores of Georgia has been continued by W. C. Phalen in connection with areal work on the Ellijay and adjoining quadrangles. His conclusions regarding certain of these deposits are contained in a paper in this volume.

The developments in the Lake Superior district have been followed closely by C. R. Van Hise and his assistants. A report summarizing the several monographs already published and bringing information and conclusions regarding the relations of the iron ores down to date is in an advanced state of preparation.

A systematic examination is being made of the manganese ore deposits of the United States by E. C. Harder, and a comprehensive report covering all known deposits, whether at present productive or not, will be prepared. Information regarding these deposits is in considerable demand, as it is at present necessary to import a large portion of the manganese ore used in this country.

The producing bauxite localities in Alabama, Georgia, and Tennessee were visited during the past season and information was procured looking to the preparation of a comprehensive report on the aluminum ores of the United States.

Structural materials.—During the past year the necessary field work has been carried on for a thorough revision of Bulletin No. 243, Cement Materials and Industry of the United States, by E. C. Eckel. This report has been out of print for some time, and it was found necessary, in view of the constant demand for information on this subject, to issue a new edition. It was determined, therefore, to bring the report up to date and embody the latest information available before reissue.

In cooperation with the structural-materials section of the technologic branch considerable work has been done during the past year on the geologic relations of building materials in the vicinity of several of the larger cities, particularly building stone and concrete materials. This work has been done chiefly by N. H. Darton and E. F. Burchard. Two brief reports giving some of their results appear in this volume.

The work on the New England granites by T. Nelson Dale has been continued during the year, and he has prepared a report on the granites of Rhode Island, Connecticut, Massachusetts, and New Hampshire, similar in scope to Bulletin No. 313, on the granites of Maine.

Work has also been in progress on the granites of the Southern Atlantic States by T. L. Watson and his report is well advanced. It will cover all the Atlantic States south of Pennsylvania and will be based in part on work of the State surveys, much of which was done originally by Doctor Watson.

In cooperation with the State of Arkansas, a thorough investigation is being made of the Arkansas slate deposits by A. H. Purdue. The detailed economic results of this work will be published by the State, and a brief statement of the economic results, together with the areal and structural geology, will be embodied in the Caddo Gap folio.

Much information regarding structural materials, including clays, building stone, and concrete material, has been collected by geologists engaged in various parts of the country primarily in the study of areal geology. This information will appear in the geologic folios.

Oil and gas.—Detailed surveys have been continued by M. J. Munn in the western Pennsylvania oil and gas fields, in cooperation with the State. The utility of this exact instrumental determination of the minor structural features of the oil and gas bearing rocks has been amply demonstrated by actual field tests with the maps previously published. The cost of prospecting is very greatly reduced by a reduction in the proportion of dry wells drilled and the indication of the most favorable locations for the accumulation of the hydrocarbons. At the same time it has led to important conclusions, that are of general application, as to the manner in which oil and gas accumulate in the rocks. The work, however, is very expensive and therefore has not been done extensively except in cooperating States.

The investigation of the California oil fields has been continued by Ralph Arnold, the Coalinga, McKittrick, Midway, and Sunset fields having been covered during the past season. Reports on these fields, similar in scope to those published during the year on the Santa Clara, Puente Hills, Los Angeles, Santa Maria, and Summerland fields, are in an advanced state of preparation.

In connection with the investigation of the lead and zinc deposits and the stratigraphy of northeastern Oklahoma, C. E. Siebenthal made a reconnaissance of the oil fields of that region. Although the work was not sufficiently detailed to throw much light on the occurrence of the oil, it indicated the need of work, which is being planned for the coming season.

Phosphates.—A thorough reconnaissance of the Utah-Idaho phosphate deposits was made by F. B. Weeks and the report in preparation, a brief extract of which appears in this volume, will suffice until there are adequate topographic maps of the region and the deposits are more thoroughly prospected. The work already done will serve to indicate to the prospector the general location of the phosphatic beds and their stratigraphic associations.

The phosphate deposits of Tennessee, South Carolina, and Florida were visited by F. B. Van Horn, and plans are being made for a comprehensive report on the rock phosphates of the United States.

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INVESTIGATIONS RELATING TO DEPOSITS OF METALLIFEROUS ORES.

By WALDEMAR LINDGREN, *Geologist in charge.*

PUBLICATIONS OF THE YEAR.

During the year the following publications on subjects connected with the investigation of deposits of metalliferous ores within the United States proper have been issued by the Survey:

Bulletins:

No. 287. The Juneau gold belt, Alaska, by A. C. Spencer, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright.

No. 320. The Downtown district of Leadville, Colo., by S. F. Emmons and J. D. Irving.

Folios:

No. 143. Nantahala (North Carolina-Tennessee), by A. Keith. Contains description of gold deposits.

No. 145. Lancaster-Mineral Point (Wisconsin-Iowa-Illinois), by U. S. Grant. Contains description of zinc and lead deposits.

No. 147. Pisgah (North Carolina-South Carolina), by A. Keith. Contains description of gold and copper deposits.

No. 148. Joplin district (Missouri-Kansas), by W. S. T. Smith and C. E. Siebenthal. Contains description of the lead-zinc deposits of the Joplin region.

No. 149. Penobscot Bay (Maine), by G. O. Smith and E. S. Bastin. Contains description of copper deposits.

No. 153. Ouray (Colorado), by W. Cross, E. Howe, and J. D. Irving. Contains description of gold and silver deposits.

The following list comprises reports for which field work has been completed, but which have not yet been issued:

Economic geology of the Georgetown quadrangle, together with the Empire district, Colorado, by J. E. Spurr and G. H. Garrey, with a chapter on geology by S. H. Ball. (Professional Paper No. 63.)

Copper deposits of the Butte district, Montana, by W. H. Weed.

Economic geology of the Park City mining district, Utah, by J. M. Boutwell and L. H. Woolsey.

Geology and ore deposits of the Cœur d'Alene district, Colorado, by F. L. Ransome and F. L. Calkins. (Professional Paper No. 62.)

Geology and ore deposits of the Goldfield district, Nevada, by F. L. Ransome.

Geology and ore deposits of the Bullfrog district, Nevada, by F. L. Ransome and W. H. Emmons.

Geology and ore deposits of the Franklin Furnace quadrangle, New Jersey, by A. C. Spencer.

Resurvey of the Leadville mining district, Colorado, by S. F. Emmons and J. D. Irving.

The Tertiary auriferous gravels of the Sierra Nevada, by W. Lindgren.

Reconnaissance of the deposits of metalliferous ores of New Mexico, by W. Lindgren, L. C. Graton, and C. H. Gordon.

The copper deposits of Shasta County, Cal., by L. C. Graton.

Ore deposits of the Phillipsburg quadrangle, Montana, by W. H. Emmons.

Ore deposits of Mohave County, Ariz., by F. C. Schrader.

Ore deposits of the Dahlonega district, Georgia, by A. Keith.

FIELD WORK.

GENERAL STATEMENT.

In May, 1907, Mr. S. F. Emmons, desiring to devote his entire time to scientific work, relinquished the administrative duties of the section of metalliferous deposits. Since the organization of the Geological Survey Mr. Emmons has always occupied the position of senior geologist in the investigation of ore deposits, and for the last fifteen years he has under varying forms of administration had entire charge of this work. It is not necessary to call attention to his distinguished services nor to tell how much the science of ore deposits has gained by his brilliant work. All those who have worked under him feel deeply how much they have been helped by his guiding hand, his pregnant suggestions, and his indefatigable interest in their work.

During 1907 the funds available for the investigations of metalliferous deposits were unusually small, owing to the thorough and extended work devoted in that year to the investigation of coal deposits. The publication of the papers in hand was also greatly delayed on account of shortage in the funds devoted to printing. For this reason very few bulletins and professional papers were issued during the latter part of the year. It is confidently expected that next year will witness a great improvement both in extent of field work and number of publications issued.

As during the previous year, the supervision of the collection of metal statistics has occupied a part of the time of Messrs. Boutwell, Graton, Hess, Lindgren, and Siebenthal. This work can not be characterized better than by quoting S. F. Emmons in Bulletin No. 315, Contributions to Economic Geology, 1906, Part I:

> This work comprises more than a mere compilation of figures furnished by others to show production. It involves the tracing of the metals back to their various sources and the verification, by comparison and analysis, of the necessarily varying results obtained by different lines of investigation. More than that, its object is to gather at the same time such geological data as will enable the geologists in charge of the respective branches of the work to prepare an annual review of the production and prospects of the different metals in their geological as well as their technical and commercial relations, and thus to provide data for an intelligent forecast of the progress of the industries involved and of the direction it is likely to take.

A disposition has been noted in some technical journals to criticise the diversion of geologic work in this direction. This criticism would doubtless be justified if the investigation of metalliferous deposits should permanently suffer as a consequence of this diversion of geologic work, but it should not be forgotten that the starting of this undertaking involved considerable labor, which will be rapidly lessened, so far as the geologist in charge is concerned, when, after acquainting himself fully with the field, he can turn over a large part of the detailed work to other men. He will retain the supervision and the reviewing, and this connection with practical work in his branch, far from being a detriment, will enable him to obtain a much better knowledge of the resources of the nation; and, moreover, the data collected, if intelligently handled, will allow him to draw many important geologic conclusions.

The following notes summarize the geologic work by members of the Survey in 1907, so far as the metalliferous deposits, except iron, are concerned:

ARIZONA.

In Mohave County, Ariz., F. C. Schrader completed in February, 1907, a three months' reconnaissance of the important deposits in the vicinity of Chloride and those in the ranges bordering Colorado River. A brief review of this investigation is contained in this bulletin.

CALIFORNIA.

In California L. C. Graton, aided by B. S. Butler, completed during the last three months of the year a detailed study of the copper deposits of Shasta County, which have gained tremendously in importance during the last few years, and near which new reduction plants of great magnitude have recently been constructed. The field season was devoted to the study of the pyritic deposits on the western side of Sacramento River.

COLORADO.

In the northern part of Colorado H. S. Gale examined extensive deposits of gold-bearing gravels, an account of which may be found in this bulletin. This work was done in connection with the study of coals in this region.

In the central part of Colorado the writer devoted two weeks to the study of certain copper deposits, most of them of pre-Cambrian age, of which an account is also given in the following pages. The localities studied are in Chaffee, Fremont, and Jefferson counties.

MONTANA.

W. H. Emmons completed in August and September the examination of the precious-metal deposits in the Phillipsburg quadrangle, Montana. On his return he spent two weeks in a reconnaissance of the gold-bearing districts of the Little Rocky Mountains. A brief report on these districts is contained in this bulletin.

IDAHO.

Little work has been done in Idaho during 1907. F. B. Weeks and V. C. Heikes spent a few days in the Fort Hall mining district, near Pocatello, and have prepared a paper on the occurrences in this region, which will be found in the following pages.

NEW MEXICO.

No geologic work was done in New Mexico in connection with metalliferous deposits. A topographic map of the Silver City quadrangle, which includes the long known gold and silver veins of Pinos Altos and the recently developed copper deposits of the Burro Mountains, has been prepared during the year.

NEVADA.

No extensive work was accomplished in Nevada during 1907. In the fall F. B. Weeks visited the gold and tungsten veins in the vicinity of Osceola, and has prepared a paper on these occurrences for the present bulletin.

Owing to ill health, F. L. Ransome was unable to visit Goldfield in order to gather the data of the latest developments in that camp for his forthcoming professional paper. A topographic map of the region extending northward from Tonopah, embracing 1° of latitude by 1° of longitude, was prepared by the topographic branch.

OREGON.

J. S. Diller and G. F. Kay investigated the gold veins and placers of the Riddles quadrangle, in southwestern Oregon, in connection with the general geologic mapping. A summary of the mining developments in that area has been prepared for the present bulletin.

MISSISSIPPI VALLEY STATES.

In the early part of the year C. E. Siebenthal completed the field work in the Wyandotte quadrangle, Oklahoma-Missouri, and studied, in connection with the general geology, the lead and zinc deposits occurring in that area.

In November F. L. Hess devoted a week to a reconnaissance of some interesting veins of antimony ore in Arkansas, a report on which is contained in this bulletin.

APPALACHIAN STATES.

In the Southern Appalachian States Arthur Keith completed the mapping of the Dahlonega special area, Georgia, which will form the basis for a report on the important gold mines of this vicinity.

D. B. Sterrett investigated the gold-bearing gravels of the Morganton quadrangle, North Carolina, in connection with the general geologic mapping.

In November, 1907, H. D. McCaskey undertook a reconnaissance of the gold deposits in Alabama, concerning which comparatively little authentic information has been available. The veins are in the main similar to those of Georgia and North Carolina. A preliminary note describing these occurrences will be found in the pages of this bulletin.

A brief reconnaissance of the molybdenum deposits of Maine was made by F. L. Hess, who gives an account of them in this bulletin.

GOLD AND SILVER.

A GEOLOGICAL ANALYSIS OF THE SILVER PRODUCTION OF THE UNITED STATES IN 1906.

By Waldemar Lindgren.

THE PRODUCTION OF SILVER.

Previous to 1860 the production of silver in the United States was almost nominal, the yearly output, according to the tables of the Director of the Mint, reaching a maximum of only 38,500 fine ounces per annum. In 1859 the output rose to 116,000 ounces. In 1861 the figure given is 1,546,900 fine ounces, and thereafter the increase was rapid, owing to the new discoveries in Nevada and Colorado. For 1876 the figures had almost reached 30,000,000 ounces. The silver from the exceptionally rich ores near the croppings of the newly discovered deposits poured into the mints and refining works. It was the time of the bonanzas at Virginia City, Reese River, White Pine, and Eureka, in Nevada; the Silver King, in Arizona; the Lake Valley mines, in New Mexico, and the Drumlummon and Bimetallic mines, in Montana. From 1876 to 1892 the production kept on increasing, and in the latter year attained the maximum recorded, 63,500,000 fine ounces. The silver derived as a by-product from copper and lead smelting began to add its quota to that from the silver mills, and so even in the face of a declining tendency of the silver market the output of silver increased. The serious decline in the price of silver began about 1875, when the average price receded to $1.24 per ounce. For many years previous—in fact, as far back as 1833—the price had hardly ever fallen below $1.30 per ounce. From 1875 to 1892 the decline was practically continuous, and in that year of maximum production the price fell to 87 cents per ounce. The low price now began seriously to affect mining and operations had to be abandoned in many camps. Naturally the silver ores—that is, those which contained no base metals and but little gold—were affected by this condition first, and the result was the decadence of the old silver milling camps where the pan-amalgamation process was the principal method of reduction. On the other hand, a large portion of the silver was now obtained as a by-product of lead and copper ores. The decline from the greatest production in 1892 covered only two years. In 1894, 49,500,000 fine ounces were mined, but the very next year the production rose to nearly 56,000,000 ounces. Since that time it has remained approximately steady, the yield in fine ounces for the last three years having been as follows: 1904, 57,682,800; 1905, 56,101,600; 1906, 56,517,900. Meanwhile the price of silver steadily went down to a minimum of approximately 53 cents as an average for the year 1902, since which time it has again gradually risen to 67 cents per ounce as an average for 1906. The great reduction in price has found but little expression in the quantity annually recovered, and, as already emphasized, this is due to the steadying tendency of the precious metal obtained from the copper and lead smelters.

GEOLOGICAL CONDITIONS.

The silver ores of the United States are of many different types and are derived from deposits in many formations.

It is well known that no silver-bearing veins exist which are the exact counterpart of the gold-quartz veins containing native gold. Native silver is almost invariably due to oxidizing surface processes acting on primary argentiferous sulphides. One class of silver-bearing veins, of which many examples may be found in Montana, Idaho, and other States, is contained in granitic rocks or is accompanied by porphyries consolidated at considerable depth. The normal gangue is white massive quartz through which the sulphides are sparsely disseminated. Such veins are apt to be rich near the surface, where secondary sulphides and sulphantimonites have formed, but generally they are disappointing below the water level, where the primary ore is reached. Others of similar type, exemplified by certain veins in Clear Creek County, Colo., contain more abundant sulphides, among which galena generally predominates, and may be successfully worked by concentration even below the surface zone of enrichment.

Another class of silver veins cut through volcanic flows which have consolidated at or near the surface, and it can be satisfactorily proved that many of these veins themselves were formed at very moderate depths. The gangue is here also prevailingly quartzose, but usually very fine grained, chalcedonic, and drusy, and in many places it contains adularia. The quartz is characterized by primary argentite accompanied by very small amounts of lead, zinc, and copper sulphides. In dry climates oxidation and the secondary deposition of sulphantimonites have enriched the upper parts to an extraordinary degree. Illustrations of this are found in the Tonopah and Comstock ores of Nevada, the Mogollon ores of New Mexico, and the Silver City ores of Idaho.

A third class of silver deposits are found in limestones and here generally in connection with intrusive rocks—granite, diorite, monzonite, or other porphyries. Almost without exception these ores contain lead, and usually also copper and zinc, and in their primary forms the value of the base metals generally exceeds that of the silver. Both quartz and calcite appear in the gangue. Secondary silver sulphides or sulphantimonites are less common in these ores near the surface, but native silver and especially horn silver (cerargyrite) form abundantly. A mechanical enrichment by the solution of the limestone aids the ordinary concentration by oxidation, and thus the upper parts of many such deposits are extremely rich, as exemplified at Leadville and Lake Valley. Oxidized iron and manganese ores, almost free from lead but containing silver, are among the end products of the oxidation of these deposits.

Very likely it will be found that the three classes of ores mentioned are simply diverse products of the same vein-forming action, their characteristics being dependent on the depth below the surface and varying physical conditions, or on the character of the rock affected. The exposure of the veins deposited at deeper levels requires, however, long erosion, and it will usually be found that these deep-seated veins were formed at an earlier period than those breaking up through volcanic surface flows. The Leadville deposits are probably older than those of Silver Cliff or those of the Mogollon district. They were probably deposited during the early Tertiary, whereas the silver ores from the two localities last mentioned are more likely to belong to the latter part of the same period.

Our knowledge of the individual districts is as yet imperfect, but we are rapidly approaching a stage where we are justified in attempting a classification of the ores on the basis of geological occurrence. Even now it may be done in a tentative way, for the more important districts are fairly well known.

CLASSIFICATION OF ORES.

A consistent classification of ores presents great difficulties from whatever standpoint it may be undertaken. This is only natural, as there are gradations between any ores that may be selected as types. Nevertheless it is possible to arrange them in certain groups, and such a classification has been undertaken in the chapter on gold and silver in the annual volume "Mineral Resources of the United States" issued by the Geological Survey. The basis for the classification is really metallurgical. The silver product is divided according to its derivation from placers, dry or siliceous ores, copper ores, lead ores, zinc ores, and mixed ores. The small amount of silver contained in placer gold is relatively insignificant. As copper ores are designated those which contain 2½ per cent or more of copper, equivalent to 50 pounds per short ton. The ores containing over 4½ per cent of lead, or 90 pounds per ton, are called lead ores. The dry or siliceous ores comprise all of those which contain only small amounts of copper, lead, or zinc or which do not contain these metals at all. In the main they are siliceous ores containing only gold and silver, although necessarily included with them are small amounts of ores containing chiefly iron pyrite or else oxidized ores rich in hematite, limonite, or oxides of manganese.

In the mines report on the production of gold and silver in 1906 the division of the silver product is as follows:

Sources of silver product in United States, 1906.

	Fine ounces.
Placers	171, 058
Dry or siliceous ores	16, 792, 799
Copper ores	15, 880, 870
Lead ores	15, 328, 653
Zinc ores	98, 423
Mixed sulphide ores	9, 090, 650
	57, 362, 453

From the standpoint of tonnage of gold and silver ores the product of the Cordilleran States, the southern Appalachians, and Alaska in 1906 is divided as follows:

Classification of gold and silver ores produced in deep mines in United States, 1906.

	Short tons.
Dry or siliceous ores	9, 230, 616
Copper ores	10, 483, 308
Lead ores	2, 270, 822
Zinc ores	68, 296
Mixed sulphide ores	1, 183, 785
	23, 236, 827

About 30 per cent of the total silver production is thus derived from dry or siliceous ores and these ores constitute about 39 per cent of the total tonnage of the deep mines.

THE SILVER-BASE METAL ORES.

It is first to be considered that there is a certain quantity of silver ore among the copper, lead, zinc, and mixed ores. If we define silver ores as those which contain not more than 3 ounces of gold per 100 ounces of silver or in which the value of the silver (at the present prices) is equal to or greater than the combined value of the other metals utilized in the ore, the following table (No. 1) can be constructed from the individual returns. In the compilation of this and the following tables I have had the assistance of Mr. James M. Hill.

TABLE 1.—*Tonnage and metallic products, by States in the United States, in 1906, of ores classed as copper, lead, zinc, and mixed ores, in which silver predominates in value.*

State.	Ore.	Silver.	Gold.	Copper.	Lead.	Zinc.
	Short tons.	*Ounces.*		*Pounds.*	*Pounds.*	*Pounds.*
Arizona	198	24,881	$174	8,844	1,221	
California	450	34,030	1,800		143,860	206,000
Colorado	178,809	3,462,654	335,785	1,564,607	16,037,819	4,868,362
Idaho	49,421	215,736	960	5,818	1,803,401	10,399
Montana	22,743	631,335	66,427	345,262	1,216,369	
Nevada	3,943	253,784	17,558	42,670	1,168,426	492
Utah	94,968	2,757,094	234,719	1,116,898	13,149,471	
	350,532	7,379,514	657,423	3,084,099	33,520,567	5,085,253

Of the great output of copper, lead, zinc, and mixed ores, approximating 14,000,000 tons, only 350,532 tons can be properly classed as silver ores. These are derived from 134 mines in seven States. Out of about 41,000,000 fine ounces of silver from such copper, lead, zinc, and mixed ores only 7,379,514 ounces, or about one-sixth, were derived from silver ores which average about 21 ounces of silver, $1.88 in gold, 8.6 pounds of copper, 94 pounds of lead, and 14 pounds of zinc per ton.

It is seen at a glance that the only two really important States, so far as these ores are concerned, are Colorado and Utah.

The product of Arizona is derived from imperfectly known districts in Gila, Mohave, and Santa Cruz counties, and in part probably represents oxidized and enriched ores. The product of California, likewise small, comes from Inyo and Orange counties.

Colorado yields about one-half of this class of ores, and they contain on an average nearly $10 in gold per 100 ounces of silver. Replacement deposits of deep-seated type in limestone of Leadville and Aspen produce 1,632,000 ounces, or about one-half of the Colorado total. A smaller part of this consists of oxidized ores. Fissure veins in various older rocks, principally deposits connected with intrusive rocks in Summit, Park, Gunnison, and Clear Creek counties, contribute 438,000 ounces. Clear Creek County alone yields 280,000 ounces mainly from sulphide ores, a small part of which were enriched by secondary sulphides. Fissure veins in volcanic flows or in close connection with them add 1,408,000 ounces to the total, and ores of this kind were confined almost exclusively to the San Juan country.

Idaho has only the small production of 215,736 ounces, which is derived from galena-tetrahedrite veins of the Wood River district and from the Gold Hunter mine in the Cœur d'Alene district. The Wood River veins cut through limestone; the Gold Hunter deposit occurs in quartzite. Both belong to the comparatively deep-seated type.

In Montana 631,335 ounces of silver are produced from ores of this type, and all of them are lead ores. Practically all these ores occur in fissure veins in or about the contacts of intrusive quartz-monzonite stocks, and a few of the deposits are contained in limestone. Silverbow County (Butte) adds 367,000 ounces and the remainder is distributed through Beaverhead, Cascade (Neihart), Granite, Jefferson, and Lewis and Clark counties.

Few lead ores rich in silver are mined now in Nevada, although formerly large quantities were obtained, chiefly from the Eureka district. In 1906 Nevada contributed only 253,784 ounces, which were principally divided between the Lone Mountain district in Esmeralda County, the Eureka and Cortez districts in Eureka County, the Reese River and Bullion districts in Lander County, and the Hunter and Newark districts in White Pine County. So far as known most of the deposits belong to the older series associated with intrusive granitic and porphyritic rocks. Many of them, as for instance those of White Pine and Eureka, are replacement deposits in limestone; others, as for instance those of Reese River, are normal fissure veins cutting through granitic rocks.

Utah contributes 2,757,094 ounces, or almost as much as Colorado. Practically the whole output is divided between Tintic and Park City, being derived from replacement deposits in limestone associated with intrusive rocks. Tintic yields 2,200,000 ounces with copper as well as lead, and Park City furnishes the remainder.

In conclusion, it appears that of about 7,400,000 ounces derived from lead ores rich in silver 4,600,000 ounces are obtained from replacement deposits in limestone; 1,323,000 ounces from fissure veins in various rocks, standing in close connection with intrusive rocks; and finally 1,408,000 ounces from fissure veins in Tertiary lava flows.

THE SILICEOUS SILVER ORES.

GENERAL STATEMENT.

Next comes the question how much of the 9,000,000 tons of dry or siliceous ores, containing about 17,000,000 ounces of silver, is derived from ores which can be classed as silver ores. Dry or siliceous silver ores may be rather arbitrarily defined as those in which the value of the silver is equal to or greater than that of the gold, and in which copper and lead are below $2\frac{1}{2}$ per cent and $4\frac{1}{2}$ per cent, respectively. In other words, on the basis of 62 cents per ounce the ore contains at least 100 ounces of silver to 3 ounces of gold. The classification of the returns results in the following table:

TABLE 2.—*Tonnage and metallic products, by States in the United States, in 1906, of ores classed as dry or siliceous in which the proportion of gold to silver by weight is 3 : 100 or less.*

State.	Ores.	Silver.	Gold.	Lead.	Copper.
	Short tons.	*Ounces.*		*Pounds.*	*Pounds.*
Arizona	180,160	1,147,089	$253,139	2,119,165	725
California	4,845	104,055	7,200		
Colorado	260,891	2,438,202	88,087	3,412,963	61,601
Idaho	36,526	809,814	85,727	920,269	
Montana	30,399	843,434	105,789	553,188	3,600
Nevada	124,451	6,080,318	1,401,248	5,725	3,699
New Mexico	19,906	309,776	128,762	11,597	1,399
Oregon	4	111			
South Dakota	600	3,600		9,000	
Texas	22,751	292,647			
Utah	14,866	131,051	4,684	188,937	8,457
Washington	161	6,419	20		
	695,560	12,166,516	2,074,656	7,220,844	79,481

From this table it will be seen that the United States produced in 1906 only about 700,000 tons of dry or siliceous silver ore, containing approximately 12,000,000 ounces of silver, $2,000,000, or roughly 100,000 ounces, of gold, about 7,000,000 pounds of lead, and 80,000 pounds of copper. The silver ores clearly contain very little copper and three-fourths of this comes from Colorado. On the other hand, much of the silver accompanies the lead. Another point brought out is that the gold contained in these ores falls considerably short of the proportion established for the purposes of this table. This means, of course, that the ores in which the gold and silver are present to approximately the same value, or in which the gold is only slightly less than the silver, form only a small part of the total tonnage in the table. The proportion shown by the table is about 100: 0.8 instead of 100: 3, as required by the rule laid down above. The silver ore is derived from 12 States, being produced at 219 mines in 103 mining districts. The average content is about 19 ounces of silver and $1.85 in gold per ton. In the number of mines as well as in the tonnage Colorado easily leads. In the quantity of silver produced, however, Nevada occupies the first rank, and in fact contributes more than half of the total production of silver and almost three-fourths of the total production of gold. The rank of the States in silver production from these ores is as follows: Nevada, Colorado, Arizona, Montana, Idaho, New Mexico, Texas, Utah, California, Oregon, Washington, and South Dakota. The only States of importance which produce silver ore without any yield of lead or copper are California, Oregon, Washington, and Texas. In the case of Texas this is not strictly true, as the tailings from the Shafter mine contain a small amount of galena.

For further discussion it will be desirable to segregate the items given in Table 2 into three classes:

1. The ores which contain lead and copper.

2. The ores which contain no lead or copper, and in which the proportion of gold to silver ranges from 3:100 to 0.5:100 by weight.

3. The ores which contain no lead or copper and in which the proportion of gold to silver is 0.5:100 or less by weight. In other words, ores which contain $10 in gold or less per 100 ounces of silver. These ores may be called pure silver ores.

THE SILVER-LEAD-COPPER ORES.

The first class is summarized in Table 3.

TABLE 3.—*Tonnage and metallic products, by States in the United States, in 1906, of silver ores classed as dry or siliceous ores, which contain lead or copper.*

State.	Ore.	Silver.	Gold.	Lead.	Copper.
	Short tons.	*Ounces.*		*Pounds.*	*Pounds.*
Arizona	66,821	620,490	$148,617	2,119,165	725
Colorado	205,937	1,654,992	79,998	3,412,963	61,601
Idaho	19,029	91,640	99	920,269	----------
Montana	21,428	520,205	70,603	553,188	3,600
Nevada	271	40,832	1,361	5,725	3,699
New Mexico	1,240	21,200	115,000	11,597	1,399
South Dakota	600	3,600	----------	9,000	----------
Utah	14,791	125,633	3,780	188,937	8,457
	330,117	3,078,592	419,458	7,220,844	79,481

The insignificance of copper as a constituent of silver ores is again seen. Colorado, Arizona, Montana, and Utah are here the most important States. A total of 3,078,592 ounces is derived from these ores, which average 8 ounces of silver, $1.30 in gold, and 22 pounds of lead per ton. The table in general comprises the same kind of ores as shown in Table 1, but with smaller percentages of lead. The largest part of the Arizona product is contributed by the Tombstone mine, working veins and replacements in limestone, quartzite, and shale near bodies of intrusive rocks.

In Colorado ores of this type may again be separated into three classes. Replacement deposits in limestone and quartzite, some from Leadville, but the majority from Aspen, aggregate 540,000 ounces. Fissure veins connected with intrusive rocks yield 130,000 ounces, chiefly from Clear Creek, but also from Park, Gunnison, and other counties. The fissure veins contained in volcanic surface flows yield 900,000 ounces, and these ores are derived chiefly from Mineral County (Creede), but also from San Miguel, Custer, Hinsdale, Ouray, and San Juan counties—all, with the exception of Custer, in the southwestern part of the State. For Idaho is recorded 19,000 ounces, from the replacement veins in limestone of the Wood River region. Montana contributes 520,000 ounces, practically all from older fissure veins in Cascade, Granite, Jefferson, and Madison counties. A small quantity, nearly 41,000 ounces, comes from the Reese River and Columbus districts in Nevada, presumably from older fissure veins. New Mexico adds 21,000 ounces from similar deposits in Luna and Dona Ana counties. Utah produces about 126,000 ounces from replacement deposits in limestone at Tintic and Park City.

To sum up, the silver ores containing a little lead (or copper) are derived approximately as follows:

Sources of silver-lead-copper ores in the United States, 1906.

	Ounces.
1. Replacement deposits in limestone	1,305,000
2. Fissure veins, connected with intrusive rocks (not always to be separated strictly from No. 1)	712,000
3. Fissure veins in Tertiary volcanic surface flows	900,000
	2,917,000

The small balance is from deposits of unknown character.

THE SILVER-GOLD ORES.

The second class of ores is summarized in Table 4, which shows that about 7,500,000 ounces of silver and over $1,500,000 in gold are obtained from dry or siliceous silver ores without reported lead or copper and with gold ranging from 0.5 to 3 ounces per 100 ounces of silver. This ore comes from 8 States, being the output of 50 mines in 22 mining districts, and averages about 28 ounces of silver and $6 in gold. Compared with the total the tonnage of these ores is small, aggregating only about 270,000 short tons.

TABLE 4.—*Tonnage and metallic products, by States in the United States, in 1906, of silver ores classed as dry or siliceous, containing no lead or copper and from 0.5 to 3 ounces of gold per 100 ounces of silver.*

State.	Ore.	Silver.	Gold.
	Short tons.	*Ounces.*	
Arizona	104,549	434,697	$100,815
Colorado	495	16,997	5,675
Idaho	17,426	714,866	85,628
Montana	4,638	122,111	24,423
Nevada	124,020	6,021,284	1,399,333
New Mexico	16,088	271,767	13,235
Utah	35	2,818	846
Washington	16	90	20
	267,267	7,584,630	1,629,975

The whole production of Arizona in this class is derived from fissure veins in volcanic flows, principally rhyolite or dacite, and the larger part of it comes from Cochise County. Colorado produces only a very small amount of these ores, about equally divided between fissure veins in volcanic flows and those connected with intrusive rocks. In Idaho the whole output is from veins connected with surface flows of lavas in Owyhee County. Montana furnishes 122,000 ounces from the Butte silver veins, in granite. By far the largest output is contributed by Nevada, principally from Tonopah, which is responsible for nearly 5,700,000 ounces; but similar ores are also mined in the Bullfrog and Fairview districts and from the Comstock. Smaller amounts come from Humboldt, Elko, and Lyon counties. All of these ores come from fissure veins or allied deposits in Tertiary volcanic flows. New Mexico yields 272,000 ounces, from veins in volcanic flows, chiefly from the Mogollon district.

To sum up, the ores of this class appear to be eminently characteristic of veins in Tertiary volcanic flows. Practically the entire output, except insignificant quantities from Colorado, Montana, Utah, and Washington, is derived from such deposits.

THE SILVER ORES.

The third class of the dry or siliceous silver ores may be called the pure silver ores. They consist of those which contain no reported lead or copper and in which the proportion of gold to silver is very small—less than 0.5 ounce of gold per 100 ounces of silver. The production of these ores by States is illustrated in Table 5.

TABLE 5.—*Tonnage and metallic products, by States in the United States, in 1906, of silver ores containing no lead or copper and less than 0.5 ounce of gold per ton.*

State.	Ore.	Silver.	Gold.
	Short tons.	*Ounces.*	
Arizona	8,790	91,902	$3,707
California	4,845	104,055	7,200
Colorado	54,459	766,213	2,414
Idaho	70	3,308	
Montana	4,333	201,118	10,763
Nevada	160	18,202	554
New Mexico	2,578	16,809	527
Oregon	4	111	
Texas	22,751	292,647	
Utah	40	2,600	58
Washington	145	6,329	
	98,175	1,503,294	25,223

The table shows that only about 1,500,000 ounces, or one-fortieth of the total production, are derived from these ores, which were extracted from 79 mines in 50 mining districts and average only 15 ounces in silver and 25 cents in gold per ton. Less than 100,000 tons were mined. The ores are derived chiefly from Colorado, Texas, and Montana. The Arizona ores are mixed and seem to be largely oxidized ores from veins connected with intrusive rocks, in the Cerbat

Range, Mohave County, also from Globe, and from mining districts in Yavapai County. The California ores are from Inyo County, also from mines near Calico, San Bernardino County, but most of them are produced near Amalie, Kern County. About 9,000 ounces are derived from volcanic flows, and the rest of the silver comes from veins probably connected with intrusive masses.

The Colorado ores form a long list. The replacement ores in limestone (here largely oxidized ores) from Leadville aggregate 114,000 ounces; those from Aspen 57,000 ounces. The mixed ores from veins genetically connected with intrusive bodies give 58,000 ounces, and veins in eruptive flows from Silver Cliff and the San Juan region aggregate 436 ounces.

Montana contributes a little over 200,000 ounces, of which by far the greater part is from Granite County and smaller amounts from Butte and from districts in Beaverhead and Jefferson counties. The product is derived entirely from veins in granitic rocks and probably genetically connected with these intrusions.

Small amounts only are derived from scattered sources in Nevada, Idaho, New Mexico, Oregon, Utah, and Washington.

From oxidized limestone replacement ores in Texas nearly 300,000 ounces are obtained; these ores contain some lead, although it is not recovered.

In conclusion, the pure silver ores are derived as follows:

Sources of pure silver ores in the United States, 1906.

	Ounces.
Replacement ores in limestone	574,000
Fissure veins in other rocks connected with intrusives	314,000
Fissure veins in volcanic Tertiary flows	466,000
Doubtful	149,000
	1,503,000

A large part of these ores consists of oxidized surface ores. Some of them are oxidized iron ores from the upper part of the deposits and really mined as flux. In earlier years this class of oxidized silver ores was far larger than it is at present.

SUMMARY AND CONCLUSIONS.

The total production of silver in 1906 according to the mines report was 57,362,455 fine ounces. Of this amount, 40,398,596 fine ounces were recovered from lead, copper, or zinc ores, and 16,792,799 fine ounces from dry or siliceous ores.

The copper, lead, or zinc ores furnished, from ores with predominating silver value, containing 3 ounces or less of gold per 100 ounces of silver and more than 4½ per cent of lead or 2½ per cent of copper, 7,379,514 fine ounces.

The yield from siliceous ores can be subdivided as follows:

Classification of silver produced from siliceous ores in the United States, 1906.

	Fine ounces.
From ores containing lead or copper, having 3 ounces or less of gold per 100 ounces of silver, and less than 4½ per cent of lead or 2½ per cent of copper	3,078,592
From ores with no recovered lead or copper; gold in the proportion of 3 ounces to one-half ounce of gold per 100 ounces of silver	7,584,630
From ores with no recovered lead or copper; gold in the proportion of one-half ounce or less per 100 ounces of silver	1,503,294
Total silver from dry or siliceous silver ores	12,166,516
Total silver from dry or siliceous gold ores	4,626,283
	16,792,799

The total silver from all kinds of ores with predominating silver value is as follows:

Production of silver from all kinds of silver ores in the United States, 1906, by States.

	Fine ounces.		Fine ounces.
Arizona	1,171,970	Oregon	111
California	138,085	South Dakota	3,600
Colorado	5,900,856	Texas	292,647
Idaho	1,025,550	Utah	2,888,145
Montana	1,474,769	Washington	6,419
Nevada	6,334,102		
New Mexico	309,776		19,546,030

The total tonnage of these silver ores is 1,046,092 short tons.

As shown by the foregoing statement, nearly one-third of the whole silver production is derived from ores properly to be classified as silver ores, although about one-half of these probably could not be profitably mined if no other metals were present.

From a geological standpoint the ores may be classified as follows:

Geological classification of silver derived from various ores in the United States, 1906.

[Fine ounces.]

Type of deposit.	Silver ores with much lead and copper.	Silver ores with little lead or copper.	Silver-gold ores.	Silver ores.	Total.
From replacement deposits in limestone and shale genetically connected with intrusives	4,600,000	1,305,000		574,000	6,479,000
From fissure veins in various rocks genetically connected with intrusives	1,323,000	712,000	314,000		2,349,000
From fissure veins in Tertiary volcanic flows	1,408,000	900,000	7,500,000	466,000	10,274,000
	7,331,000	2,917,000	7,814,000	1,040,000	19,102,000

This leaves a balance from deposits of unknown character of about 444,000 ounces.

The facts cited above bring out prominently the well-known affinity of silver for lead and quite as markedly the slight degree in which copper and zinc are associated with the silver ores properly so called. They also emphasize the selective action of limestone in the precipitation of silver-lead compounds.

The relative quantities in the last table apply of course only to present conditions. During the early days of silver mining the pure silver ores of the oxidized zones greatly prevailed. Nor do the figures give the precise relation of the absolute supply of silver ores in nature. The limestone ores carrying silver and lead are sought after by the smelters. On the other hand, there is a large supply of low-grade siliceous silver ores for which at present no great demand exists. Although free-milling quartzose ores containing $5 of gold per ton may be mined and reduced economically, a corresponding grade of siliceous silver ore with sulphides would, as a rule, be unprofitable, for if wet milling processes were adopted the necessary roasting and heavy loss would render the operation too expensive, and, on the other hand, the smelter charges would probably not be less than $5 or $7 per ton on such material. Only in the pyritic smelting process and for converter lining could such ores ordinarily be used.

On further tentative generalization it seems that the copper ores, which ordinarily contain very small amounts of silver, tend to deposit under conditions of high temperature and pressure. The greater part of the lead-silver ores, which occur in deposits genetically connected with intrusive granitic or porphyritic rocks, have probably been deposited under conditions of moderate temperature and pressure. The major part of the silver-gold ores, which contain little or no lead or copper, occur in fissure veins cutting through lava flows of Tertiary age (rhyolites, dacites, or andesites). They have been deposited comparatively near the surface and under conditions of still lower temperature and pressure, though probably never much below the temperature of boiling water.

These ores in Tertiary lavas yielded in 1906 10,274,000 ounces of silver, or more than half of the total silver from silver ores. In only a small part of them, chiefly from the San Juan region, is the silver associated with notable amounts of copper and lead.

Conditions in the Cordilleran province indicate that there is some foundation for the belief that the maximum precipitation of metals in ascending thermal waters occurs in the following order: Copper, zinc, lead, silver. The precipitation of copper takes place most easily at lower depths. The precipitation of silver is most abundant near the surface. Gold is freely deposited under widely varying conditions, though most abundantly near the surface.

NOTES ON SOME GOLD DEPOSITS OF ALABAMA.

By H. D. McCaskey.

INTRODUCTION.

During a hasty reconnaissance of parts of Alabama in November, 1907, advantage was taken of visits to various gold mines, particularly those of Hog Mountain, which have been the principal producers of the precious metals in this State for several years, to obtain some notes descriptive of the deposits. Although the treatment is preliminary, this sketch has been prepared for publication with the hope that it may supply, to some extent, demands for recent information concerning gold districts of this State. For courtesies in the field the writer is indebted to so many citizens of Alabama that only general acknowledgment can be made in a paper so brief as this.

The general relief of northeastern Alabama is marked by dissected ridges which lie in a northeast-southwest direction and correspond therefore to the prevailing Appalachian trend. These watersheds confine the main streams for the greater part, although they are at intervals cut across by drainage channels. Down their slopes to the northwest and southeast flow the minor streams whose work is reducing this entire region to a peneplain.

The altitudes of this portion of Alabama are no longer great, only a small fraction of the areas of the higher hills rising above the 1,000-foot contour. The slopes are not unusually steep and the valleys are well matured.

GEOLOGY.

The southwestern portion of the Appalachian Mountain and Piedmont Plateau belts, including the gold deposits of the Southern States, is made up for the most part of metamorphic igneous and sedimentary rocks, but includes also isolated patches of slightly metamorphosed sediments and unmetamorphosed intrusives. These rocks extend into the east-central portion of Alabama, and the Piedmont Plateau disappears under the Cretaceous sediments toward the southwest. The portion of this area of metamorphic rocks lying in Alabama has roughly the shape of an equilateral triangle, with its base lying on the middle third of the Alabama-Georgia boundary line and the apex extending nearly to Calera, about 30 miles due south of Birmingham. On the northwest lie the folded Cambrian and Silurian strata, and to the southwest are the overlapping Cretaceous formations. In addition to intense folding, there has been extensive faulting apparently along northeast-southwest lines.

The area of metamorphic and crystalline rocks of Alabama, thus roughly outlined, includes the greater part or all of Cleburne, Randolph, Clay, Chambers, Tallapoosa, Coosa, and Lee counties and parts of Talladega, Chilton, and Elmore counties, and is over 4,000 square miles in extent.

The rocks within this area include the "Talladega formation," of partly metamorphosed slates and sandstones, the Alabama representative of the Ocoee group of formations, which are of Cambrian age, according to Keith;[a] a small area of later slates, probably Devonian or early Carboniferous, lying along the northwestern border of Clay County; the older gneisses and schists; and the intrusive granites and greenstones. The general relations of these were outlined some years ago,[b] and brief notes are offered here, but considerable detailed study of them remains to be done.

The Ocoee group or "Talladega formation" as described by Smith[c] embraces a series of conglomerates, quartzites, dolomites, quartz schists, and slates. The latter two are the most common rocks and include brownish, greenish, and grayish quartz and clay schists and slates, bluish graphitic slates, and magnetitic schists. Three fairly well defined belts of the Ocoee rocks, trending from northeast to southwest, and beginning next the determined Paleozoic rocks to the northwest, alternate with three roughly corresponding areas of much more highly crystalline rocks consisting chiefly of granitic gneisses. These belts may be conveniently described as the "upper," "central," and "lower slate belts." The first two of these belts are referred to and briefly defined on pages 42 and 44. The third belt, the narrowest and best defined of the three, contains the Silver Hill, Blue Hill, Gregory Hill, and other gold deposits, once famous in Alabama gold mining, but now dormant and unproductive. A number of these old mines were visited by the writer, but all the workings were found to have been abandoned for many years and the time given to them was brief. This belt is characterized in part by a conspicuous outcrop of a light-yellowish saccharoid sandstone described by Tuomey, Phil-

[a] Keith, Arthur, Geologic Atlas U. S., folio 143, U. S. Geol. Survey, 1907, p. 3.

[b] Phillips, W. B., A preliminary report on a part of the lower gold belt of Alabama: Bull. Geol. Survey Alabama, No. 3, 1892. Brewer, W. M., Smith, E. A., Hawes, G. W., Clements, J. M., and Brooks, A. H., A preliminary report on the upper gold belt of Alabama, with supplementary notes on the most important varieties of metamorphic or crystalline rocks of Alabama: Bull. Geol. Survey Alabama, No. 5, 1896.

[c] Smith, E. A., op. cit., pp. 110–115.

lips, and Brewer.[a] This sandstone is from 20 to 80 feet thick and extends across the country to the northeast for many miles. It is the "Devil's Backbone" of Phillips. The sandstone is interfoliated with the bluish auriferous slates of the Silver Hill belt of Phillips and Smith, and is itself auriferous, according to Phillips. These rocks strike N. 20°–45° E. and their planes of schistosity dip rather steeply to the southeast. To the southeast of this belt is a broad area of crystalline rocks extending to the Georgia line.

An isolated patch of slates lying in the upper slate belt in the northern part of Clay County was found to contain fossils thought by Smith[b] to be Carboniferous, and as these rocks had previously been classified with those of the "Talladega formation" considerable doubt was thrown on the supposed Cambrian or earlier age of the "Talladega" rocks. The problem received the attention of C. W. Hayes and David White, who concluded after field study that these slates were unconformable with the Ocoee and probably of Devonian or later age.[c]

Of the highly metamorphosed or crystalline rocks of doubtful origin the rather coarse-grained gneiss is by far the most generally distributed. According to Smith, these gneisses are chiefly granitic in composition, but vary in the southeastern area into more basic dioritic gneisses; and in structure they may be considered means between the end terms of slightly gneissoid granites on the one hand and highly fissile mica schists on the other. Samples of the gneiss of Pinetuckey show megascopically a medium-grained foliated rock made up of considerable quartz, somewhat less feldspar, and white and brown mica, the latter slightly in excess. This gneiss is cut by pegmatite dikes containing much biotite in broad sheets and feldspar that is now altered, where exposed near the surface, to kaolin. Associated with these gneisses and with the Ocoee rocks are various mica schists of equally doubtful origin. They are chiefly fine-grained, dark-colored, rather basic schists, so altered that their composition is not readily made out without resort to thin sections. A dark mica is common, and in the schists of the Pinetuckey mine garnets are developed. The garnets occur also with the quartz of the vein and the garnetiferous portion of the schist next the vein carries gold and is mined with the ore. The garnets would seem to be later than the regional metamorphism and to be genetically related to ore deposition; but as the mine was flooded at the time of the writer's visit satisfactory determination of this point could not be made. The schists form the walls of the vein, and their planes of schistosity are parallel

[a] Tuomey, M., Second Bienn. Rept. Geol. Survey Alabama, 1858. Phillips, W. B., op. cit., pp. 58, 61. Brewer, W. M., op. cit., pp. 6, 7.

[b] Smith, E. A., Science, new ser., vol. 18, 1903, pp. 244–246.

[c] Oral communication from Dr. C. Willard Hayes.

with those of the adjoining gneiss of the country rock. The determination of the age, relation, and origin of these gneisses and associated mica schists presents many difficulties and awaits the most careful detailed work.

Of less doubtful origin is the "Hillabee green schist" described by Brewer, Smith, Clements, and Brooks,[a] and noted by the writer at Chulafinnee and Arbacoochee. This rock occurs along the northwestern border of the gneisses and as an intrusive in the Ocoee slates. It is a light-green, fine-grained, slightly foliated schist and is pyritiferous, at least in part. The slight schistosity is brought out by the appearance of the pyrite along wavy parallel planes of foliation. The rock appears to be an altered basic igneous intrusion of later age than the Ocoee slates, but earlier than the close of the regional metamorphism.

A type of acidic intrusive is present in the granite of Hog Mountain, a medium-grained holocrystalline rock made up of quartz, orthoclase, and biotite, with some muscovite and a little plagioclase. This rock, which is probably an equivalent of the granite at Villarica, in the Marietta quadrangle, occurs as a thick tabular sheet in the Ocoee slates of Hog Mountain and is exposed in the group of hills bearing this name.

ORE DEPOSITS.

The ore deposits of the mines here described belong to two structural types, that of fissure veins, as illustrated by the Hog Mountain veins, and that of lenticular bodies lying for the greater part within planes of schistosity of the inclosing rocks, as illustrated by the ore bodies of Gold Ridge, Pinetuckey, and Tallapoosa. The country rock at Hog Mountain is an intrusive granite, that of Tallapoosa and Gold Ridge consists of Ocoee slates and schists, and that of Pinetuckey is gneiss. All the ore bodies are on the border of gneisses and granites on the one hand and of the Ocoee slates on the other. At Gold Ridge and Pinetuckey a fine-grained mica schist, carrying pyrites and gold, forms the foot wall, and in this schist garnets are developed. At Pinetuckey the garnets assume both a banded structure and the form of fresh "augen" in the schist. Garnets are also found in the vein quartz at this mine, adjoining the garnetiferous schist. Thin sections of ores and rocks have as yet been studied by the writer only of samples from the Hog Mountain mines. Here the vein quartz next the granite walls contains veinlets of tourmaline and is associated with large foils of sericite. The quartz of this vein matter is of two generations, the older being a smoky blue quartz containing fluid and gas inclusions and indeterminable opaque substances and showing strong strain shadows between crossed nicols; with this

[a] Op. cit., pp. 84, 120, 173, 195–197.

quartz are associated some of the gold and sulphides. The younger quartz is fresh and light colored, shows few inclusions or strain shadows, and is also associated with the sulphides. The granite of the walls is somewhat altered, the feldspar being changed largely to sericite, and tourmaline and colorless garnets being present, as observed in thin sections.

The granite of Hog Mountain is intrusive in the Ocoee group. The gneiss of Pinetuckey is reported by Mr. Sam Wallace to underlie all of the Ocoee; but drill holes have shown that granite also alternates with these rocks.[a] The garnetiferous and auriferous mica schist of the foot walls of the Gold Ridge and Pinetuckey veins has not been studied in thin section and its origin is unknown. It is conformable with the Ocoee slates of the Gold Ridge and with the gneisses of the Pinetuckey mines.

The strike of all the veins conforms mainly to the general structural trend to the northeast, being in part more easterly in the Hog Mountain veins and more northerly at Pinetuckey and Gold Ridge. The dip of the veins of the lenticular type is to the southeast, ranging from 30° to 50°; that of the Hog Mountain fissure veins is from 50° to 60° NW.

The veins of the lenticular type show sheeted or banded structure, with scales of white mica developed along parting planes. The veins of Hog Mountain indicate crushing and recrystallization. The slates adjoining the Tallapoosa vein are in many places much crumpled next the vein. The granite wall rock of Hog Mountain shows strain, but has not been rendered gneissoid.

Hydrometamorphism, or weathering, has extended everywhere to water level, which is from 40 to 80 feet below the present surface. The Ocoee slates and all the schists have been completely altered by oxidation and hydration to this level, but the granite of Hog Mountain and the gneisses are but slightly changed. All the ores have been oxidized and the gold is commonly found for the most part free-milling and associated with hydrated iron oxides above water level. The vein quartz is somewhat honeycombed in the Hog Mountain ores, and rather porous in the lenticular veins, in the oxidized zone. Below water level free gold is still found in the lenticular veins, but from 60 to 80 per cent of the total gold is so closely associated with the unaltered sulphides that the ores are not amalgamable at a profit. The "blue ores" of Hog Mountain, or those of the sulphide zone, are not free-milling in any degree.

The Hog Mountain veins are fairly regular in width and values so far as explored in depth; the lens-shaped ore bodies, however,

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[a] Nitze, H. B. C., and Wilkins, H. A. J., Gold mining in North Carolina and adjacent southern Appalachian regions: Bull. North Carolina Geol. Survey No. 10, 1897, p. 88.

pinch and swell, part and rejoin, but they also persist, both in average width and in values, as far as they have been followed, in the sulphide zone.

Data for a satisfactory discussion of the genesis of these deposits are yet incomplete. Their age is probably post-Cambrian. In all the veins the fillings are along lines of structural weakness and deposition was followed by strain, shear, and recrystallization along the same lines. All of this would seem to have taken place before the close of regional metamorphism referred to the Appalachian upheaval. Deposition occurred probably at great depth and under high heat and pressure; and that of the Hog Mountain ores at least seems to be genetically referable to igneous after effects. As stated above, the ore deposits occur along the border of the Ocoee slates and the granites and gneisses; and the latter appear to be gneissoid granites and therefore igneous rocks. It seems probable that several thousand feet of vertical extension of the veins have been removed since their deposition; and the lower limits of the ore bodies have not yet been defined.

PRODUCTION.

The production of the precious metals in Alabama has never been great for any given year, but this State has been credited with a continuous output for more than a century. The exact date when gold was first mined in Alabama is not known. It seems quite probable that the Indians found nuggets in the streams long before the advent of the white man and beat them into rude ornaments. The early Spaniards doubtless observed these ornaments and obtained some of them or learned where they came from. Nuggets are still found in Clear Creek and elsewhere in Alabama, especially after heavy rains. Evidence that the streams were worked at least a hundred years ago was observed on the banks of a small stream in the Pinetuckey district, where in extensive dumps, apparently of old placer washings, trees at least a century old have grown. However all this may be, Phillips[a] states that the earliest records seem to point to the beginning of real gold mining in Alabama in about the year 1830.

From the reports of the Director of the Mint to 1903, inclusive, and from those of the Geological Survey for 1904, 1905, and 1906, Alabama is credited with a total production of gold and silver valued at $760,470 for the one hundred and seven years beginning with 1800. This would represent an average annual production of $7,107. Only once in the twenty-four years from 1880 to 1903, inclusive, did the recorded production reach this mark; but, chiefly owing to recent

[a] Phillips, W. B., op. cit., p. 10.

activity at the Hog Mountain mines in Tallapoosa County, the production for the three years 1904 to 1906 has been as follows:

Production of gold and silver in Alabama, 1904–1906.

Year.	Gold.	Silver.	Total.
1904	$29,300	$116	$29,416
1905	41,530	203	41,733
1906	24,921	83	25,004

The production for 1907 will probably show a slight increase over that of 1906, owing to the continued activity at Hog Mountain and recent operations at the Gold Ridge mines.

DETAILED DESCRIPTIONS.

GOLD RIDGE.

Gold Ridge is in the extreme northeast corner of Randolph County, on the Randolph-Cleburne county line and about 2 miles west of the Alabama-Georgia boundary line. It is a small hamlet situated on a hill of 1,100 feet elevation bearing the same name. Considerable placer work has been done here in the past, but records giving the production are not available. Attention has recently been attracted to this place by the introduction of northern capital and by preparations for working the ores in depth.

The exposures indicate the continuation northeastward to this hill of the " Talladega " (Ocoee) beds of the central slate belt as laid down on the geologic map of Alabama.[a] This belt extends from a point 7 miles northwest of Wetumpka, where it is 2 miles wide, northeastward through Alexander and Wedowee, increasing in width to about 9 miles at the Alabama-Georgia line. On both sides of this belt occur the crystalline igneous and metamorphic rocks. Gold Ridge is on its northern border. The hill is, for the greater part at least, made up of argillaceous and siliceous slates and schists, striking from N. 10° E. to N. 40° E., and with planes of schistosity dipping from 30° to 45° S. 80° E. to S. 60° E. Certain of the clay slates and quartz schists appear to be of sedimentary origin, and the inclosing rocks of the quartz veins belong mainly to this class of rocks. The origin of the foot wall of the Eckert vein, however, which is a highly garnetiferous mica schist, and that of a quartz-magnetite schist found in association with another vein a mile to the south, is of considerable doubt. The garnets of the Eckert foot wall are much decomposed, but are shown to be of the iron-alumina variety. Many of them are dodecahedra from 2 to 3 inches in diameter. The matrix of the

[a] Geologic map, Geol. Survey Alabama, Eugene A. Smith, State geologist, 1894.

schist is highly micaceous. The quartz-magnetite schist is made up almost entirely of these two minerals, as shown by a megascopic examination, with light-colored micas here and there along the planes of schistosity. Many of the magnetite crystals are 0.1 inch in average diameter. A green pyritiferous chlorite-epidote schist found bordering this belt to the north and interfoliated with certain of the other schists seems undoubtedly of igneous origin and is probably the "Hillabee schist" of Brewer and Smith,[a] thin sections of which were studied by Clements and Brooks.[a]

The mine workings are situated on the east side of the hill and about 1 mile northeast of Gold Ridge. Two veins are exposed by numerous pits, trenches, and crosscuts. The upper or Black vein shows at least 10 feet of dark quartz at the best exposure, with a hanging wall of red clay resulting from weathered slates. The foot wall is not exposed, but below this vein and above the Eckert are found the red clays characteristic of certain weathered beds of the Ocoee. The foot wall of the Eckert vein is a green garnetiferous schist, much of which is slaty in appearance. The Eckert vein is from 6 to 36 inches between walls. The general strike of both veins is from N. 10° E. to N. 20° E. and the dip is from 20° to 43° S. 80° E. to S. 60° E. One dip fault, of the normal type, was observed in a drift on a narrow quartz vein similar to the Eckert and possibly a continuation of it, about a mile south of the present workings. The throw of this fault measured 4 feet. Evidences of strike faults with similar short throws and of slickensides also prove that there has been some slight fracturing and displacement of the veins.

The Black vein has not been worked and is but little developed. It is made up of rather massive quartz, stained with manganese oxides, and is reported to average in assay value from $9 to $10 across a face of 9 feet. Systematic sampling, however, has not yet been done on this vein and its real value is unknown. On the Eckert vein an inclined shaft has been sunk for about 100 feet and drifts have been turned on the 50-foot level to the north and south for about 250 feet. The vein is not yet explored below water level and the wall rocks are weathered almost beyond recognition. The pay streak of this vein is along the foot wall, which itself carries gold and for a distance of 12 to 18 inches from the quartz is mined at a profit. The vein matter is, where exposed, a rather porous quartz of schistose structure, and white mica is developed along the planes. The vein pinches and swells and thick portions of it in cross section in weathered exposures show reentrant angles simulating grooving. One "pipe," with its long axis lying in the line of strike, showed an oval cross section with corrugated border and having no connection with

[a] Op. cit., pp. 84, 120.

portions of the vein either above or below. A section of this "pipe" removed from the clay looked very much like a silicified tree trunk a foot or more in diameter. The ore is free-milling above water level, and sulphides of iron have yet been encountered only to a slight extent in the veins. The garnets of the foot wall are rolled and many of them are from 1 to 2 inches in diameter, giving the schist a knotted appearance.

A steam 2-stamp mill began operations on these ores toward the last part of 1907, and, according to reports, the results have been satisfactory. Work on these ores must be considered largely experimental until development underground has gone below groundwater level.

CLEAR CREEK.

Immediately to the southeast of the determined Paleozoic formations as shown on the geologic map of Alabama[a] lies a broad belt of rocks well exposed in Blue, Talladega, and Rebecca mountains, constituting what may be termed the upper slate belt, and extending from the Cretaceous sediments at Clanton northeastward through Edwardsville into Georgia. This belt is from 7 to 25 miles wide, and is made up largely of light and dark micaceous argillites, quartzites, and conglomerates, and in the Turkey Heaven Mountains, according to Smith,[b] of dark-colored graphitic and magnetitic schists. To the southeast of this belt of rocks, mapped by Smith as "Talladega," lies a continuous belt of the "Hillabee schist," noted above, bordering a broad area of acidic gneissic and granitic rocks separating the upper and central slate belts. At Chulafinnee, about 15 miles a little to the south of west of Heflin, Cleburne County, the schist is well exposed. It is there found in close association with the Ocoee auriferous slates, as it is at Arbacoochee and Clear Creek.

Between Gold Hill and Kemp Mountain, in Cleburne County, lies the well-matured valley of Clear Creek, a tributary of Tallapoosa River flowing southwestward. These are outlying hills parallel to the Horseblock-Brymer range to the north and their axes trend N. 45° E. parallel to the strike of the rock exposures. Kemp Mountain is from 1,400 to 1,500 feet in elevation, and Gold Hill is somewhat lower. The general dip of the planes of schistosity of all the rocks is about 45° S. 45° to 60° E. On the south slope of Gold Hill, near Arbacoochee, are old workings and dumps indicating the presence of the familiar lenticular quartz veins in the schists. The works have been abandoned for so long that the shafts and slopes are caved and partly filled with surface wash. Two quartz veins lying within quartz schists and dipping 45° S. 45° E. were noted in the mouth of

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[a] Geol. Survey Alabama, 1894.

[b] Brewer and Smith, op. cit., p. 113.

an inclined shaft about one-fourth of a mile southwest of Arbacoochee. The quartz is white and shows cavities filled with limonite. Fragments of this quartz litter the hillside down to the flood plain of Clear Creek and may be found, together with old pits, along the strike (N. 45° E.) through the forest for over a mile. The veins where measured were 2 and 6 inches thick. They are reported to have been rich in free gold.

The flood plain of Clear Creek is about half a mile wide at the point about the same distance southwest of Arbacoochee, where placer operations are now being carried on. The valley floor is rather overgrown with small shrubs, and has until recently supported some forest growth, as is attested by the large number of tree stumps remaining. Below the soil cap lies gravel to a depth of 8 to 14 feet, with a foot or more of white clay near the bottom. The bed rock is reported to consist of the upturned edges of the slates, striking here to the northeast and therefore lying parallel to the average course of the streams. The cutting of this bed rock has exposed many narrow veins of quartz carrying scattered rich pockets of free gold. It would seem therefore that operations here extending to the bed rock have worked gold in place as well as alluvial gold caught in the rock and found with stream gravel. Well-authenticated accounts have been given to the writer of rich pockets yielding $7,000 and over in gold, but it has been difficult to determine whether the gold has been in place or not. The probabilities would seem to favor the conclusion that the rich pockets consist mainly of alluvial gold. Good-sized nuggets are still found along the sides of Gold Hill after heavy rains. As might be expected, much broken vein quartz is mixed with the Clear Creek gravel, and samples of it from dumps of the dredge have assayed from $3 to $4 to the ton.

Placer mining on Clear Creek has long been famous in Alabama and has undoubtedly yielded from $50,000 to $60,000 in gold from small workings alone. In 1905 the Clear Creek Mining Company built a small bucket dredge with a daily capacity of 600 cubic yards for the purpose of working the gravels on a larger scale than had been done before. Some work was done in that year but operations were not entirely successful and the plant was closed down. Possibly tree stumps interfered with the dredge to some extent or local strata of white clay balled up some of the gold; certainly it was found that some of the gold was not in alluvial form, but in comparatively fresh broken vein matter, and it was thought that the tailing dumps could be worked at a profit by crushing and amalgamation. Facilities for this process were therefore added to complete an extensive plant. At the end of 1907 the Gold Ridge Mining Company was completing preparations to sluice the gravel by the use of giants and to elevate it by suction pipes to a series of sluice boxes of conventional type and riffles, 120 feet in length. Operations began too recently to enable the writer to judge of the success of this plan. There seems to be considerable gold still available in the valley of Clear Creek, but a close study of the economic and geologic features involved should precede final judgment on this point.

PINETUCKEY.

Between the upper slate belt in Cleburne County and the central slate belt in Randolph County lies a wedge-shaped area of acidic gneissic rocks. This area extends in a broad belt to the southwest through Ashland and Rockford and includes the granite near Alexander, which is the same as that of Hog Mountain. As mapped by Smith [a] it wedges out where the two slate belts join near the Alabama-Georgia line. Near the Cleburne-Randolph county line and about a mile to the southwest of Micaville dikes and apophyses of pegmatite occur within this area, affording considerable supplies of kaolin and of large sheets of mica. Three of these parallel dikes have been explored and they are found to trend from southwest to northeast for at least half a mile. Where they have been worked for mica and kaolin they are from 30 to 50 feet wide, and are bordered in part by zones of light-colored facies of granite free from mica or other dark minerals. Tourmaline and ilmenite were found in large crystals in some of these pegmatitic veins by Mr. Sam Wallace, who has carried on extensive exploratory work in this area.

About 2 miles south of Micaville and a quarter of a mile northwest of Pinetuckey are the historic Pinetuckey mines. Extensive lines of old trenches, pits, and tailing dumps indicate work on the surface ores extending back for many years. Considerable modern underground work has also been done and a 20-stamp mill was erected several years ago to treat the ores by the milling-amalgamation process; but owing to difficulties in obtaining a high extraction by this method and uncertainty of the best future procedure the mines and plant have been closed for several years and the mine is now flooded.

The country rock of the ore deposits is a medium-grained gray gneiss made up of quartz, feldspar, and mica. The immediate walls of the veins are of thin sheets of dark-green mica schist in which garnets are highly developed, assuming the form of "augen" and, more conspicuously, a marked banded structure. Garnets are found also at the boundary plane between the schist and gneiss. This schist of both walls is auriferous and is reported to carry from $4 to $7 to the ton in gold, partly in pyrites. The vein matter proper is hard bluish quartz with a sheeted or banded structure and contains both

[a] Geologic map, Geol. Survey Alabama, 1894.

free gold and auriferous sulphides. Between bands of quartz films of muscovite are developed, and garnets are found with the quartz. All these garnets would seem to be genetically related to the ore deposits.

Several veins have been worked at Pinetuckey down to water level and some very rich ore has undoubtedly been taken out. Handsome specimens showing flakes of free gold in the quartz as large as kernels of corn are easily obtainable. The vein on which most of the modern work has been done is from 6 inches to 3 feet thick and of lenticular type. On this vein have been sunk three shafts and two winzes, and from 500 to 600 feet of drifts and stopes have been worked. The vein strikes N. 10° E. to N. 30° E. and dips about 50° S. 80° E. to S. 60° E. The outcrop is traced for nearly a mile by lines of old pits and dumps. The ore shoots are somewhat irregular, but are reported to swing almost due east.

HOG MOUNTAIN.

GEOGRAPHY.

Hog Mountain is situated in the east-central part of Alabama, in the northern part of Tallapoosa County, and is about 12 miles east of Goodwater and about the same distance a little east of north of Alexander, stations on the Central of Georgia Railway.

Hog Mountain derives its name from its profile as seen from the lower country to the west. It is formed by three prominent knolls connected by saddlebacks and lying in a north-south direction. A short distance to the east, and separated from it by a rather narrow valley, lies a somewhat similar group of knolls known as Little Hog Mountain. Of Hog Mountain proper the north knoll rises slightly above 1,000 feet, the middle knoll is about 860 feet high, and the smaller knoll to the south rises slightly above the 800-foot contour.

HISTORY.

The early history of the explorations on Hog Mountain is very imperfectly known. The first definite reference to these deposits in the reports of the Geological Survey of Alabama is apparently that of W. B. Phillips,[a] who mentions them in connection with the well-defined Goldville belt lying in the slates immediately to the southeast. The deposits were first worked along the outcrops some time before the civil war, and much free gold was undoubtedly extracted by the crude methods in use at that time. More recently shafts were sunk on the south knoll, and tunnels now inaccessible were driven, to provide ore for a 10-stamp mill situated at the base of the hill on the

[a] Op. cit.

western side. Within the last few years the Hillabee Gold Mining Company has carried on a large amount of exploratory work to expose the ore bodies, and of experimental work to solve the difficult problem of the best method of treating the ores. The Hog Mountain mines have been the principal producers of the precious metals in Alabama during this time.

GEOLOGY.

The slates of Hog Mountain, presumably Ocoee, form the east and west flanks and the north slope of the hill, and a fine-grained granite, apparently intrusive, occupies the ridge of the hill and the crests of the knolls. This granite extends southward along the ridge, and is probably related to the great area of presumably igneous and certainly highly metamorphosed rock bordered by the slates and extending from southwest to northeast through Coosa and Clay counties and wedging out in southern Cleburne County. The general dip of the slates is here about 60° S. 60° E. and the exposed ridge of granite cuts across these rocks in a direction almost due north and south.

Considerable detailed work will be required to make clear the structure of Hog Mountain. The observed dips of the slate are, however, fairly persistent in the direction S. 60° E., and in two exposures underground on the northwestern and western sides of the hill the slate passes under the granite. Conclusive evidence of faulting was not observed at this place. The igneous intrusive therefore seems to have forced its way between the planes of schistosity of the slates and to lie in this part of Hog Mountain in a great tabular mass whose dip would roughly conform with that of the schistosity. This question of structure is of considerable economic importance, as the veins here profitably worked are confined to the granite. As the granite is not gneissoid it has not been folded with the slates and is therefore later than their dynamometamorphism.

The slate is a fine-grained mica slate, dark gray in color in the fresh specimens and weathering to reddish brown. Some quartz and considerable white mica may be distinguished megascopically. Planes of schistosity are brought out by weathering, but are not readily seen in fresh samples. White mica (muscovite) is well developed along these planes. Under the microscope the rock exhibits a finely granular texture and allotriomorphic structure. Rounded quartz grains have been crushed and recrystallized. Feldspars are not determinable, being probably altered to fine scales of sericite, which occur in aggregates of irregular form. A marked development of muscovite is noted, and there is some light-brown biotite in small flakes, apparently secondary. Magnetite grains occur in the muscovite very plentifully and fine needles of apatite are found in the quartz and micas. The occurrence of tourmaline in small prisms is observed. At the granite contact and near the Blue vein considerable pyrrhotite is found in the slates. The rock seems to be a dynamometamorphosed muddy sediment that was later somewhat altered by contact metamorphism following the granite intrusion.

The granite is a normal fine-grained granite of hypidiomorphic structure, and is made up of biotite, orthoclase, and quartz. A plagioclase with albite-oligoclase characteristics occurs very rarely, and some muscovite is noted. As inclusions are found magnetite in the biotite and apatite in the orthoclase. The orthoclase shows notable alteration to sericite. Some of the crystals of this feldspar are idiomorphic and are fairly well bounded by zones showing varying extinction. The quartz is in mosaics of irregular anhedra filling spaces between the micas and the feldspars, is fairly fresh and free from inclusions, and shows few strain shadows. The muscovite is rare, but present in shreds and flakes and as sericite in minute scales and foils. Pyrrhotite occurs rather plentifully in the sample of fresh rock obtained from the vein walls and is associated with quartz and biotite. Garnet, colorless in transmitted light, occurs locally in both anhedral and euhedral forms replacing quartz and feldspar grains, and is isotropic in part. The rock is a typical fine-grained intrusive granite showing only traces of dynamometamorphism. From a comparison of these data with unpublished notes of C. W. Hayes on the granite at Villarica, Ga., which is the youngest acidic intrusive observed by Doctor Hayes in Alabama or Georgia and in which the ore deposits of Villarica are reported to be, the rocks would seem to be remarkably alike. Mineralogically, however, the granite at Villarica contains an excess of muscovite over biotite.

ORE DEPOSITS.

The ore deposits of Hog Mountain are fissure veins in a granite that is apparently intrusive in the slates. They are confined, so far as explored, to the granite, and pinch out or fork on reaching the contact with the slates. On the north knoll the general strike of the veins is northeast and southwest. On the middle knoll, however, and on the western slopes of the saddle between these knolls the veins strike nearly east and west, although the two largest, the Barren vein and the Blue vein, swing around to the northeast on the south slopes of the north knoll and on approaching the eastern edge of exposed granite. The veins are steeply inclined and dip to the northwest. The slates are known to cover at least a portion of the flanks of the eastern area of the granite, as the Blue vein has been followed in granite for a short distance under the slates on this side of the mountain. The veins show a general tendency to decrease in width from a line about midway between the granite-slate contacts, and to taper out irregularly and gradually on approaching the slates until at the contact they pinch out. Three of the veins on the middle knoll, whose horizontal extensions, as shown by the outcrops and shallow workings, seem to be not more than from 600 to 800 feet, apparently do not reach the slates before pinching out. They range in width from 6 inches to 8 feet. The veins have in general continued of good width and values, so far as exposed from the higher surface croppings to the 100-foot level, through a vertical distance of about 300 feet. Displacement has apparently followed the fracturing of the granite to but a very slight extent. The ore shoots have so far not been definitely determined, but their pitch is apparently to the north and is therefore somewhat flatter than the dip of the veins. The greater parts of the veins seem to be ore bearing, and as the ore is almost all of comparatively low grade the limits of the ore shoots would naturally be rather poorly defined. If the intrusive granite proves to be in a broad, thick sheet, as indicated above, the economic importance of the swinging of the ore shoots away from a westerly direction is obvious.

The chief ore mineral is auriferous pyrrhotite. With this occurs a little pyrite and rarely traces of chalcopyrite. The gold obtained is associated not only with these minerals, but also with the dark-blue quartz. The gangue is quartz, of at least two generations. The older or "blue" quartz is somewhat glassy and smoky in appearance, is dark blue in color, and is fairly clouded with minute inclusions of liquids and gases and of several opaque and semiopaque substances not determinable under the highest powers of the microscope. This quartz shows abundant strain shadows and some apparent granulation and recrystallization, indicating crushing of the vein matter. The hand specimen of ore exhibits the general appearance of brecciation of the earlier quartz filling, followed by the introduction of the sulphides, in part at least, and by fresh quartz. The latter is light-colored, ordinary vein quartz, fairly free from inclusions and undulatory extinction. Near the walls of the vein large foils of muscovite and veinlets of tourmaline occur with the quartz, and the sulphides are also present in the granite itself. The orthoclase of the granite is also altered in part to sericite and includes apatite. The granite contains garnets at the contact with the slates, where fine stringers of quartz and pyrrhotite are found. The orthoclase of the slates is altered to sericite and the presence of tourmaline was noted in thin sections. Selvage is lacking.

The gold ores of Hog Mountain have in practice proved to be almost invariably of low grade. A number of assay returns were published by W. B. Phillips[a] in 1892, and four of these were from

[a] Op. cit., pp. 49–54.

samples collected by him at random from old dumps. These four showed gold 2.8, 0.3, 1.1, and 0.5 ounces; silver, 0.8 ounce, trace, trace, and 0.2 ounce per ton; and total values of $58.67, $6.20, $22.73, and $10.53 per ton. Mr. A. F. Hoffer had some assays made of Hog Mountain ores in 1886 and 1887, "perhaps sixty or seventy," and, according to his recollection, the values ranged from $2 to $31 and averaged about $7.50. Extensive sampling underground has returned average assay values of $9 to $10 per ton; and 99 per cent of this is in gold. Extraction, however, has so far given considerably lower returns than this. Richer ore is occasionally found, but on the other hand the values have been at times as low as $2 according to reports quoted above.

The surface or "red" ores are oxidized and are largely free-milling. The Barren vein is so called from the fact that it carried only traces of gold at the outcrop, but the vein furnishes good ore below. At the present time the "blue" or unoxidized ore is supplying much of the output and is treated with the surface ores.

The free-milling surface ores were treated in the early days by crude washing operations. Later a 10-stamp California mill was erected. A report from the St. Louis Sampling and Testing Works, submitted in 1889 as the result of a trial mill run of a small lot of Hog Mountain ore,[a] showed a saving by amalgamation of 73.7 per cent of the gold.

The present process, worked out on the ground during two years of experiments by Mr. T. H. Aldrich, jr., and Mr. A. P. Kennedy, combines the rather original feature of heating in a revolving kiln to 350° F. with coarse crushing and cyaniding. Fine crushing had been tried and found a failure. The ore is crushed between two sets of rolls to pass through ½-inch and ⅛-inch screen slots, and is then introduced directly into a revolving kiln in which a temperature of 350° F. is maintained by wood firing. From the kiln the ore is trammed direct to the cyanide vats. The process is at present experimental, but has so far been fairly successful both with the usual mixture of two-thirds of "red" ore to one-third of "blue," and with the "blue" ores alone. The effect of the kiln treatment is not an oxidizing roast, as this is not desired, but seems to be the thorough shattering of the quartz, due partly perhaps to increased internal pressure of included gases, and the great increase, thereby, of porosity in the ore and of leaching by the cyanide. As complete analyses are not yet available and as minute opaque substances in the ore are yet undetermined, intelligent discussion of processes of treatment is difficult.

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[a] Phillips, W. B., op. cit., p. 53.

THE TALLAPOOSA MINE.

Lying in the middle of the central slate belt, as outlined in the description of the Gold Ridge mines, and about 4 miles southeast of Hog Mountain, is the Tallapoosa mine. This mine is apparently along the line of strike of the Goldville belt of gold deposits described by Phillips [a] as extending from Hillabee Bridge to Goldville, in Tallapoosa County, a distance of 14 miles. The country rock is the Ocoee slate, and the ore bodies are lens-shaped quartz veins striking N. 23° E. to N. 35° E. and dipping 45° S. 67° E. to S. 55° E. One vein only has been extensively developed. This is from 6 inches to 4 feet thick and usually lies between the walls of dark-blue fine-grained mica schist or slate, but here and there crosses the planes of schistosity at slight angles. The vein is somewhat banded in structure and consists in part of alternating bands of white and dark-blue quartz with white and brown mica developed along parting planes. In places the walls of fine-grained slate contain narrow flattened "rods" of quartz lying with longer axes parallel to the strike of the schistosity and resembling the "pipes" of similar material and structure of the Gold Ridge mines. The vein swells and pinches, parts and reunites, but holds its persistent strike and dip fairly well. The slate walls are in many places much crumpled.

At the surface the wall rock is weathered to reddish-brown clay and the vein matter is usually a rather sandy and friable white or iron-stained quartz, with parting planes of white mica. The gold is free-milling and much of it occurs in large flakes or grains. With increasing depth the gold becomes finer and for the most part locked up in iron sulphides, although even below water level it is free-milling in part. The greater part of the work in this mine has been the extraction of the oxidized ores, and rich pockets have frequently been found. The average value of the ore is reported to be about $16 to the ton.

The present workings consist of an inclined shaft down 185 feet, from which drifts have been laid off on both sides. The surface ore to water level, at a vertical depth of about 40 feet, has been largely stoped out. The process of treatment has been amalgamation, stamp milling, fine crushing, and cyanidation, and a modern plant of solid construction was erected, but was run only a short time before closing down pending the company's reorganization.

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[a] Phillips, W. B., op. cit., pp. 36–48.

THE MINERAL DEPOSITS OF THE CERBAT RANGE, BLACK MOUNTAINS, AND GRAND WASH CLIFFS, MOHAVE COUNTY, ARIZ.

By F. C. SCHRADER.

INTRODUCTION.

The field work forming the basis of this paper was a reconnaissance made by the writer under the direction of Waldemar Lindgren from October, 1906, to February, 1907. The purpose of the work was to obtain a general idea of the mineral resources of western Arizona, concerning which relatively little has hitherto been known. The writer wishes to express here his appreciation for the valuable assistance he has received from mining men throughout the field, from members of the division of chemical and physical research of the Survey, and from Mr. Lindgren, who has also made the microscopic determinations of the rocks and ores herein described.

DESCRIPTION OF THE REGION.

LOCATION.

The region containing the deposits here described, as outlined in the accompanying sketch map (fig. 1), lies in the central part of Mohave County, Ariz., on the main line of the Atchison, Topeka and Santa Fe Railway. It is bordered on the west by Nevada and California, from which it is separated by Colorado River, and on the east by the Colorado Plateau and similar highlands extending southward, from which it is separated by the Grand Wash Cliffs and their southern continuations. It extends from a point near the Big Bend of the Colorado and the mouth of the Grand Canyon on the north to Mellen and the southern extremity of the Black Mountains on the south, a distance of 90 miles. Its width is about 75 miles and its area about 7,000 square miles. Most of the region is shown on the Camp Mohave and Diamond Creek topographic sheets of the United States Geological Survey.

The principal towns are Kingman, Hackberry, Chloride, Gold Road, and Vivian. Kingman, the county seat of Mohave County, situated on the railroad, is the principal distributing point for nearly all the mining districts of northwestern Arizona and adjacent parts of Nevada. Chloride, situated about 20 miles north of Kingman and connected with it by a branch railroad, is the principal

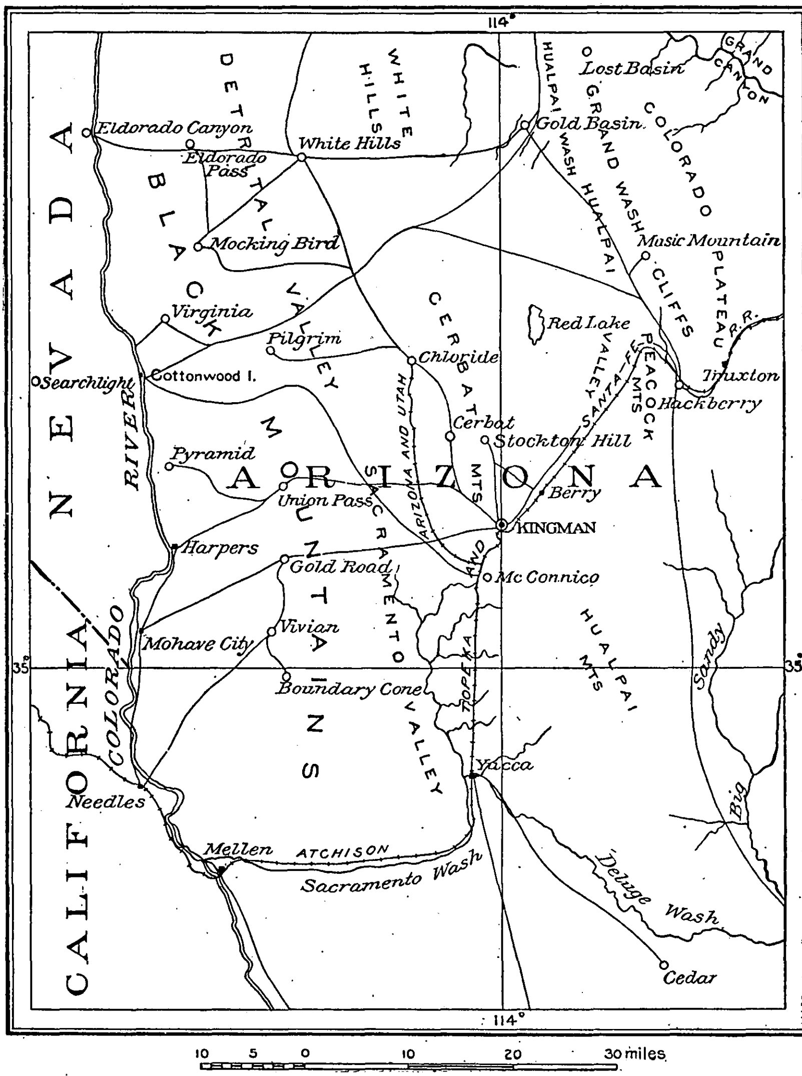

FIG. 1.—Map showing mining camps in a part of western Arizona.

trading point for the northwestern part of the region. Hackberry is situated in the eastern part of the region, on the railroad; Gold Road is in the western part, about 24 miles southwest of Kingman, on the upper west slope of the Black Mountains; and Vivian is about 3 miles southwest of Gold Road.

TOPOGRAPHY AND DRAINAGE.

The principal topographic features of this region are barren desert ranges and intervening broad, plainlike, gently sloping, detritus-filled valleys, the southward extensions of the features of the Great Basin so well known in Nevada. In addition are the great trough of the Colorado on the west and the Grand Wash Cliffs on the east. There is a marked parallelism of all these features, and they trend a little north of west.

The elevation ranges from 500 feet on the southwest, at Colorado River, to 8,266 feet on Hualpai Peak, but the mountains average somewhat less than 5,000 feet in elevation, and the valleys about 2,500 feet. The general slope of the region is southwestward toward the Colorado, into which all the drainage leads.

The mountains seem in general to be due to erosion, but portions are deformational forms or fault blocks. They are more or less rugged and largely exhibit the rounded forms produced by the weathering of granite. They are composed mainly of a pre-Cambrian complex of granitoid and metamorphic rocks and are flanked or locally overlain by Tertiary or younger volcanic rocks.

The ranges, like the valleys, average 10 or 12 miles in width and their aggregate area is about equal to that of the valleys. Named in order from east to west they are the Grand Wash Cliffs, Cerbat Range, Black Mountains, and Eldorado Range. The first two are separated by Hualpai Valley, the second and third by Detrital and Sacramento valleys, and the last two by the great trough of Colorado River.

The Grand Wash Cliffs, well developed on the northeast, mark the great fault scarp between the Colorado Plateau at an elevation of 6,500 feet and the Hualpai Valley 3,000 feet below.

The Cerbat Range, which is somewhat broken above Chloride and at Kingman, consists from north to south of the White Hills, the Cerbat Mountains, and the Hualpai Mountains, as indicated on the accompanying map. The Peacock Mountains, situated between Kingman and Hackberry, are a spur or outlier of the Hualpai Mountains.

The Black Mountains lie between Detrital and Sacramento valleys on the east and the great trough of the Colorado on the west. Their western side for the most part descends from an elevation of 5,500 feet at the crest, in long, gentle, lava or gravel covered, canyon-scored, graded slopes, to the elevation of 500 or 600 feet at the river.

Rising from the great trough of the Colorado on the west to a maximum height of 6,000 feet along the eastern border of Nevada, is the Eldorado Range, which contains the Searchlight, Eldorado Canyon, and other producing camps. This range is not discussed in this paper, the descriptions being confined to the Arizona mines.

GEOLOGY.

The principal rock formations of the region are the pre-Cambrian complex, the Paleozoic sediments, and the Tertiary volcanic rocks.

PRE-CAMBRIAN ROCKS.

The pre-Cambrian complex consists essentially of coarse, in places roughly porphyritic, granite and granitoid rocks, gneisses, and schists of various kinds. It contains numerous quartz veins and lodes, in which occur the mineral deposits mined in the Cerbat Range and Grand Wash Cliffs. Its rocks have been extensively subjected to dynamic forces which have affected them in varying degrees in different regions. The dominant trend of the schistosity is about N. 30° E., with dip vertical or eastward, usually at steep angles, and the main jointing strikes north-northwest, with dip vertical or steeply inclined to the east-northeast. This latter direction is also approximately the trend of most of the fissures containing the quartz veins. These rocks are widely distributed. They largely constitute the mountain ranges and underlie the region as a whole, forming the eroded, uneven floor upon which all the other formations rest. They make up the greater portion of the Grand Wash Cliffs, whence they extend eastward beneath the Paleozoic rocks of the Colorado Plateau. They compose the greater part of the White Hills and practically the whole of the Cerbat, Hualpai, and Peacock mountains. They are also the principal rocks exposed in the northern part of the Black Mountains and are prominent in the Eldorado Range beyond Colorado River.

PALEOZOIC SEDIMENTS.

About the only Paleozoic sediments of the area are the Tonto (Cambrian?) and the Redwall (Carboniferous) formations, which form the upper part of the Grand Wash Cliffs on the east. At one time they must have covered the entire region, from which they have since been eroded.

OLDER INTRUSIVES.

The pre-Cambrian rocks are locally intruded by igneous masses and dikes which are considerably older than the Tertiary volcanic rocks next to be described, but whose age is not definitely known. The most important of these intrusives are granite and quartz syenite porphyry.

GRANITE.

The intrusive granite occurs mainly in the Cerbat Mountains, where it extends interruptedly from Stockton Hill to Chloride, being practically coextensive with the mineral belt of the mountains. The principal masses, however, occur in the Mineral Park district, where the granite forms the upper part of a prominent foothill or knob on the northwest known as "Niggerhead." It also constitutes a considerable portion of the mountains on the opposite side of the wash to the south, and extends interruptedly throughout the greater portion of the basin eastward for a distance of 1½ miles into the slope of the range. Its structure or jointing, well shown across the northern part of the Mineral Park district, dips westward at angles of about 35°.

In a fresh specimen the granite is normally a light gray to white, medium to fine grained, granular aplitic microcline granite. It usually contains garnet and a very little biotite. The rock has a pronounced gneissoid or schistose structure, and weathers from light brown to dark, by reason of which it is not easily distinguishable in the field from its pre-Cambrian host.

QUARTZ SYENITE PORPHYRY.

The quartz syenite porphyry is a pinkish, medium to coarse grained rock, composed essentially of a quartz-orthoclase groundmass, largely orthoclase, in which the quartz occurs in granophyric growths. The principal other minerals present are biotite or chlorite derived from biotite and a small amount of magnetite, the latter occurring in small grains.

This rock occurs in two masses, one of which makes up the Hardy Mountains, an outlying group several miles in diameter, situated about 2½ miles west of Gold Road; the other occupies an area of unknown extent embracing the hills in the vicinity of the Moss mine, about 4 miles northwest of Gold Road.

TERTIARY VOLCANIC ROCKS.

GENERAL OUTLINE.

The erosion of the Paleozoic sediments from the region was followed by the eruption of a great mass of Tertiary lavas which more or less completely covered the entire area. The present bodies of these rocks, ranging from mere local outcrops to mountain masses occupying several hundred square miles and presenting sections 3,000 feet in thickness, are mere remnants of the former vast lava field which extended over the region. The rocks consist essentially of andesites, trachytes, rhyolites, dacites, and latites disposed in broad superimposed flow sheets with intercalated beds of ash, tuff, and flow breccia. They are best developed in the Black Mountains, particularly in the southern part, and contain most of the mineral deposits occurring in that range.

OLDER ANDESITE.

The oldest or basal formation of the Tertiary volcanic series, as exposed in the Vivian region, is a light-gray, purple, or pale-green medium to fine grained tufaceous andesite. It commonly contains chlorite, calcite, and biotite and is locally silicified or rhyolitic. It is at least several hundred feet thick, and occupies the border of the foothills extending from a point near the Vivian and Leland mines southwestward to the mesa of the Colorado, 1 or 2 miles distant. It is not known to contain mineral deposits of commercial value. West of the Leland mine it is intruded by dikes of the green chloritic andesite next to be described.

GREEN CHLORITIC ANDESITE.

Overlying the older andesite on the northeast is the second formation of the series, an altered green andesite, locally known as "antique porphyry." It is highly porphyritic and consists essentially of innumerable phenocrysts of white feldspar about three-eighths of an inch in maximum diameter embedded in a medium to fine grained green chloritic groundmass. It is locally calcitic or pyritic. In some places it contains a little quartz and magnetite, and in others chalcedony-pyrite veinlets. In the unaltered state, however, exposures of which are few, the rock is black, with the phenocrysts fresh and glassy.

This formation extends from Vivian northward to the Mossback mine. It occupies an area of 35 or 40 square miles and has a maximum thickness of 800 feet. It is disposed in heavy beds or flows inclining gently eastward into the range.

UNDIFFERENTIATED VOLCANIC ROCKS.

Overlying the green chloritic andesite in the Gold Road district is a group of about 2,000 feet of as yet undifferentiated volcanics consisting essentially of andesites, trachytes, rhyolites, and latites. This group constitutes the bulk of the range in this locality and is important economically, as it contains the Gold Road vein and neighboring deposits. It extends from the vicinity of the Gold Road mine nearly to the summit of the range and has produced the rugged topography of that district.

RHYOLITE.

The above-described undifferentiated rocks are overlain by the fourth formation of the series, consisting of a group of rhyolites composed of tuffs, ash, flows, and breccias. In some localities this group attains a thickness of 1,000 feet or more. It extends interruptedly throughout the length of the Black Mountains, and is known as the "water rock," from springs that occur in it.

In the Cerbat Range it essentially composes the Kingman Mesa, situated between the Cerbat and Hualpai mountains, and surrounds

Kingman, where the tuffs seem in part at least to be water-laid. It also interruptedly borders a considerable portion of the western base of the Cerbat Mountains. Its dikes cut nearly all the underlying volcanic rocks as well as the pre-Cambrian complex.

YOUNGER ANDESITE.

Overlying the rhyolite and locally cutting it as dikes is the fifth formation of the series, consisting of local flows of dark-reddish andesite. It occurs in the Gold Road region and in the Cerbat Mountains northwest of Kingman. It is usually dense, but is locally vesicular and resembles the overlying basalt.

OLIVINE BASALT.

The youngest of the effusives is black olivine basalt. It occurs in sheets of two or more periods locally overlying and cutting through the older rocks, including the andesite last described and the Quaternary gravels. It is usually dense, but is locally vesicular or amygdaloidal.

MINERAL DEPOSITS.

METALLIC MINERALS.

INTRODUCTION.

The discovery of metallic mineral deposits in this region dates from early in the sixties, when rich gold ore was found at what has since been known as the Moss mine, situated about 4 miles northwest of Gold Road near the old Camp Mohave trail. A decade later the discovery of silver-gold ore in the Cerbat Range drew the attention of prospectors thither, and the rich veins of the Cerbat and Hualpai mountains were opened. The ores from these mines were so rich that large profits were returned from them, although the expense of freight and treatment ran into hundreds of dollars per ton, owing to the fact that they had to be packed long distances on burros to Colorado River, thence transported by river steamer down the Gulf of California and up the coast to San Francisco, whence they were shipped to England for treatment. This was the method of marketing ores until the advent of the railroad in 1882. During this period the region was classed as a silver camp, until the decline of silver drove prospectors back into the gold belt of the country. Later the Gold Road and Vivian mines, to which the San Francisco mining district owes its present prosperity, were found.

Up to the eighties, for want of transportation facilities and machinery, there were but few shafts more than 150 feet deep, although the production of high-grade ores ran well up into the millions.

With the advent of the railroad a new mining era began and practically the first development work below water level was inaugurated. During the last few years the industry has taken a new lease and many properties are being exploited and opened up. Old and abandoned mines are being unwatered and their dumps tested and cyanided or milled. With deeper and more systematic mining, new ore shoots are found, and the once "low-grade" ore bodies are utilized by means of the latest improved milling and value-saving apparatus. This activity, with the reduction in shipping rates to the smelters, marks an epoch in the history of mining in this region and enables the owner to handle his dump ores at a fair profit. In the early days the smelters paid for silver only, making no allowance for the gold, lead, or copper contained in the ore, but now the producer receives pay for all these metals.

GENERAL CHARACTER OF THE DEPOSITS.

The metallic deposits occurring in the ranges here described contain gold, silver, lead, copper, zinc, and tungsten, and exhibit considerable diversity in character and occurrence. They naturally fall into two very distinct groups. The first consists of quartz fissure veins containing pyrite, galena, zinc blende, and locally also arsenopyrite. The sulphides yield principally silver, but also gold. These deposits are confined chiefly to the Cerbat Range and usually occur in the pre-Cambrian rocks. It is possible that they are genetically connected with the intrusive mass of light-colored aplitic granite which breaks through the pre-Cambrian rocks in the Cerbat Mountains mainly in the Mineral Park district. They are oxidized to a depth ranging from 50 to 300 feet. The change from the oxidized to the unoxidized ore is not usually sharply defined, but occurs within a zone having a vertical range of 10 to 20 feet or more. At the present time the sulphide ores are principally utilized. In the oxidized zone cerargyrite, or horn silver, is the principal valuable mineral, but is at many places accompanied by native silver and ruby silver. The water level is found at about 400 feet below the surface.

The second group comprises the deposits of the Black Mountains. They differ markedly from those of the Cerbat Range just described in four important respects. First, they occur chiefly in the Tertiary volcanic rocks, especially in the green chloritic andesite, and are younger than the Cerbat veins. Secondly, though they occur chiefly in fissure veins, these veins seem to have originally contained a calcite gangue, which is still present in many of them. In the most valuable deposits, however, a mineralogical change has taken place by which the calcite has been replaced by quartz and adularia. Third, the values are almost exclusively gold. Fourth, the oxidation extends to a depth of 600 or 700 feet, and, as a rule, no sulphides are found. The general water level is probably about 700 or more feet below the surface.

The deposits as a whole seem to owe their origin to mineralized, principally hot-water solutions that circulated through the fissures and fractures they now occupy.

Owing to the great number of the deposits, their mode of occurrence, the "chloriding" method pursued in the past for the removal of values, and the fact that work was generally abandoned when water was encountered, the area contains a large number of small mines, which are either producing or capable of becoming productive. In the following descriptions these may be most conveniently considered by districts, of which the most important are the Chloride district in the Cerbat Range and the Gold Road district in the Black Mountains. No attempt is made to identify these areas with the legally established mining districts.

DETAILED DESCRIPTIONS.

CERBAT RANGE.

INTRODUCTION.

The principal districts in the Cerbat Range, named in order from north to south, are the Gold Basin, White Hills, Chloride, Mineral Park, Cerbat, Stockton Hill, McConnico, and Maynard. Of these the four most important are the Chloride, Mineral Park, Cerbat, and Stockton Hill districts. These are located in the middle part of the Cerbat Mountains, extending from a point just south of Stockton Hill and Cerbat to a point north of Chloride, a distance of about 12 miles, and they have certain features in common.

The rocks of this portion of the mountains, as described under "Geology," are essentially of the pre-Cambrian complex and consist of gray granite, gneissoid granite, and dark schists, including hornblende, mica, and garnet schists. They are flanked on the west in the Cerbat district by local areas of rhyolite and other Tertiary volcanic rocks. To the north, through Mineral Park and toward Chloride, they are intruded by granite masses. Furthermore, they are locally cut by dikes of pegmatite, aplitic granite, diabase, vogesite, kersantite, minette, and rhyolite.

The deposits occur in well-defined fissure veins, of which there are two sets, one striking about N. 20° or 30° W., and the other N. 70° W., usually with steep dips. Some of the deposits are also intimately associated with the vogesite, minette, and aplitic dikes.

The croppings, which are generally prominent, consist of red or dark reddish-brown iron and manganese stained quartz and altered, silicified country rock. Many of the veins are frozen to the walls;

others are separated from them by several inches of soft argillaceous or talcose gouge. The gangue is quartz and the ores are sulphides of silver, lead, copper, and zinc, generally containing gold. Silver and lead predominate in the Chloride, Mineral Park, and Stockton Hill districts, and gold and silver in the Cerbat district.

The ore deposits as seen in some mines suggest two epochs of ore deposition which have been followed by deep oxidation and sulphide enrichment. The great depth of this oxidized ore is a favorable indication for the future of the district. Many of the mines, notably in the Chloride and Mineral Park districts, which near the surface were silver mines, with increase in depth have become base-metal or lead mines, and with greater depths are becoming cupriferous. The so-called copper belt of the area extends from Mineral Park northwestward toward Chloride, a distance of several miles.

CHLORIDE DISTRICT.

General outline.—The Chloride district, the most important in the region, is situated about 20 miles north-northwest of Kingman, on the west slope of the Cerbat Mountains and the adjacent border of Sacramento Valley. It covers an irregular area about 6 miles in diameter. The mountainous portion is in part rugged, and is scored by several deep washes. Within a distance of about 2 miles the surface descends from the altitude of 6,000 feet at the crest of the range to about 4,000 feet at its base, where it meets the plain of Sacramento Valley.

Chloride, the shipping and distributing point, is favorably situated just northwest of the center of the district in the open border of the valley at 4,000 feet elevation. As a camp it dates from the early sixties and as a town from the early seventies. From that time it continued to be more or less active and in 1899 and 1900 reached its zenith, with a population of about 2,000; but for the last four or five years it has been very quiet. Several of the more important mines, however, are in operation and considerable work is being done on a score of other good properties. Lack of water has been the chief drawback, but the deeper mines show that by sinking wells plenty of water can be obtained.

Many of the veins are persistent and have an extent of nearly a mile. The ores carry principally silver and lead, with some gold and copper. They have produced several hundred thousand tons of lead and several millions of dollars in gold and silver. Exact figures are not available.

The district contains about 20 mines, located mostly in the lower slope of the mountains. Six of these mines have been opened to depths of 500 to 600 feet, and many others range from 200 to 300 feet in depth. The most important are the Tennessee, Samoa, Lucky

Boy, Towne, Pinkham, Altata, Midnight, Minnesota-Connor, Elkhart, Schuylkill, Juno, and Pay Roll, the first seven being the principal present producers. Of these the Samoa, Minnesota-Connor, and Tennessee are the most prominent.

Tennessee mine.—The Tennessee mine is located a mile east of Chloride, at the base of the mountains, its elevation being 4,050 feet. The country rock is pre-Cambrian gneiss, with granite and schist occurring near by. The gneiss is composed essentially of sericitized feldspar and crushed quartz. The mine is located on the Tennessee vein, which further north has also been opened by the Schuylkill and Elkhart mines. It is developed to the depth of 600 feet by two shafts and six levels, which aggregate about 5,000 feet of workings. It produces some water. The principal surface improvements are a well-equipped 100-ton concentrating mill and two steam hoists.

The vein dips steeply to the east. The croppings show quartz stained brown or black by iron and manganese oxides. The walls are hard, smooth, and regular and show several systems of slickensiding. In places the vein itself is fissured. The ore contains the sulphides of lead, zinc, and iron, carrying silver values and some gold and copper. Its average run of mine, omitting zinc, is about as follows: Lead, 20 to 70 per cent, concentrates 75 per cent; silver, 8 ounces, concentrates 25 ounces; gold, small amount; copper, some in deep part of mine. Of the output about one-third is high-grade shipping ore; the remainder is milled.

The mine has been productive from the surface. Thousands of tons of rich galena have been shipped to the smelter from the upper 400 feet. Here the ore shoot had a horizontal extent of about 250 feet, and was locally 15 feet in width. There is still much good ore in this section of the mine. On the 400-foot level solid galena was mined for a vein width of 21 feet and 5 inches, extending horizontally for about 40 feet. From the fourth to the fifth level there is a decrease in the value of the ore due to local increase of zinc, but from the fifth to the sixth level the ore again contains more lead. The 500-foot level contains good ore for a distance of 800 feet and the upraise from it yields much solid galena. Toward the end of the 200-foot drift north, on the 600-foot level, the vein now shows about as follows beginning on the hanging-wall side: Good ore with quartz coming in toward hanging wall, 2 feet 9 inches; milky quartz waste, 8 inches; fair-grade ore with bunches or lenses of feldspar and quartz, 7 feet. It is stated that the tailings on the dump contain much zinc blende which can be recovered by concentration. The ore is shipped to the smelter at Needles, on Colorado River, or to Deming, in southwestern New Mexico.

Samoa mine.—The Samoa mine is situated 3½ miles east of Chloride, near the crest of the range, at an elevation of about 6,000 feet.

It is developed to a depth of about 400 feet by tunnels, shafts, and drifts, aggregating over 3,000 feet of underground work. It produces some water. The principal surface improvements are two well-equipped power plants, with gasoline engines, aggregating about 90 horsepower, for operating the steam and air-compressor drills and the hoists. The country rock is principally dark medium-grained biotite granite of pre-Cambrian (?) age. It is intruded by the light aplitic granite near by. There are six veins, which strike nearly north and are either vertical or dip steeply to the east. Of these the principal producer, known as No. 3, is about 4 feet thick and its ore shoot ranges from 1 to 30 inches in width. The ore contains gold and silver, some galena, pyrite, zinc blende, and here and there a little molybdenum. As shown by the smelter return sheets from 1903 to 1906 inclusive, it averages about as follows: Gold, 1½ ounces; silver, 15 ounces per ton; lead, 8 per cent; and zinc, 5 to 8 per cent. The total production has been about $180,000. The present rate of output is about 90 tons per month. The ore is shipped principally to the Needles smelter.

Towne mine.—The Towne mine is situated 1¼ miles southeast of Chloride, in the Sacramento Valley about one-half mile from the base of the mountains. It is developed by six shafts and drifts. It produces considerable water. The country rock is pre-Cambrian schist. A vogesite dike is associated with the vein on the foot-wall side. The vein, which is 3 to 8 feet wide, dips steeply to the north. The gangue is quartz and the ore shoot, ranging from 3 to 18 inches in width, averages about 5 inches and favors the foot-wall or dike side of the vein. The ore contains silver, gold, copper, lead, and zinc and runs about $200 per ton mostly in gold and silver. The production from 1882 to 1906 was about $100,000.

Pinkham mine.—The Pinkham mine, perhaps the most important copper mine of the region, is located about 2 miles southeast of Chloride, near the foot of the mountains. It is developed by a 250-foot shaft and five levels containing about 1,000 feet of drift and crosscuts. It contains considerable water. The principal surface equipments are a steam hoist and two smelters, one coke and one oil, both recently installed. The country rock is pre-Cambrian granite. The vein is about 12 feet in width. It strikes N. 30° W. and is nearly vertical. The ore occurs in elongated lentils and chimneys. It is mostly chalcopyrite and bornite associated with iron sulphide, and averages about 3 per cent of copper and 18 ounces per ton of silver.

Midnight mine.—In the Midnight mine, situated near the Pinkham mine, the vein is less well defined than the Pinkham vein and contains considerable zinc. A recent carload shipment of the ore ran silver 66 ounces per ton, copper 4.5 per cent, and gold $2.50 per ton. The production under the present management is reported to be 100 tons of shipping ore, averaging $50 per ton, and 2,000 tons of milling ore, containing values of about $10 per ton.

In association with the Pinkham and Midnight deposits or cutting the pre-Cambrian rocks near by are microcline granite and diabase dikes.

MINERAL PARK DISTRICT.

General outline.—The Mineral Park district lies about 4 miles southeast of Chloride, mainly in a basin several miles in diameter, between the elevations of 4,000 and 5,000 feet. The drainage issues westward into the Sacramento Valley, mostly through Mineral Park Wash. Chloride is the principal supply point, but ore and heavy freight are hauled direct to the railroad 3 miles west.

The first locations were made in 1870, when considerable ore was soon taken out and shipped to the Selby smelter at San Francisco, at a cost for freight of $125 per ton. Production continued more or less active until 1882, since which time it has been small, only a few of the mines being worked.

The pre-Cambrian complex is here intruded by the Mineral Park mass of aplitic granite and by dikes of rhyolite, diabase, and minette. The deposits contain gold, silver, lead, and copper, which usually occur together, mostly in fissure veins or lodes, some of which are extensive. The mines, numbering about 20, are small. Few of them exceed 300 feet in depth or 1,000 feet in amount of underground work. Some of the principal ones are the Rural, Buckeye, Ark, Queen Bee, Tyler, Keystone, Fairchild, Metallic, Accident, Lady Bug, Standard, and Golden Star. The most important producers at present are the Keystone, Tyler, and Queen Bee.

Keystone mine.—The Keystone mine is situated on open ground, about one-fourth mile east of Mineral Park. It is developed mainly by a 450-foot shaft and 500 feet of drifts, mostly down to the 150-foot level, above which the greater part of the ore is worked out. The principal country rock is aplitic granite. The vein dips steeply to the north. The ore occurs mostly as lenses about 1 foot wide in a quartz gangue. It contains silver, copper, zinc, and iron, the better grade running 200 ounces per ton in silver, some of which is glance; 2½ per cent of copper; 8 or 10 per cent of zinc; and about 12 per cent of iron. Locally it is irregularly banded toward the outside of the lenses. It is richest where the vein pinches. The ore averaging $20 or more per ton is shipped to the Humboldt smelter. None lower than this grade is handled. The output is about 20 tons per month. As most of the ore runs $12 to $15 per ton, it should be milled on the ground. The total production is stated to be $50,000.

Tyler mine.—The Tyler mine is located 2¾ miles southeast of Mineral Park, near the summit of the range, on a steep northeast slope.

It is developed by crosscut tunnels and drifts, mostly within a vertical range of 100 feet. The country rock is sheared pre-Cambrian biotite granite. The vein has a width of about 40 feet, and dips steeply southwestward into the mountain. It seems to consist mainly of an altered and replaced crushed aplitic granite or rhyolite dike. The values favor the foot-wall side of the vein, being greatest near its contact with the granite. This mine produces gold-silver-lead ore. The last carload shipment made at the time of the writer's visit averaged: Gold 3.16 ounces and silver 8 ounces per ton, and lead 17.5 per cent.

Rural and Buckeye mines.—These two mines are located in the northeastern part of the Mineral Park district, at an elevation of about 5,000 feet. They are but a few hundred feet apart and are situated on the same vein, the Rural being on the west and the Buckeye on the east side of the same gulch. The principal developments in the Rural consist of a 200-foot shaft and about 100 feet of drift, and in the Buckeye of 750 feet of drift, toward the face of which the vein is faulted off to the north by a lateral throw of about 75 feet. The Rural shaft contains water. The vein in the Rural mine dips southward at angles of about 80°, but in the Buckeye it dips to the north at angles of about 70°. It is 2 to 8 feet thick and is associated with a dike of the aplitic granite intruded into the country rock, which is pre-Cambrian schist. It locally shows a 4-inch to 20-inch ore shoot, mostly iron and copper pyrites, with streaks of arsenopyrite, black oxide of manganese, and some chert and quartz, the quartz being more prominent in the Buckeye than in the Rural. The walls are generally frozen. The ore contains silver, gold, and copper, with the values high in gold.

Golden Star mine.—The Golden Star (formerly Lone Star) mine is located about a mile northeast of Mineral Park, on open ground. It produced rich sulphides of silver, containing gold and lead, from 1870 until 1902, when the ore seems to have fallen off in grade and become base and refractory. The mine is developed principally by a shaft 300 feet in depth and two levels, with 600 feet of drift on each level. The ore is stoped down to the 100-foot level. The vein dips steeply to the south. It is 2 to 4 feet in width, and the ore is all low grade. The total production is stated to be $375,000.

Ark and San Antonio mines.—The Ark mine, located about 2 miles southwest of Mineral Park at the west base of the mountains, is developed by a 250-foot shaft and three levels, comprising about 1,300 feet of workings. It produces considerable water. The vein, which is 5 or 6 feet in width, dips steeply to the northeast. The ore is of a sulphide character and contains gold, silver, and copper. It runs about 175 ounces of silver and 3.15 ounces of gold per ton. The production is about $150,000. Adjacent to the Ark mine is the San Antonio, which has produced $75,000.

CERBAT DISTRICT.

General outline.—The Cerbat district, an area about 4 miles in diameter, is situated south of the Mineral Park district, in the foothills at an elevation of 3,500 to 5,000 feet, 3 miles east of the Arizona and Utah Railroad. It has produced more than $2,000,000. It is drained principally by Cerbat Wash, which leads westward into Sacramento Valley. The mines north of this wash are gold bearing; those to the south yield silver and lead. The principal mines are the Golden Gem, Vanderbilt, Champion, Oro Plata, Paymaster, Cerbat, New London, St. Louis, Flores, and Twins, the three first named being among the most important present producers.

Golden Gem mine.—The Golden Gem mine, located on Cerbat Wash, is developed principally by a 430-foot shaft and four levels comprising 1,200 feet of drift and stopes. The stoping is on the 130-foot level, and extends 166 feet horizontally and from 62 to 81 feet vertically. This mine yields considerable water. The vein dips steeply to the northeast. It ranges from 6 to 14 feet in width, and usually carries 2 to 6½ feet of pay ore running from $10 upward per ton. The values favor the foot wall. The gangue is quartz. The ore is gold ore and carries also silver, locally 60 ounces per ton, lead 5 to 6 per cent, antimony and zinc a trace, and some iron pyrites. The production to date is $190,000. A 40-ton mill is now turning out about $350 worth of concentrates a day from ore formerly left on the dump.

Idaho mine.—The Idaho mine adjoins the Golden Gem on the west, and the ore is similar to the Golden Gem ore. The mine has been worked in a small way since 1871, and the total production is reported to be about $200,000.

Cerbat mine.—The Cerbat mine, located about a mile northeast of the Golden Gem mine, is 200 feet in depth. The vein is 4 to 10 feet thick, and the total production is stated to be about $300,000 in gold and silver.

Paymaster mine.—In the Paymaster mine, about 1¼ miles northeast of the Golden Gem mine, the vein dips steeply to the north. The ore contains silver and gold, runs high in values, and carries much ruby silver. The production to date is said to be $200,000. Considerable water is found in this mine.

Oro Plata mine.—The Oro Plata mine, located about a mile northeast of the Paymaster mine, is 280 feet deep and is developed by about 7,000 feet of underground work. It produces considerable water. The pre-Cambrian country rock is here intruded by the aplitic granite. The ore values are chiefly in gold and sulphide of silver, with locally some lead. They run about $37 per ton. The total production is given as $500,000.

STOCKTON HILL DISTRICT.

General outline.—The Stockton Hill district joins the Cerbat district on the east, being situated on the opposite slope of the mountains, about 10 miles north of Kingman. It is about 4 miles in diameter and ranges from 3,500 to 5,500 feet in elevation. It is generally rough, but the mines are all accessible by wagon roads, in the main of easy grade. The drainage issues eastward into Hualpai Valley. The principal camp is Stockton Hill, situated in the eastern part of the district. The veins in general strike northwestward. The district contains about 10 mines, of which the principal are the Banner Group, Treasure Hill, Little Chief, Cupel, Prince George, De la Fontaine, C. O. D., and '63.

Banner Group mine.—The Banner Group mine is situated near the center of the district. It is developed by more than 2,000 feet of underground work, including the "tunnel" or drift, which extends in 1,600 feet on the vein. The vein dips steeply to the northeast. It is 6 to 8 feet in width, and the ore shoot is 2 to 2½ feet thick and favors the foot-wall side. In some localities the ore consists of pure galena, but usually it contains gold, silver, zinc, iron, and copper, the gold in places amounting to several ounces per ton. The amount of zinc increases in the deeper north portion of the mine. The production is reported to be many thousand dollars in gold, silver, and lead, the zinc thus far being culled and left on the dump. The ore is shipped to the Needles smelter.

Treasure Hill mine.—The Treasure Hill mine is located in the foothills in the southeastern part of the district. It is developed by inclined shafts and drifts, and yields a large supply of good water. The veins, six in number, dip steeply to the northeast. They average about 5 feet in thickness at the surface and widen downward. They are associated with what seems to be a small stock of the aplitic granite, and the two next to it are now being worked. The ore favors the hanging wall and occurs in shoots 100 to 200 feet in extent, with intervening clay or talcose gouge and sulphides. It runs about 100 ounces of silver and $5 to $16 in gold per ton, and 7 to 10 per cent of lead. The total production is stated to be $100,000.

Cupel mine.—The Cupel mine is situated at Stockton Hill camp. It is now being reopened and an excellent 200-ton mill and plant of the Joplin type have just been installed. It is developed to a depth of 400 feet, principally by shafts, drifts, and stopes, and is said to yield about 25,000 gallons of water per day. It is located on three veins, whose general trend is northerly. The ore in general contains ruby and horn silver, together with black sulphide of silver, but in some places is rich in high-grade galena and carries about $5 per ton in gold. About 2,000 tons of ore said to run from $6 to $7 per ton lie on the dump. The production to date is reported to be about $500,000.

Prince George mine.—The Prince George mine, located about one-fourth mile southeast of the Cupel mine, is developed by a 180-foot shaft and drifts, and is said to yield about 2,000 gallons of water a day. The vein dips steeply to the north and is about 12 feet thick. The total production is about $100,000.

De la Fontaine mine.—The De la Fontaine mine, located at the west side of the district, on the crest of the range, is 400 feet deep, and comprises about 1,400 feet of drift. The vein is 7 to 10 feet in width, and dips steeply to the north. The ore runs about 35 per cent in lead and zinc, and contains some gold. Good ore bodies, 2 to 4 feet thick and of considerable extent, are blocked out in the lower 300 feet of the mine.

'63 mine.—The '63 mine, located in the southern part of the district, is 200 feet deep and is stated to have produced a total of $500,000, mostly in rich silver ore.

Little Chief mine.—The Little Chief mine, located one-fourth mile west of Stockton Hill camp, is about 100 feet deep and contains about 1,000 feet of underground work. The vein, supposed to be one of the veins of the Treasure Hill mine already described, dips steeply to the northeast. The production, amounting to many thousand dollars, is all shipping ore, averaging in silver about 350 ounces and in gold 5 to 10 ounces per ton, with 8 to 40 per cent of lead.

C. O. D. mine.—The C. O. D. mine, located 2½ miles north of Stockton Hill camp, in the upper part of C. O. D. Gulch, is developed by a shaft 400 feet deep, drifts, and stopes, on and between two main and two subordinate levels, aggregating in all about 2,500 feet of underground work. The principal surface equipments consist of a 50-ton concentrating mill and engines. The vein dips steeply northward, and is about 7 feet thick. The ore, whose principal value is in silver, runs about as follows: Silver, 160 ounces per ton; gold, 2 ounces per ton; lead, 12 per cent; with some zinc and a little copper. Except the low-grade ore, it is mostly worked out for a distance of about 400 feet on either side of the main shaft, beyond which good ore is reported. The mine closed down late in 1904 and is now full of water. The total production is reported and in part verified by smelter return sheets to be $1,300,000, that of silver alone amounting to about $1,000,000.

GOLD BASIN DISTRICT.

The Gold Basin district is situated in the eastern part of the White Hills, in the Gold Basin mining district. It extends over a hilly area about 6 miles in diameter, sloping and draining to Hualpai Wash on the east, and ranges from 2,900 to 5,000 feet in elevation. The water supply is scanty. The nearest railway station is Hackberry, 40 miles to the south.

The deposits are mainly fissure veins in the pre-Cambrian granitoid rocks. They dip southeastward or northwestward, mainly at angles of 40° to 70°. The gangue is quartz, and the metal is gold, mostly free-milling, but it is locally associated with lead or copper, copper stain being a good index of gold values.

The principal mines are the Eldorado, Excelsior, Golden Rule, Jim Blaine, Never-get-left, O. K., and Cyclopic. They are developed chiefly by shafts (some 250 feet deep), drifts, and tunnels. The production of the district is given as about $100,000, of which about $65,000 came from the Eldorado mine and $25,000 from the O. K.

WHITE HILLS DISTRICT.

The White Hills district, about 2 miles in diameter, is a part of the Indian Secret mining district. It lies 28 miles north of Chloride, in the western border of the White Hills, at an elevation of 3,000 feet. It drains westward into Detrital Valley, and the camp. White Hills, is situated in the main wash in the southern part of the district. The country rock is pre-Cambrian granitoid gneiss. It dips eastward and is flanked or overlain on the east by the Tertiary volcanic rocks, which in turn are capped by younger basalt.

The deposits are quartz veins, some of which are blanket veins. They are about 5 feet in average width, and dip to the northeast at angles of 20° to 70°. The ore is mostly silver chloride, much of it horn silver, with local values in gold.

The developments, some of which extend nearly 1,000 feet in depth, consist of inclines, shafts, and drifts, aggregating probably more than 10,000 feet. A plentiful supply of good water is usually reached at the depth of 400 to 600 feet. The district contains 12 or 15 mines, of which the most important are situated within three-fourths of a mile of the camp, but only a few of the smaller ones, located in the northern part of the district, are now worked. The camp has a well-equipped 40-stamp mill. Mineral was first discovered here in 1892 and the camp soon reached its zenith, with a population of about 1,200, but has been almost deserted since the decline in the market value of silver. The total production, which is known to be large, is reported to be about $3,000,000.

M'CONNICO DISTRICT.

The McConnico district is situated about 6 miles southwest of Kingman, east of McConnico station on the Santa Fe Railway, in the border of Sacramento Valley and the adjacent foothills and scarp of Kingman Mesa, between the elevations of 2,800 and 3,500 feet. It trends north and south and has a length of about 4 miles.

The country rock is pre-Cambrian granite, which in the valley portion of the district is covered by wash débris.

The ore deposits are contained principally in gold-bearing pegmatite dikes and shear zones, cutting the granite in a northerly direction and, in some places, associated with later basic intrusives. The principal deposits are those of the Bimetallic mine, the McKesson Group, and the Boulder Creek Group.

MAYNARD DISTRICT.

The Maynard district is an indefinite area in the Hualpai Mountains, 10 miles or more southeast of Kingman, in which strong and persistent veins, similar to those in the Cerbat Mountains, occur, mostly in pre-Cambrian red granite. Among the most important of these veins are the American Flag, Enterprise, Great Eastern Group, and Siamese Group. The ore shoots, usually rich, range from an inch to 3 feet in thickness. The ore is principally horn silver, but that of the Siamese Group is promising in copper. Water can be derived from most of the mines and pine timber suitable for mining grows near by.

Other metals reported to occur in the Hualpai Mountains are molybdenite, found in association with copper, and native quicksilver, associated with lead carbonate. Just beyond, in the Aquarius Range, about 50 miles from Kingman, is a tungsten mine which annually produces 25 tons of tungsten ore, worth $400 per ton at Kingman, whence it is shipped.

GRAND WASH CLIFFS.

The principal districts in the Grand Wash Cliffs are Music Mountain and Lost Basin.

MUSIC MOUNTAIN DISTRICT.

The Music Mountain district, about 3 miles in diameter, lies about 25 miles north of Hackberry, in the foothills of the range, between 3,000 and 4,000 feet in elevation. The country rock is the pre-Cambrian (?) granitoid complex and it is intruded by dikes and masses, mostly basic.

The deposits occur in several quartz fissure veins, which dip steeply to the northeast. The most important is the Ellen Jane vein, about 4 feet in average width, on which the Ellen Jane mine is located. This mine is developed principally by a main shaft 200 feet deep and two levels, containing about 300 feet of drifts, and by 600 feet of adit drifts. It produces about 5 barrels of potable water per day. The ore shoot is from 4 to 6 inches thick and the ore is said to run $200 to $300 in gold per ton.

LOST BASIN DISTRICT.

The Lost Basin district lies in the northern part of the region, between Hualpai Wash on the west and Pierce Mill Canyon on the east.

The principal deposits are located about 7 miles northeast of Gold Basin, between 2,000 and 3,000 feet in elevation. They trend east and west and extend for about 6 miles. They occur principally in the pre-Cambrian rocks, in quartz fissure veins, of which there are two sets. Those on the west trend northward, with a steep easterly dip, and are principally gold bearing; those on the east trend west-northwestward and are chiefly copper bearing. The nearest water supply is Colorado River at Scanlon Ferry, 7 miles to the north.

BLACK MOUNTAINS.

INTRODUCTION.

The deposits of the Black Mountains, as stated elsewhere, differ markedly from those of the Cerbat Range, in that they occur chiefly in the Tertiary volcanic rocks. Their gangue is chiefly calcite or calcite replaced by quartz and adularia; they are deeply oxidized and, as a rule, contain no sulphides; and their values are almost exclusively gold, there being usually no base metals present.

The districts in the Black Mountains, named from north to south, are the Eldorado Pass, Gold Bug, Mocking Bird, Virginia, Pilgrim, Union Pass, Gold Road, Vivian, and Boundary Cone. Of these the most important is the Gold Road district. The two first named are in the Eldorado Pass Mining District, the next two are in the Weaver mining district, and the Gold Road and Vivian in the San Francisco mining district.

ELDORADO PASS DISTRICT.

The Eldorado Pass district, an area about 2 miles in diameter, is located west of White Hills at Eldorado Pass on the road leading to Eldorado Canyon, at an elevation between 2,500 and 3,000 feet.

The topography is one of gentle relief. The country rock is the pre-Cambrian granite, and it is intruded and locally overlain by the Tertiary volcanic rocks. The principal properties are the Burrows, Bagg, Young, and Pauly. They are in the prospect stage, but have produced some gold, the production of the Burrows being reported to be about $10,000. The metals of the three first named are gold and silver in quartz veins, and the Pauly, which seems to be at the contact between the granite and the volcanic rock, contains principally copper.

GOLD BUG DISTRICT.

The Gold Bug district is situated near the summit of the range about 3 miles south of Eldorado Pass. The only mine is the Gold

Bug mine, which is developed by several shafts and drifts to the depth of 300 feet.

The deposits consist chiefly of two main veins situated about 22 feet apart in minette or andesitic tuff similar to that at the Mocking Bird mine. (See below.) The veins dip steeply to the northeast. The ore is rich gold-bearing quartz with a little silver. It favors the hanging wall, where in part it is associated with a diorite (?) dike. The production of both shipping and milling ore has been considerable, and much ore is said to remain in the mine.

MOCKING BIRD DISTRICT.

General outline.—The Mocking Bird district lies 25 miles northwest of Chloride in a reentrant parallel side valley in the east foothills of the range, at elevations between 3,000 and 4,000 feet. The valley is bounded on the east by a spur of volcanic rocks extending in a northerly direction from the flank of the range. The district trends north and south; it has a length of about 5 miles and a width of about 2½ miles. It is hilly on the south but open on the north, merging with the Sacramento Valley, which receives its drainage. Water is scarce, but some is encountered in the mines. The principal mines are the Mocking Bird, Hall, Great West, and Pocahontas. The Mocking Bird and Hall are now producing.

Mocking Bird mine.—The Mocking Bird mine is situated in the open northern portion of the district. Its principal developments are 12 or 15 shafts, ranging from 25 to 60 feet in depth, and about 500 feet of drift. The vein lies nearly flat in a local sheet or flat-lying dike of oxidized and schistose minette or andesitic tuff. It is about 6 feet thick and consists of red and green quartz and breccia. The metal is gold with a small amount of silver. The gold occurs in a finely divided state, usually associated with hematite, of which considerable is present. The ore averages about $10 per ton. The production to date is reported to be upward of $20,000; several times this amount of ore is blocked out in the mine and valuable tailings are now on the dump.

Hall mine.—The remaining mines are situated near together in the low foothills of pre-Cambrian granite in the southern part of the district. The veins here all dip steeply to the north. The Hall mine, which works the most northerly of the veins, is developed principally by a 210-foot shaft and two levels, containing about 200 feet of drift. The vein ranges in thickness from a few inches to 2 feet, and is locally associated with diabase dikes. The gangue is quartz, some being of the honeycomb variety. Some of the ore is very rich, shows free gold, and is said to contain values of $10,000 and upward per ton. A 24-ton mill is operated at the mine.

Great West mine.—The Great West mine is developed principally by adit drifts, shafts, crosscuts, and winzes to a depth of more than 200 feet. The vein is approximately 3 feet thick and consists essentially of gold-bearing, iron-stained, oxidized quartz, reported to run from $10 to $80 per ton.

Pocahontas mine.—The Pocahontas mine is developed by a shaft and drifts to the depth of 200 feet, and a new cyanide mill has recently been built to replace the stamp-amalgamation mill formerly used. The value of the ore is in gold, which occurs mainly in white iron sulphides contained in a somewhat stained and crushed quartz gangue.

VIRGINIA DISTRICT.

The Virginia district, about 3 miles in diameter, lies 25 miles west-northwest of Chloride, near the middle of the west slope of the Black Mountains, 5 miles east of Colorado River and nearly opposite the Searchlight district, Nevada, at an elevation of about 1,500 feet.

The country rock consists of the Tertiary volcanic rocks with rhyolite and green chloritic andesite most abundant. The veins dip southwestward, usually have a calcite gangue, and locally grade into the country rock. The Red Gap vein, however, consists of more or less brecciated quartz, probably with adularia. It is similar to that in the Gold Road mine, and carries good values.

The ore of the district is mostly free-milling gold. It averages about $7 to $8 per ton, and the best values are associated with specks of hematite distributed throughout the gangue, as in much of the ore in the Union Pass and Gold Road districts.

PILGRIM DISTRICT.

The Pilgrim district, which is about 2 miles in length and trends northwestward, lies 9 miles west of Chloride, in the eastern foothills of the range, at an elevation of about 3,600 feet. The country rock is principally rhyolite and granite porphyry. The main opening is the Pilgrim mine, on the northwest. This mine is situated on a contact vein of quartz, with a little adularia, and rhyolite breccia, with trachytic rhyolite forming the hanging wall and granite porphyry the foot wall. It is developed by inclined shafts, two levels, and drifts to a depth of 360 feet, and oxidation extends to the bottom of the mine. The vein is about 20 feet thick and about half a mile in length. It dips to the west at an angle of about 30°. The ore is reported to average about $8 in gold per ton, the gold occurring free. Twelve tons of $100 ore are reported to have been shipped and about 1,000 tons of $6 to $7 ore lie on the dumps.

UNION PASS DISTRICT.

General outline.—The Union Pass district lies about 30 miles west of Kingman, on the west slope of the range. It extends from Union

Pass westward to Colorado River at Pyramid, a distance of 13 miles, and has a width of about 3 miles. It ranges in elevation from 4,000 feet on the east to 500 feet on the west. The topography is rough and mountainous on the east, with low hills, broad, open washes, and gravel-covered areas sloping toward the river on the west. The water supply is scanty except near the river. On the east it consists of a few springs or shallow wells in the mountains.

The country rock on the northwest and on the south is essentially the pre-Cambrian complex, which, in the remainder of the district, is more or less deeply buried by heavy deposits of the Tertiary volcanic rocks, consisting principally of rhyolite. On the west the deposits are fissure veins in the pre-Cambrian granite. On the east they are found chiefly along or near the contact of the rhyolite and granite; locally associated with diabase, a later intrusive; and in conjunction with one or more of these intrusives along fault planes. They occur in the form of fissure veins or lodes, blanket veins, and irregular bodies. The mineral deposits were probably formed by circulating hot solutions which accompanied and followed the invasion of the intrusives, especially the rhyolite. The most important of the deposits in the eastern part of the region trend northwestward and those in the western part northeastward; those intermediate in position vary between these two directions. The metal is gold. The prevailing gangue is calcite, which locally is associated with, gives way to, or is replaced by quartz and adularia.

The western part of the district has produced considerable ore, the most of which has come from the Sheep Trail, Boulevard, and Katherine mines.

Katherine mine.—The Katherine mine is situated 1¾ miles east of the river and about 450 feet above it on an open, gravel-covered slope in the pre-Cambrian granitoid gneiss. The lode is about 75 feet in width, trends N. 64° E., and to judge from outcrops in alignment, may have an extent of nearly 5 miles. In the mine it shows faulting and slickensiding.

The ore on the whole resembles that of the Gold Road mine (see below) and consists mainly of fine-grained quartz and adularia, mostly replacing calcite. The greater portion is of low grade, ranging in value from $6 to $7 per ton; but toward the north it contains a rich streak said to run $200 to $300. The ore is treated at the Sheep Trail mill, Pyramid. About 5,000 tons have been produced.

GOLD ROAD DISTRICT.

General outline.—The Gold Road district lies about 24 miles southwest of Kingman. It extends from Meadow Creek on the east slope of the range northwestward to the Moss and Golden Star mines, about 6 miles beyond the crest. It has a length of about 10 miles and a width of about 4 miles. It lies mainly on the west slope, and ranges in elevation from 2,000 feet on the west to 4,500 feet at the top of the range. The range portion, which is about 3 miles in width, is rugged, particularly on the west, being marked by precipitous fault scarps, deep gulches and canyons. The remainder consists mainly of low rounded mountains or hills, open washes, and gravel-covered gentle slopes or mesas. On the east the drainage flows by way of Meadow Creek into Sacramento Valley and on the west through Silver Creek into Colorado River.

The principal country rock in the eastern or range portion of the district consists of Tertiary volcanic rocks; on the west appear also local areas of the pre-Cambrian complex and intrusive quartz syenite porphyry, in places covered by sheets of gravel. The deposits are chiefly gold-bearing fissure veins or lodes. They occur in the undifferentiated volcanic rocks, the green chloritic andesite, and the quartz syenite porphyry, described under "Geology," and also along certain of their contacts, where rhyolite is usually the intrusive. They number about a dozen and consist of two main types—those in which the gangue is chiefly quartz and adularia and those in which it is chiefly calcite. The former occur mostly in the undifferentiated volcanic rocks and have a general northwesterly trend; the latter occur mainly in the green chloritic andesite and trend northward. The most important of the former type is the Gold Road vein; of the latter the Pasadena and Mossback veins.

Gold Road mine.—The Gold Road mine, the most important in the district, is situated at Gold Road, on the western rugged slope of the range about 1 mile below the crest, at an elevation of about 2,900 feet. It is developed principally by a main shaft and seven levels, aggregating about 2,000 feet of drift, to the depth of 700 feet, and most of the ore has been mined for a distance of about 150 feet on either side of the shaft. The mine is located on the western part of the Gold Road vein, which extends eastward to the crest of the range, a distance of more than a mile. The vein lies mostly in a deeply cut gulch. Its croppings range in elevation from 2,800 feet on the west to 4,100 feet on the east. It strikes N. 50° W. and dips northward at angles of about 80°. It is strongest on the west, where, as developed in the mine, it is about 10 feet thick, is locally enriched by oblique stringers on the hanging-wall side, and is usually in sharp contact with well-defined walls of the country rock, consisting of andesite, trachyte, latite, and rhyolite.

The ore is nearly all milling ore and runs about $10 in gold per ton. It consists chiefly of fine-grained, light-colored, in places greenish quartz, which has a peculiar chalcedonic or drusy appearance and in which the gold is finely disseminated. Adularia is commonly intergrown with the quartz, and it is very probable that these minerals replace calcite, which is present in varying quantities. As a rule no sulphides are present, and but little limonite.

The gold is extracted on the grounds by milling and cyaniding. The ore is crushed in solution and, owing to its oxidized condition, is easily milled and treated, 25 per cent of the gold being liberated in two or three hours and 85 per cent in ten hours. The plant used consists of six Huntington mills having a total capacity of more than 200 tons per day. The present rate of output, however, is about 180 tons per day, one mill being usually held in reserve.

The principal source of the power used, amounting to about 700 horsepower, is California fuel oil, freighted by wagon from Kingman. The ore is now mined at a cost of $2.50 to $3 per ton, or mined and milled for about $5 per ton, allowing $8 ore to be handled with good profit. With the installation of cheaper power, ore of much lower grade might be worked.

The production to the end of 1906 was large, and is reported to have been considerably in excess of $1,000,000, nearly all of which was produced during 1905 and 1906. Besides the output of the Gold Road mine, nearly $1,000,000 is reported to have been produced from work done at several other points on the vein, especially on the Billy Bryan claim, about half a mile southeast of the Gold Road mine. This makes the total production of the Gold Road vein more than $2,000,000. It is stated that at the close of 1906 there were also in sight 120,000 tons of ore running about $11 per ton.

The camp has a population of about 350, of which the mine employs 180 men. It is equipped with modern improvements, is well kept, and is plentifully supplied with excellent water pumped from the east slope of the range. The mine also produces about 12 gallons of water per minute.

Pasadena mine.—The Pasadena mine is situated 1½ miles west of Gold Road, on open ground. It is developed principally by a main shaft 300 feet deep and three levels containing about 100 feet of drift. The country rock is the green chloritic andesite. It is intruded by rhyolite and basic rocks, all seemingly older than the vein. The vein or lode dips westward at angles of about 70°. It is from 10 to 140 feet in width and has a known extent of more than a mile. It consists essentially of calcite and quartz, the quartz increasing with depth. Some of it is of the Gold Road type, and this carries the best values.

In the main ore body, which ranges in width from 4 to 10 feet, the ore is reported to average about $10 per ton and is excellent cyaniding ore.

Mossback mine.—The deposit of the Mossback mine, situated about 3 miles north-northwest of Gold Road, in open country near the foot of the range, is geologically and mineralogically similar to that of the

Pasadena mine. The mine is developed to the depth of 320 feet and yields considerable water. The vein is about 23 feet wide and the main ore shoot is about 12 feet wide. About 900 tons of medium-grade milling ore, said to run from $5 to $100 per ton in gold, lie on the dump.

Moss mine.—The Moss mine lies about 4 miles northwest of Gold Road, on the southeast slope of a group of outlying hills. It is developed by a 230-foot shaft and 600 feet of tunnel and crosscuts. The vein consists mainly of calcite and a small amount of quartz. It is about 20 feet thick, and extends for more than half a mile. It is in the quartz syenite porphyry, and dips steeply southward, with fault breccia on its foot wall.

The total production is reported to be about $500,000 in gold, nearly all of which was obtained near the surface, about one-half from an excavation about 10 feet in diameter and depth. It occurred mostly as incrustations, flakes, beads, and nuggets associated with quartz and hematite, and represents a local concentration, for deeper work shows the vein to consist of a large body of low-grade ore, much of it running about $4 per ton.

Golden Star group.—The Golden Star group, including "Meals ledge," an outlying lode on the east, comprises seven or eight properties mainly in the prospect stage. It lies in open country in the northwestern part of the district, extending from a point near the Moss mine northward to Cottonwood Wash, a distance of about 2 miles.

Miller mine.—The Miller (formerly Hardy) mine is situated two miles northwest of Gold Road, on Silver Creek, on the northeast slope of the Hardy Mountains, an outlying group. It is developed by two shafts (to a depth of 289 feet) and contains 800 feet of drift, tunnels, and crosscuts. The country rock is the quartz syenite porphyry, into which rhyolite is intruded near by.

The mine is located on the north end of the Hardy vein, which dips steeply to the north. The vein is about 30 feet wide and extends about 4 miles. The Jack Pot, Homestake, and Navy Group mines are also located on or near it. It is composed mostly of quartz, probably with adularia, and contains some associated green fluor spar. The ore carries gold, but it contains more silver than that at any other mine in the district, and is stated to average on the whole about $5 per ton. In the Navy Group mine, however, 2 miles farther west, it is said to range from $8 to $30. The production to date is reported to be about $100,000.

VIVIAN DISTRICT.

General outline.—The Vivian district, an area about 4 miles in diameter, lies in the southwestern part of the region and adjoins the

Gold Road district on the south. Vivian, the principal camp, is situated west of the center of the district, about 3 miles southwest of Gold Road. The district lies in the foothills at elevations between 2,200 and 2,800 feet, and is traversed by several broad washes through which the drainage issues southwestward.

The dominant country rock is the green chloritic andesite, which, on the southwest, gives way to the underlying older andesite, the basal member of the volcanic series. So far as learned, this older andesite does not contain workable mineral deposits, and as the veins seem to practically terminate with the lower limit of the green chloritic andesite, the ability to differentiate these two formations is of vital importance to the mine operator. This ability can best be gained by studying the rocks along their zone of contact, which is well exposed crossing the ridge southwest of the Vivian mine, beyond which it ascends the wash northward to the west base of Leland Monument Mountain, the high dome-shaped portion of the ridge just west of Vivian and nearly 700 feet above it.

Leland mine.—The Leland mine is located just west of Vivian, in the upper part of Leland Monument Mountain. It is developed mainly by adit drifts and tunnels aggregating about 3,000 feet of workings, distributed within a horizontal distance of half a mile and a vertical range of 700 feet. This work was nearly all done in 1903 and 1904. The surface equipment, comprising a 40-stamp mill and railway, were installed at a cost exceeding $400,000.

The mine is located on the western part of the Leland vein, which has a known extent of about a mile and dips steeply to the south. At the mine it ranges from 5 feet in width on the east to 25 feet on the west, and is of the Gold Road type, being composed essentially of fine-grained pale-greenish quartz and adularia, locally accompanied by calcite and country-rock breccia. It contains vugs lined with quartz crystals and black oxide of manganese, and many of them carry much free gold. Throughout the mine the vein contains a large amount of $5 to $10 ore, which probably continues in depth with the green chloritic andesite. The same seems to be true of the Mitchell vein, which lies about 400 feet south of and parallel to the Leland vein, but dips steeply to the north.

In the light of the foregoing conclusion concerning the termination in depth of the veins of the district with the green chloritic andesite, the widely accepted view which holds that by sinking to a depth of 1,200 or 1,500 feet at a point midway between the Leland and Mitchell veins a large body of rich ore will be encountered at their junction should be accepted with caution, as the lower limit of the andesite may lie at too shallow a depth for the veins to meet in this formation.

The production of the mine was not learned, except that about 4,500 tons of the ore were milled, some of which averaged $15 per ton and a less amount $50 to $60 per ton.

German-American mine.—The German-American mine lies in the southern part of the district three-fourths of a mile east of Vivian. It is developed by drifts, tunnels, and shafts to a depth of about 250 feet and contains about 2,000 feet of workings, mostly at the Treadwell and 35th Parallel shafts, which are situated about 1,200 feet apart on the vein. The principal surface equipments are several steam hoists, a 10-stamp mill, and a cyanide plant.

The dominant country rock is the green chloritic andesite, which locally west of the vein on the foot-wall side is in contact with the light-gray older andesite, and the vein may lie in part on the contact of these two rocks. The vein dips steeply to the east. It extends for three-fourths of a mile and ranges from 1 to 60 feet in width. It consists essentially of calcite, some of which is replaced by quartz and adularia, with some brecciated country rock. The foot wall is usually well defined with the vein solidly frozen to it; the hanging wall is ragged. The values favor the hanging wall and are associated mostly with quartz.

The production has been 2,700 tons of ore, which averaged about $10 in gold per ton. A large dump at the 35th Parallel shaft is reported to be all good milling ore.

Tom Reed mine.—The Tom Reed (formerly the Blue Ridge) mine lies in the eastern part of the region, in Blue Ridge Wash. It is developed to a depth of nearly 200 feet by two shafts, and has three levels and drifts, aggregating about 600 feet of underground work, nearly all done in 1904 to 1906. It produces considerable water, the level of which lies at about 100 feet below the surface. The principal surface improvements are a 10-stamp mill and a gasoline hoist.

The country rock is the green chloritic andesite. The vein dips steeply northeastward. It is about 20 feet in width, with the walls usually ill-defined, and is thought to be a continuation of the Pasadena vein, in which case it has a length of about 3 miles. It is mainly of the Gold Road quartz-adularia type, with but little calcite present in the principal part of the mine, and is reported to have run $25 in gold and a little silver per ton for the first 30 feet in depth, and about $12 from that point down. As considerable gold remains in the tailings the ore should be treated by cyaniding. The production is reported to be about $120,000.

Victor-Virgin mine.—The Victor-Virgin mine is situated in the southeastern part of the district. It is developed principally by two shafts, situated 900 feet apart, to a depth of nearly 300 feet, together with drifts. Elaborate surface improvements, including the installation of a 650-horsepower plant at Needles, 16 miles distant, are now in process of construction, but hardly seem warranted for a mine of its size, in which the deposits have not yet been shown to extend to any great depth.

The dominant country rock is the green chloritic andesite, but the underlying older andesite occurs near by on the west. The vein dips steeply to the northeast. It is from 1 to 18 feet in width, but is locally associated with silicified country rock or breccia 100 or more feet wide. It is of the Gold Road type, being composed principally of quartz and adularia, with a small percentage of calcite. The ore is said to contain from $9 to $50 in gold per ton, $20 being reported as a fair average. The total production is about $500 and a considerable amount of low-grade ore lies on the dump.

Midnight mine.—The Midnight mine, located 1½ miles northwest of Vivian, is developed by an inclined shaft, drifts, and stopes to a depth of 50 feet, and is equipped with a gasoline hoist.

The country rock is the green chloritic andesite. The vein dips westward at angles of 30° to 40°. The portion of it worked is about 3½ feet in thickness and consists principally of quartz, with some calcite, fluorite, and probably adularia. It has been worked from the surface almost to the bottom of the mine and laterally for a distance of about 120 feet, and in this extent has averaged about $18 per ton in gold, the production being considerable for so small a mine. Where now worked in the bottom of the shaft the ore is of low grade, running about $7 per ton, and consists of a mixture of partly altered soft country rock traversed by stringers and veinlets of calcite and quartz.

Vivian mine.—The Vivian mine is located about one-fourth mile below Vivian, just west of Vivian Wash. It is developed to a depth of about 270 feet by three shafts and drifts. The surface equipments, which unfortunately seem to have been prematurely installed, are new, of the best modern type, and very complete, and include a 10-stamp mill.

The country rock is the green chloritic andesite, which just west of the mine gives way to the older andesite. The vein dips steeply to the south and extends for about half a mile. It is about 3 feet in average thickness and consists essentially of calcite and a little quartz. The values are reported to occur chiefly in pockets running very high in gold, and are richest in the quartz, which occurs in association with dark calcite. The production is small. The mill was run about forty days after its completion in 1906. The principal dumps show that the older andesite has been encountered, from which it seems probable that no workable ore will be found at greater depths.

BOUNDARY CONE DISTRICT.

The Boundary Cone district lies in the southwestern part of the region, just south of the Vivian district last described. It extends from Boundary Cone, a prominent landmark on the west, 3 miles eastward nearly to the crest of the range, and is 2 miles or more in width. The topography is mostly rugged, of the volcanic rock type, with the mountains rising 1,500 to 2,000 feet above the intervening washes, through which the drainage issues westward.

The country rock is mainly a dense reddish-brown or purplish andesite, locally known as "phonolite," and is underlain by an earlier tufaceous andesite, below which the pre-Cambrian granite is exposed on the extreme southwest. These rocks are all intruded by rhyolite in the form of plugs and dikes, of which Boundary Cone is a typical example.

The deposits are gold bearing and occur in fissure veins in the purple andesite and also on the contact of the intruded rhyolite and the andesite or the granite. The gangue is made up of fine-grained and usually brecciated quartz and adularia, locally containing an admixture of country rock.

The veins, five or six in number, occur in the eastern part of the district. They trend northwestward, with steep dips. The principal properties located on them are the Iowa, which has been most extensively developed, the Lazy Boy, Krause, and Highland Chief.

The Iowa mine is situated in the northeastern part of the district, at an elevation of about 2,600 feet. It is developed by a shaft 200 feet in depth, and by about 100 feet of drift and crosscuts distributed on three levels, and is equipped with a gasoline hoist. The vein dips steeply to the south. It ranges from 3 to 8 feet or more in width and consists principally of greenish brecciated quartz and a little calcite, with locally some rock breccia. It is traversed by veinlets of secondary quartz and calcite. The values run from $3 to $14 per ton, and are largely found within 3 feet of the hanging wall.

The deposits at the contact occur chiefly in the western part of the district. They are best exposed along the upper edge of the andesite collar encircling the rhyolite plug that forms the upper part of Boundary Cone. They occur mainly on the west and south sides of the cone, where they extend interruptedly for about a mile. The values average from $3 to $17 in gold, and occur in a zone of quartz and adularia 6 to 8 feet wide, chiefly on the rhyolite side of the contact. The rhyolite within 2 or 3 feet of the quartz also contains values.

NONMETALLIC MINERALS.

The principal nonmetallic minerals occurring in the region here discussed are building stone, cement rock, travertine, turquoise, and graphite.

Building stone.—The most important building stone in the region is the rhyolite tuff underlying Kingman Mesa. It occurs in abundance in heavy beds and is easily quarried in the scarps near Kingman. It is medium grained and fairly uniform in texture, and dresses well. The most important buildings in Kingman are built of it.

Cement rock.—The main cement material of the region is a fine-grained pumaceous phase of the rhyolite tuff just described. It occurs in a deposit of considerable extent west and southwest of Kingman and probably elsewhere, and is said to have been proved by experiment to be excellent for making cement. It requires no calcining. Briquets made with it are reported to have a higher tensile strength than the Vesuvian products and to stand salt-water tests with excellent results.

Travertine.—Local deposits of travertine, used as flux at the smelters, occur in Sacramento Valley near Chloride and Mineral Park.

Turquoise.—Turquoise is mined at two localities, Ithaca Peak and Turquoise Mountain, about a mile south of Mineral Park. It occurs in coarse altered granite porphyry in the form of veins and globular and irregular bodies, 1 to 8 inches in diameter, some of which are connected by stringers or mere seams and others isolated in the solid rock. The production is shipped in monthly installments to New York, where it is mostly sold in the rough for jewelry purposes.

Graphite.—Graphite, possibly of commercial value, occurs in the pre-Cambrian schists on the east slope of the Cerbat Range near the old Government trail in the first gulch north of C. O. D. Gulch, about 15 miles north of Kingman.

WATER SUPPLY.

Throughout that portion of the area which lies north of the latitude of Kingman water is scarce, the only natural source of supply besides precipitation being a few small springs, found along the base of the ranges. In the pre-Cambrian rocks, however, particularly in the Cerbat Range, as shown in the mines, ample water of good quality is usually encountered at depths of 300 to 600 feet; and in the vicinity of Kingman in the rhyolite tuff a copious supply is reached at depths of about 130 feet, as shown by numerous inexhaustible wells. In the Black Mountains also the best water-bearing formation is the rhyolite tuff, commonly known as the "water rock," extending in a belt of considerable width from Union Pass southward beyond Gold Road. It is the source of the water used at Gold Road and other localities, and, as at Kingman, the supply seems inexhaustible.

GOLD PLACER DEPOSITS NEAR LAY, ROUTT COUNTY, COLO.

By Hoyt S. Gale.

INTRODUCTION.

The existence of gold-bearing sands and gravels in a field of considerable extent in the central portion of Routt County, Colo., and adjacent parts of Wyoming, has been known for a number of years. These gold placer deposits are said to have been first discovered in 1887 in the northern part of the district, on Fourmile Gulch, and also in Dry Gulch, about 20 miles west of Baggs, Wyo., both localities near Little Snake River. Interest in the field seems to have begun about that date and to have continued more or less actively down to the present time.

The district in which these deposits occur lies west of the Elkhead Mountains, north of Yampa or Bear River, and east of the lower course of Little Snake River, along whose valley near the Colorado-Wyoming line the most extensive developments have been made. Only the southern portion of the territory thus outlined is directly concerned in the present report.

The following report is the result of observations made in the early part of July, 1907, by the author, who was at that time engaged in a study of the geology and an examination of coal lands in the fields south of this district. Especial acknowledgment is due to Mr. A. G. Wallihan, of Lay, for the locations of the claims shown on the map (Pl. I), and for assistance during the progress of the work and information concerning former prospecting in the field. The author is personally familiar only with that part of the field which lies south of the Iron Springs divide, and all statements and inferences concerning the deposits north of that line or lying in the Snake River drainage basin are based on the reports of others, interpreted from a general knowledge of the whole region.

A brief description of the territory and developments along Little Snake River prior to 1895 is given in an article by E. P. Snow.[a] In

[a] Fourmile placer fields of Colorado and Wyoming: Eng. and Min. Jour., vol. 60, 1895, pp. 102–105.

1901 a dredge was set up in Timber Lake Gulch, 10 miles south of Baggs, Wyo., and operated with some success for four years, but it is now lying idle. It is said that about $70,000 was cleared up during that time, but that work was suspended with the exhaustion of the richer ground. A dry washer outfit was set up in Timber Lake Gulch (T. 10 N., R. 92 W.) during the summer of 1903. It was claimed that the machine made $20 per day on ground averaging 75 cents per yard, when the dirt was perfectly dry. The rainy season of that year prevented continuous work.[a] Recent reports state that a ditch is being constructed from Slater Creek to carry water to the Iron Springs divide, and that pipe to cover a distance of about 2 miles has been purchased and hauled into the country.[b]

In 1905 a dredge was installed in the valley of Lay Creek, on the south side of the Iron Springs divide. Since that time a small area (about 10 acres) has been worked over. Most of the delay or failure to achieve immediate results has been due, it is said, to minor difficulties in the operation of machinery and the management of the rather scanty water supply. A recent report states that the Blevins property, controlling the dredge and some 480 acres of placer filings about 7 miles north of Lay post-office, has been sold for $100,000. It is also stated that an active revival of operations in the neighboring tracts is under way, and that considerable development work is promised in this southern part of the field during the coming season.

DESCRIPTION.

The territory west of the Elkhead Mountains is a broad stretch of rolling prairie of moderate relief and monotonous topography. Geographically it may be defined as a roughly triangular area lying between Little Snake and Yampa rivers. These streams furnish the chief water supply of the district, although its eastern margin is more or less readily accessible to their tributary headwaters on the western flanks of the Elkhead Mountains. The climate, although not that of a true desert, is exceedingly dry, with but little rainfall during the summer and it is said but little snow in winter. Springs are scarce throughout the region and settlement is consequently scattering and confined chiefly to the river valleys.

The region is traversed by several well-known roads which afford access from the Union Pacific Railroad in southern Wyoming to the settlements along Yampa River in Colorado. The freighting route from Rawlins to Craig and Hayden passes through the eastern part of the district, and also furnishes the present means of communica-

[a] Information from Mr. John H. Marks, of Denver.
[b] Information from Messrs. L. Calvert and J. W. Cavendor, of Baggs, Wyo.

tion with the placer fields. A daily stage is run from Rawlins to Dixon and Baggs, on the Little Snake, whence connecting routes extend into Colorado. An old road that was formerly a regularly traveled stage route passes diagonally through the placer districts, running to the southwest from Baggs by way of Lay, and thence southward toward Meeker. This and the old Thornburgh wagon road were formerly the best-known routes of travel through this region, being the principal means of access to the Union Pacific Railroad from a large territory to the south in Colorado before the advent of the railroad lines on Grand River. Many minor wood and hauling wagon roads meander across the prairie hills and valleys, so that the region is fairly accessible in almost any part.

GENERAL GEOLOGY.

Precise knowledge concerning the structure and stratigraphy of the field as a whole is somewhat meager. It lies within the territory mapped by the Fortieth Parallel Survey, and is described in that Survey's reports and its geology mapped in the atlas accompanying them. The rocks are classed with the groups there denoted as Green River and Vermilion Creek[a] of the Eocene. The following description of the district is given by S. F. Emmons, the geologist who visited that region.[b]

> To the north and west of Fortification Peak[c] extends a low, rolling country, covered with soft, earthy material of a prevailing red color, in which no outcrops are visible. The character of the soil, however, shows that it is probably made up of decomposed beds of the Vermillion Creek Eocene. These beds are found exposed on the western face of the Elkhead Mountains, at the baylike indentation between Mount Weltha and Navesink Peak, where they consist of coarse, red sandstones, with intercalated beds of reddish and cream-colored clays and arenaceous marls. The limits of these beds are not well defined, on account of the character of the surface in this region, but their connection can be traced, over the broad plains to the west, to characteristic outcrops, in such a manner that there can be little doubt as to the horizon to which they belong. Though they present here little difference of angle with the underlying Cretaceous beds, they are probably unconformable, as they are seen to be to the westward, and the lowest beds of the series can not therefore be definitely determined. On the little Snake River they are represented by yellow, coarse, gritty sandstones containing casts of *Melania*.

Recent investigations in territory adjoining this field, both north and south of the area under discussion, tend to corroborate the general statements of these earlier reports; but, as might naturally be expected, some details of the areal distribution of these strata were generalized or overlooked entirely in the first general maps.

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[a] "Vermilion Creek" is equivalent in part at least to the Wasatch as used by the Hayden Survey, and the latter name, which has priority and established usage, has been adopted for these beds by the Geological Survey.

[b] King, Clarence, Rept. U. S. Geol. Explor. 40th Par., vol. 2, 1877, p. 187.

[c] Now better known as Cedar Mountain, situated about 6 miles northwest of Craig.

As described by Emmons the whole field is underlain by sedimentary strata of loosely consolidated or readily disintegrated material. The beds observed at outcrop are variable in composition, including marls of red or variously colored and banded appearance; loose coarse-grained sandstone or sandy beds, white or of darker weathered hues; and banks of more regularly bedded shale exposed here and there. At some places the varicolored beds of marl that commonly distinguish the Wasatch ("Vermilion Creek" of King) are exposed in great scars or badland washes.

Considerable areas of beds distinctly more recent than the Tertiary strata already described are present along the southern margin of the district here considered. These deposits consist of soft, friable material, made up largely of rounded quartz grains more or less consolidated by calcareous cement, with few harder consolidated strata. They are everywhere of a chalky-white appearance. They extend eastward as far as Cedar Mountain, whose summit is composed of these beds protected by an overlying cap of basalt. They correspond to the strata of the "Browns Park group" as described by Powell and others, and are markedly unconformable on all the older strata. They occur invariably in essentially horizontal position, with every appearance of having been deposited in a lake basin of late Tertiary or possibly more recent age. Although these beds at another locality are described very briefly, and with much doubt as to their age, in the Fortieth Parallel reports, they are there included with the Green River group as shown on that geologic map. They appear not to have been recognized at that time as occurring in the territory east of Little Snake River. C. A. White,[a] who afterward studied this region, described their eastward extension and regarded these beds as equivalent to the latest Eocene strata exposed south of the Uinta Mountains, although his reasons for this assumption are not clear, and now seem to have been unwarranted by the facts.

The whole region is covered to a greater or less extent with a scattered drift whose origin seems intimately connected with the source and history of the present gold deposits. This drift is described in more detail in the following paragraphs, as it forms the material of the bars or terraces from which the gold is now derived.

The only igneous rocks that are known to occur within the field are the basaltic intrusives and outflows, which are at least as recent as late Tertiary. These basalts are of very moderate extent on the open prairies, being confined chiefly to the higher summits and ridges of the Elkhead Mountains to the east. A prominent dike known as the "Rampart" extends westward from these foothills of that range, cutting the Tertiary strata a few miles beyond the Craig-

[a] On the geology and physiography of a portion of northwestern Colorado and adjacent parts of Utah and Wyoming: Ninth Ann. Rept. U. S. Geol. Survey, 1889, p. 691.

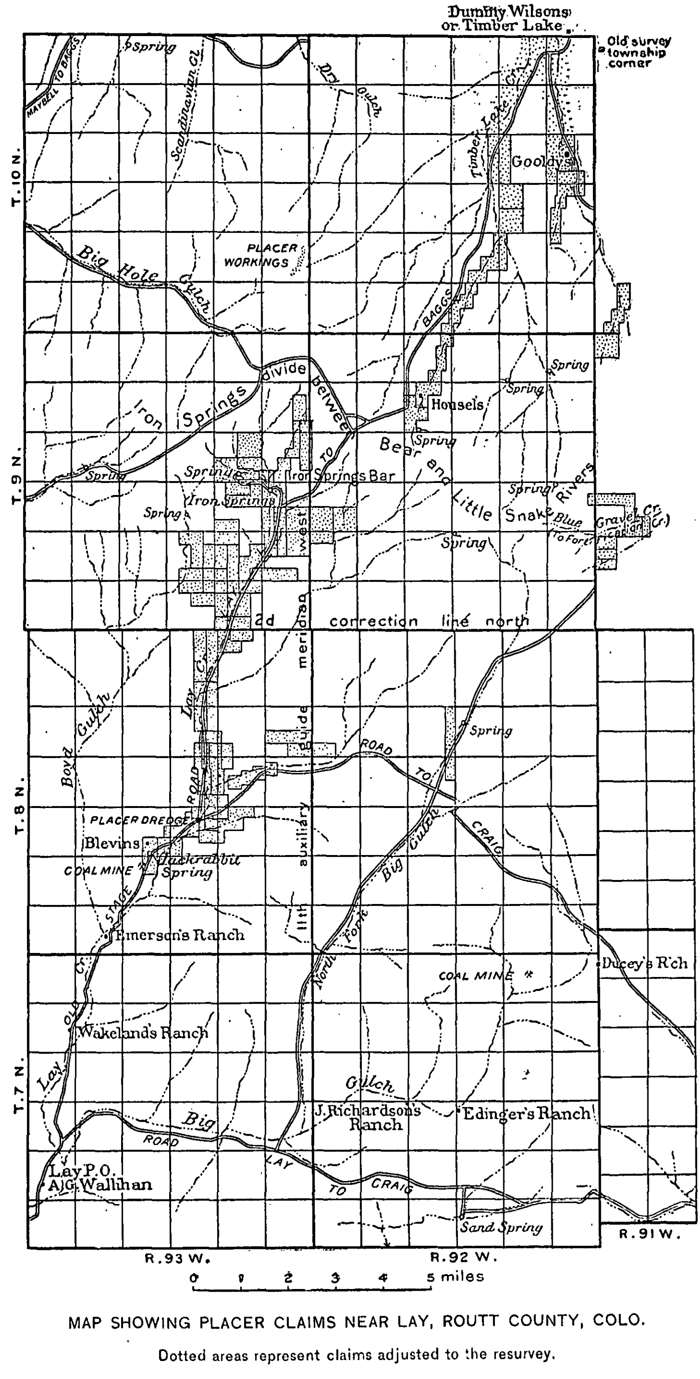
Rawlins stage road. Fortification Butte, or Cedar Mountain, an isolated peak on the southeast margin of the district, is capped by this basalt.

The geologic structure of the whole district is exceedingly simple. The strata occupy a broad synclinal trough or basin, over the greater part of which the beds lie approximately horizontal. At the southern margin of the basin the beds are tilted rather abruptly, rising over the Axial Basin anticline, just south of the placer field here described. This broad structural basin is considered as a southeastward continuation of the great structural depression known as the Green River Basin of Wyoming. The Bridger and Washakie basins as described by King are also subdivisions of this larger structural feature.

DISTRIBUTION OF AURIFEROUS DEPOSITS.

The map accompanying this report (Pl. I) is intended to outline the approximate extent and distribution of the more valuable ground as shown by the claims that have been filed on within the region. It can be seen at a glance that these claims are distributed along the drainage channels of the larger dry washes heading from the Iron Springs divide. A study of the ground itself, however, reveals the fact that the richest deposits lie on a bar or terrace ranging from 20 to 100 or more feet above the present creek bottom.

The Blevins dredge is now situated near the south end of the placer filings. A mile or so farther downstream Lay Creek enters a narrower valley cut in the tilted beds of harder and geologically older strata, and the upper bar is not readily distinguished below that point. The dredge stands on ground 20 or 30 feet above the level of the stream channel. Northward from this point along the main channel of Lay Creek the upper bench or bar rises more steeply than the stream grade itself. At Iron Springs the bar is about 70 feet above the creek and springs. As seen from its own level this bench appears to represent a former valley much broader than that of the modern drainage channels. Remnants of approximately the same elevation may be traced across the gulches to the flanks or tops of neighboring ridges. North of the Iron Springs bar the topography of the old valley level and of the main divide beyond is broad and open, a rolling, sagebrush-covered prairie. So far as can be gathered from reports of those who have prospected in the field, the gold-bearing gravels are distributed almost universally over all of this territory. It is stated on reliable authority that "pay" ground is found even on the highest summits of the main divide, and in fact pretty generally over all of that high ground. It also appears, from the selection of the located claims, that the most promising values are found on or near the so-called "bars," which as stated are thought to represent former drainage valleys. Although the sand and char-



MAP SHOWING PLACER CLAIMS NEAR LAY, ROUTT COUNTY, COLO.

Dotted areas represent claims adjusted to the resurvey.

acteristic gravels are found in the bottoms of the present streams, it seems probable that these materials are only reworkings from the higher deposits and they do not appear to be as rich as the original ground itself. Colors have been found in the bed of the creek lower down on its course, as, for instance, at Lay post-office, but not of sufficient value to attract attention. It is therefore assumed that, for the most part, modern drainage channels represent a concentration of too small a portion of the gold-bearing uplands to show important values, or else that much of the gold that may have been washed into those channels has passed on downstream, and possibly has been largely carried away.

It is probable that the auriferous deposits in the Little Snake drainage basin have the same history and origin as those in the southern part of the field. This is indicated in the following paragraph, which is quoted from the report of the Fourmile placer fields previously cited:

> The gravel beds are not, as is usually the case, in the various gulches, but form the mesa or upland and cover the entire country, the bed rock of the gravel being from 10 to 150 feet above the valley through which the streams flow to Snake River.

COMPOSITION OF AURIFEROUS DEPOSITS.

The beds composing the bars consist largely of loose white or light-colored quartz sand, in places containing coarser gravels and even larger, perfectly rounded pebbles and bowlders. Clear, glassy quartz grains, however, form by far the chief constituent of the sand. The gravel contains some clay which becomes evident on mixture with water, and clay also occurs in layers or beds somewhat irregularly distributed. Here and there it is more or less stained with iron, which gives it a rusty-brown or yellow color. More consolidated layers of conglomeratic material occur, evidently cemented by iron, but these are thought to be of local nature and of comparatively recent origin, having been derived from ferruginous deposits similar to the slimes now accumulating about the characteristic iron springs of the region. At some places, especially along the upper or headwater portions of the bars, and more particularly noticed near the Iron Springs divide, the material contains a variety of coarser pebbles or bowlders. A study of these pebbles shows them to have been derived from the following rocks:

Red quartzite.
White quartzite and hard sandstone.
Conglomeratic quartzite (rare).
White vein quartz.
Jet black chert.
Chert of various colors, some of it fossiliferous.
Gneissoid granitic or felsitic rock.
Crystalline granitic rocks (rare).
Pegmatite.
A feldspathic porphyry, with fine red or gray groundmass.
Silicified wood in waterworn fragments.

The character of this material is significant, denoting as it does its origin in the older formations of the Uinta and Rocky Mountain uplifts. Lower down the valleys, notably in the ground where the Blevins dredge is now situated, the coarser pebbles are more rare and the sand is very white and of a fairly uniform grain.

BED ROCK AND DISTRIBUTION OF PAY STREAKS.

No clearly defined bed rock can be traced from place to place among the prospects that show pay dirt. In places it is pointed out to be a coarse white sand, while the overlying pay dirt is composed of similar though more clayey material, the latter probably constituting the true bed rock which has served for the retention of the gold. At other places the bed rock is said to be a mottled clay of irregular pink and blue-gray patches underlying the sand or gravel pay dirt. Evidence seems to indicate that the agency which has served to retain the gold is the clay, which occurs either in the form of well-defined beds or mixed in certain layers of the gravel. The clay readily separates in water, however, and does not interfere with the recovery of the gold in washing.

To judge from the descriptions given of values and pay streaks in a number of pits and trenches visited in the vicinity of the Iron Springs bar, as well as the present shallow digging policy at the dredge, it seems a warrantable conclusion that the values are irregularly distributed in depth throughout the body of the gravel or sand-bar deposits. Although it would thus not be strictly true to state that the values are uniformly distributed throughout the gravel, any project for the recovery of the gold will probably have to consider the handling of practically the whole of that material from top to bottom, inasmuch as the values seem as likely to be found at the grass roots as they are to occur at any definite horizon lower down.

CHARACTER OF THE GOLD.

The gold from this ground is said to be very pure, ranging from 885 to 935 in fineness, and bringing between $19 and $20 an ounce. It is of very fine grain, in small, well-rounded nuggets which are estimated to average about 1,000 to the cent. On magnification, the grains are seen to be well worn and of a rounded or nugget form rather than in flakes. An examination of some of this gold under the microscope showed a few copper-colored or reddish grains. The color was apparently contained only in cavities in the irregular grains and looked like an iron rust or stain. The statement has been made that a portion of the gold seems to be coated so that it is not amalgamated in the riffles of the dredge. No direct evidence of this condition could be obtained, however, and the suggestion is urged rather that the wooden riffles of the dredge are probably not well adapted to the work at that place, and may for that reason fail to hold the gold.

The final concentrates that remain with the gold are notably free from the heavy black minerals such as magnetite, ilmenite, etc. In some small samples that were obtained by panning, these dark constituents formed scarcely a third of the concentrates, the remainder being made up largely of garnet and a number of clear colorless minerals. Among the latter were noted many small, perfectly formed crystals of zircon.

ORIGIN OF THE GOLD.

The gold-bearing sands and gravels appear to have been the latest deposits laid down in the region. No direct evidence is now at hand to fix the geologic time of their deposition, but they are seen to cover the eroded surface of all other recognized formations. They seem to have preceded the cutting of the present stream channels and to have been scattered widely over an older land surface which somewhat resembled that of the present day.

The occurrence of the auriferous deposits so far removed from areas of granitic rocks in place, to which it is natural to turn as the source of such material, has been the cause of much conjecture relating to their origin. The wide distribution of the gold-bearing beds over summits, divides, and valleys alike makes the determination of the means of their transportation and deposition still more complicated. Were the deposits grouped along present or past channels of the principal rivers flowing from the Park or Gore Range, it would be easy to assume that that region was the source of the material and that these streams constituted the transporting agency.

These deposits have been discussed by White in the reports of the Hayden Survey, and they are probably related or equivalent to the scattered drift denominated the Bishop Mountain conglomerate by Powell, in the report on the Uinta Mountains, and the Wyoming conglomerate by King, Emmons, and Hague, in the reports of the Fortieth Parallel Survey. The most complete discussion is given by White, who concludes that the deposition of these beds may have been contemporaneous with that of the great northern glacial drift, and suggests that they were of glacial origin. By Powell and Emmons they are believed to have been of subaerial origin, resulting chiefly from the action of rains and streams, or, according to Emmons, representing littoral or shore deposits.

The sources from which the pebbles have been derived are not difficult to trace in a general way. The wide extent of the territory thus defined, however, leaves quite as much doubt as to the actual situation of the vein deposits from which the gold has been derived.

The greater part of the pebbles are fairly characteristic of the older formations exposed along the main uplifts of the Uinta Mountains. The red and white quartzites and conglomeratic pebbles of the same class are readily distinguished as identical in composition with the "Uinta" quartzite of Powell, which forms the core and highest portion of that range. The various chert pebbles, some fossiliferous or stained in bright colors of red and yellow, as well as the black chert, are with almost equal certainty derived from the Carboniferous limestones exposed along the flanks of the same mountain range. Here and there pebbles of the limestone itself are also found. The derivation of the red or gray feldspar porphyry is more in doubt. A few granitic rocks, such as the granite, pegmatite, and related types, seem almost as certainly to have come from the other direction, or the Park Range of the Rocky Mountain system on the east. King describes some hornblendic and metamorphic rocks at the northeast end of the Uinta Range, but it is thought that no such rocks as granite or pegmatite are known there.

The sources and general trend of all the drainage of this region would more readily explain the transportation of materials from the Rocky Mountains to the east than from the Uinta Range to the west. In fact, the gravel and bowlder deposits that cap some of the elevated mesas along Yampa River are composed almost entirely of granitic rocks of such composition that they are certainly derived from the headwater streams in the Rocky Mountains. So far as is known to the author, very little gold has ever been reported from the rocks of the Uinta Range—a fact which would also tend to support the theory that most of that metal has come from the east.

It is of interest to note in this connection that a corresponding outspread of gravel and bowlders of almost identical composition, consisting of materials apparently derived from the same sources, must have taken place near the close of Cretaceous time. Evidence of this is now afforded by an extensive and continuous bed of conglomerate, marking an unconformity in the uppermost Cretaceous strata of the region, and possibly representing the orographic disturbances which produced the adjoining mountain ranges. The outcrop of this conglomerate bed may be found in the hills south of the placer field. It crosses Lay Creek near Emerson's ranch, the bowlder bed occurring immediately above a huge white sandstone stratum which dips beneath creek level at that place. The same beds may be traced continuously eastward, passing south of Cedar Mountain and crossing Fortification Creek about 2½ miles north of Craig. To the west they extend continuously for several miles to the point where they pass beneath and are concealed by the overlying "Browns Park beds." This conglomerate has been prospected to some extent, but does not appear to have attracted much attention. It might be expected to carry values somewhat similar to those of the more recent gravel deposits, but its occurrence is limited to the narrow outcrop of that particular bed.

PROSPECTS AND DEVELOPMENT.

In 1905 a dredge was installed just above Jack Rabbit Spring, and in September of that year started operation on what is known as the Blevins property. This dredge has been worked intermittently since that date and now (August, 1907) stands near the middle of the N. ½ sec. 22, T. 8 N., R. 93 W. An area of approximately 10 acres has been worked over. The season is said to last from about April 1 until about the middle of October, after which the work is likely to be interrupted by freezing.

The water supply is rather meager, coming from Jack Rabbit Spring about one-half mile below (southwest of) the dredge. The channel of Lay Creek is normally dry and apparently no attempt has ever been made to store the winter run-off; in fact, such a project may not be feasible on account of the scant precipitation. A steam pump has been placed at the spring and the whole available water supply is raised and carried by pipe line and ditch to the working ground. When the dredge was first started much difficulty was experienced in holding the water to float the boat, but it is stated that as the dredge has advanced toward higher ground there has been a smaller seepage and less trouble from this cause. The engines at both dredge and pump are supplied with fuel from a conveniently located coal bank, which has been opened expressly for that purpose. The coal is an excellent bed nearly 12 feet thick, without seams or partings and with a good roof. It outcrops at the side of the gulch just below the spring and is readily accessible, wagons being driven directly to the face of the entry for loading. The coal, a good subbituminous grade, of lighter weight than some of the coals of the Yampa field, slacks rapidly, but burns well and gives a satisfactory heat.

The gravel bar at the dredge is low, probably 20 or 30 feet above the level of the stream channel. The pay gravel is composed almost entirely of a loose white sand with very little coarser material. Apparently no especial effort has been made to reach bed rock in the dredging ground, the digging having reached, as estimated, only 5 or 6 feet below the top of the ground. Very little appears to be known as to the nature of the underlying bed rock at that place. This is doubtless due to its rather indefinite nature, as explained on another page.

Above or north of the Blevins dredge the most important group of claims in the field south of the Iron Springs divide lies near what is known as the Iron Springs bar, in the east half of T. 9 N., R. 93 W.

The claims are located on a somewhat irregular bench or high terrace averaging 70 feet or more above the present stream channel. The bar just east of Iron Springs is about a mile long from north to south and a quarter of a mile in width, sloping southward at a grade of about 60 feet to the mile. Benches corresponding to this level appear on the neighboring ridges. The sand and gravel deposits to the north are said to rise even to the summit of the main divide. The irregular sage-covered plain affords too poor exposures for satisfactory tracing of these beds.

In sec. 14, T. 9 N., R. 93 W., a small reservoir just below the spring marks the site of some past development work. Claims here are said to have been first located by a Mr. Scrivener, who washed the narrow gulch bottom with a sluice, using the water from the spring. The claims were later taken up by a Mr. Lahr, who discovered pay gravel in the banks, and drifted in 100 feet from the bottom of the gulch, being able, it is stated, to make his living from the washings in the meantime. This drift evidently reached a depth of 30 feet or perhaps considerably more below the sand or gravel cap rock, and this fact may be taken to indicate that the gold will be found down to considerable depths in some parts of the field. The claims were later dropped and are now in other hands. An old gasoline engine used to pump the water for sluicing stands at the place. This property is said to have contained some rich pay streaks.

VALUE OF THE GROUND.

It may be assumed that the site selected for the operation of the dredge is as favorable a locality as any other in the field. Estimates made by one of the interested persons placed the value of the ground already worked over, as from 25 cents to several dollars per cubic yard. It was said on the same authority that the dredge was then standing on ground that would yield $2.40 per cubic yard.

A series of tests were conducted by Mr. Wallihan on material obtained near the Iron Springs bar, but are hardly complete enough to be considered thoroughly representative of the field. Test pans were taken from various prospects in that vicinity. The pits themselves have been dug more or less at random over the placer ground. They vary somewhat in size, at least one of them reaching a depth of 15 feet or more.

The sample taken in each case was a stricken pan containing 20 pounds of dry material. This was then panned, all of the black sands and gold being saved and the concentrates being sent to Denver for assay. The following results have been calculated from the returns of these assays, on the assumption that one cubic yard of ground will weigh 1½ tons. A set of twelve such assays showed a range in value from 1.6 to 63.7 cents per cubic yard. The average amount of black sand was found by the same tests to be 1 ton in 368 tons of material.

It is thought, however, that the samples taken for testing are not in every case representative or an average of the whole thickness exposed in the pit. This is probably true of those samples which show the higher values, as these are very likely to have been shoveled from some particular part of the pit thought to contain the pay streaks. If this is so, allowance should be made to obtain the average grade of all the material handled.

GOLD DEPOSITS OF THE LITTLE ROCKY MOUNTAINS MONTANA.

By William H. Emmons.

INTRODUCTION.

The eastern half of Montana is in the main a nearly level country and at most places is devoid of conspicuous topographic features. A number of small buttes rise above the plains and here and there small groups of mountains relieve the monotony of the horizon. The Little Rocky Mountains form such a group, their rounded green summits contrasting in a striking manner with the featureless gray plains by which they are surrounded on every side. These mountains are in the southeast corner of Chouteau County, Mont., between Missouri and Milk rivers. The group as a whole is rudely elliptical in outline, about 10 miles in greatest length and 8 miles wide, the longer axis trending northeastward. The elevation of the surrounding plains is approximately 3,000 feet above sea level, and the highest peaks of the mountains reach elevations of about 6,600 feet.

The Little Rockies are 35 miles south of the Great Northern Railway and directly south of the Fort Belknap Indian Reservation. The principal mining camps in the mountains are Zortman, Whitcomb, and Landusky, each of which is provided with a post-office and is connected by stage with the railroad. One line of stages makes three round trips a week from Malta to Zortman. Another line makes three round trips a week from Dodson to Whitcomb and Zortman, the two stages leaving the railroad points on alternate days. A third line of stages runs three times a week from Harlem to Landusky. The trip to the mountains is made in one day from each of these points.

In 1895 Messrs. W. H. Weed and L. V. Pirsson visited the mountains to examine the mineral resources of the Fort Belknap Indian Reservation for the commissioners appointed to treat with the Indian tribes, with a view to segregating the mineral lands of that reservation. The scientific results of this visit were published the following year.[a]

[a] Jour. Geol., vol. 4, 1896, pp. 399–428; Eng. and Min. Jour., vol. 61, 1896, pp. 423–424.

At this time the mines had produced a small amount of rich ore, but very little underground development had been done, and the principal lodes now producing had not been discovered. In October, 1907, the writer, incidental to other work in Montana, made a visit to the mountains, the results of which appear herewith. He is indebted to Messrs. Weed and Pirsson, whose valuable historical and geologic data have been freely drawn upon; and to the operators and prospectors of the district, who have been uniformly courteous in facilitating his investigations.

HISTORY OF DEVELOPMENT.

The placer deposits occurring in the beds of the streams that flow southward from the Little Rocky Mountains to Missouri River had been worked intermittently but with small success for several years before the lode deposits were discovered. The lode deposits came into prominence in 1893, when gold was found in the August mine, which at that time was within the boundaries of the Fort Belknap Indian Reservation. This mine was worked quietly without the knowledge of the Indian agents, and about $32,000 was taken out in sinking a shaft 65 feet deep. The following year the Goldbug and other claims near Landusky were actively explored, the Goldbug producing a small amount of rich ore. Subsequently the mineral lands were segregated from the Indian reservation and thrown open to prospecting. As most of the ore was not of shipping grade the development of the mines was slow. About $55,000 worth of gold ore was shipped from the Alabama mine in 1899 and 1900, but aside from these shipments the production was practically nothing until the spring of 1903, when the Zortman cyanide mill was completed. This mill was built by the Alder Gulch Mining Company and was supplied with ore from the Alabama and Pole Gulch mines. It was in operation about six months of each year for four years. In October, 1907, the mill was idle and the mines of the company were under bond to the Little Rockies Exploration Company, which had a force of men doing exploration and development work.

The Ruby Gulch mill was completed in January, 1905, and began treating ore from the Independent mine. This mill was at first a 100-ton plant, but in 1907 its capacity was increased to 300 tons a day. It has been in successful operation ever since it was built, and according to the superintendent, Mr. E. E. Berry, it has produced about $600,000.

Aside from the returns from placer mining for which authentic information is not at hand, but which were probably small, the total production of the Little Rockies is about $950,000. The average annual production for the last four years, since the first cyanide mill was built, is a little less than $200,000. The returns for 1907 will probably show an increase over this amount.

The location of the various mines is shown in fig. 2.

MINING AND MILLING.

The form of the deposits and the character of the ore favor very low costs for both mining and milling. The Mint, Independent, and Pole Gulch mines are all worked by the open-cut method. The ore falls to the bottom of the hopper-shaped cavities and is drawn through chutes into tunnels driven under the deposits from 100 to 200 feet below the outcrop of the ore bodies. By this method little

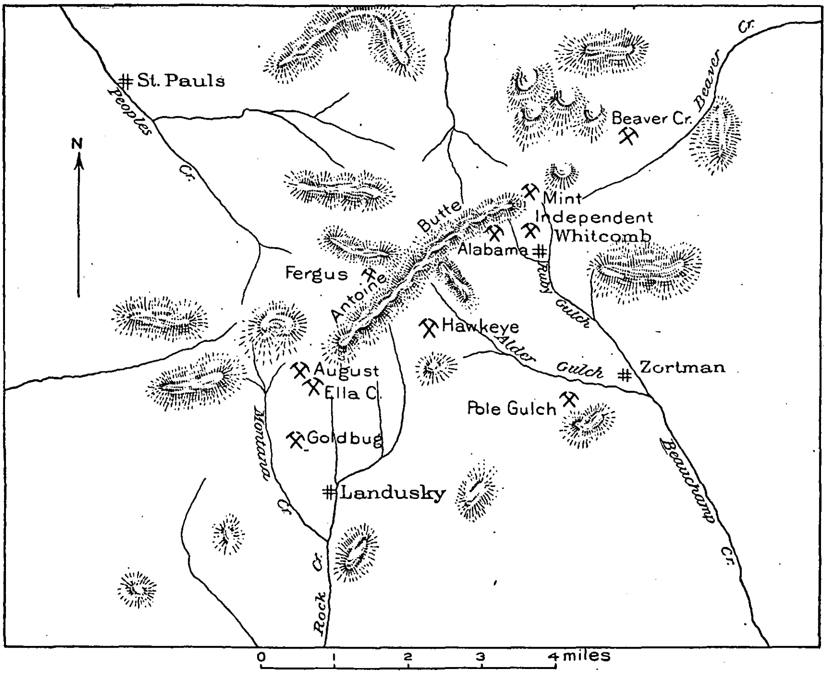


FIG. 2.—Sketch map of Little Rocky Mountains, Montana, showing location of mines.

timbering is necessary, as the walls stand fairly well; and at the Mint mine three men, one on each shift, are able to supply the mill with 300 tons of rock per day. The ore is soft and requires but little breaking for passage through the chutes, though some difficulty is experienced when the moisture content of the ore is high. After rains or melting snow, water collects in the ore pits, forming a mud with the soft clayey ore. With the present method of treatment no water is added to the ore until it reaches the cyanide tanks, and excessively wet ore is very undesirable because it clogs the ore chutes and the elevators. The water which reaches the open cuts is not surface water in the strict sense, but it probably soaks into the ground just above the cuts and seeps out into the ore chambers after a very short underground course. There is a luxuriant growth of small pine trees surrounding the pits and this prevents surface drainage. The moisture content of the ore could probably be reduced if the country just above the pits were cleared of vegetation and if a number of ditches were dug so as to lead the surface water from points above the mine directly to the deep gulches near by, and thus prevent it from soaking into the ground and so reaching the ore pits.

The Ruby Gulch mill was the only plant in operation in 1907. This is a 300-ton cyanide plant located in Ruby Gulch, 1½ miles above Zortman. The ore passes from a gravity tramway connected with the mine through a No. 3 Gates crusher, from which it passes over a 1-inch mesh Jeffries screen set at an angle of 45°. From the screen the undersize goes to the tanks and the oversize is passed through a set of 14 by 24 inch rolls and from these through 12 by 14 inch rolls, of which there are two sets. From the fine rolls the ore passes over a 1-inch mesh impact screen, the fines going to the tanks and the coarse material being returned to the same rolls. For leaching the mill is provided with six 300-ton tanks and six 110-ton tanks. The usual period for leaching is seven days. Although the screens used for oxidized ore are 1-inch mesh, the angle at which they set is so steep that the material passing through is much finer. A test on screened ore showed that 70 per cent of this material would go through a 12-mesh screen after passing through the mill. Much of the ore is very fine as it comes from the mine. At one time a 300-ton tank was filled with ore which had not passed through the mill at all and a satisfactory saving was made after twelve days of leaching. For the oxidized ore the saving is commonly 90 per cent, but for sulphide ore it is lower. The strength of solution best adapted for leaching is one-twentieth of 1 per cent. The ores assay from $3 to $21 per ton. The average value of the ore since the mill was started is $6.55. The usual cost of mining and milling is said to be as low as $2 per ton when conditions are favorable. As the country is remote from a railroad, the cost of supplies is high. Steam power is used and wood is burned for fuel, at a cost of $8 a cord delivered at the mill, which requires 8 cords per day. The company owns coal mines and water rights on Rock Creek, and contemplates the installation of a power plant and the erection of a transmission line from the coal mines to the mill. The lime used in the mill is burned from the Carboniferous beds which form a rim around the mountains and it is said to be of a satisfactory quality.

The Zortman mill, which is a 100-ton cyanide plant located in Alder Gulch, about 1 mile west of Zortman, treated ore from the Alabama and Pole Gulch mines. From the Alabama mine the ore was hauled in wagons down grade about 1¾ miles to a bin just below the mill. The ore was elevated by a short tramway to the head of the mill, whence it passed to a Gates D crusher through a double shaking screen, the upper plate of which was 1-inch mesh and the lower plate $\frac{5}{8}$-inch mesh for oxidized ore and $\frac{1}{8}$-inch mesh for sulphide ore. The ore passing over the screen was sent through coarse rolls and elevated back upon the screen. The ore going through the 1-inch screen was passed through finer rolls and thence was also returned to the screen; and the ore passing through the lower screen was sent over belt conveyors into the tanks. The plant is provided with five 100-ton tanks for leaching. The usual period for leaching was five days and the saving is said to have been about 90 per cent for oxidized ore. The method of treatment was essentially the same as at the Ruby Gulch mill.

The Goldbug mill is located at Landusky. It is equipped with a 7 by 10 inch Blake crusher, 10 gravity stamps, amalgamation plates, and two Frue vanners. It was built in 1902 to treat the lower grade ore of the Goldbug mine, but the saving was not satisfactory and only a few tons of ore were milled. The oxidized ores are easily cyanided, but only a small percentage of the values can be saved by amalgamation. The quantity and value of the sulphides in the tailings from the ore, so far as developed, are not sufficient to render mechanical concentration profitable.

GEOLOGY.

GENERAL FEATURES.

As has been shown by Weed and Pirsson, the Little Rocky Mountains form a dome-shaped uplift of sedimentary and metamorphic rocks which has been modified by the intrusion of a thick sheet of porphyry and by the erosion of the younger beds from the top of the dome. In its broader features the structure is simple. As one approaches the mountains from the nearly flat Cretaceous beds which underlie the surrounding plains he passes successively over beds of greater age, and well toward the interior of the little mountain group he encounters crystalline schists which are highly metamorphosed and older than any of the bedded sedimentary rocks. The dip of the beds is outward from the central axis of the mountains toward the surrounding plains, at a greater angle than the average slope of the mountains. For this reason the older beds are exposed toward the center of the group and in general are of higher elevations than the younger beds that overlie them.

METAMORPHIC ROCKS.

The oldest rocks are crystalline schists which are exposed in the deep gulches in the interior of the mountains and at some places on the higher ridges near the crest. These schists are of pre-Cambrian age and are overlain by Cambrian quartzite, but at many places they are separated from the Cambrian by the intruding porphyry. The prevailing rock among the schists is a dark, glistening hornblende schist or amphibolite. Locally this is garnetiferous, and at some places rich in quartz and feldspar. On the road from Zortman to the Alabama mine the schists consist of thin alternating beds of different character, and at some places quartzites are included in them, showing that the series is, in part at least, of sedimentary origin. These rocks everywhere have been profoundly metamorphosed.

SEDIMENTARY ROCKS.

The Cambrian beds rest unconformably upon the metamorphic rocks or are separated from them by intruding porphyry. At the base of the Cambrian is a quartzite bed about 75 feet thick, overlain by shales and limestone, making altogether a series about 500 feet in total thickness. Above the Cambrian, with no apparent unconformity, is a succession of impure limestones, in which no fossils have been found, but which are presumably of Silurian or Devonian age. Resting upon these limestones are large massive beds of white or light-gray limestone rich in Carboniferous fossils. These rocks are more resistant to erosion than the underlying limestones and form a chain of ridges and peaks around the mountains, the continuity of which is interrupted here and there by valleys that have been cut through the limestone by numerous small streams flowing outward from the central mountain crest. This broken rim of Carboniferous rocks is a conspicuous feature of the landscape, and it has been aptly compared to the limestone girdle which encircles the Black Hills of South Dakota. On the low ridges which slope gently away from the mountains toward the plains the Jurassic limestones overlie the Carboniferous beds and these in turn are covered by the Cretaceous sandstones and shales. The Jurassic and Cretaceous formations are not known to occur within the mountain group proper, but together they cover great areas of the surrounding plains and badlands country.

PORPHYRY.

A large, thick sheet of igneous rock forms the central axis of the mountains and is the country rock for the most important ore deposits. It is composed of syenite porphyry and other closely related varieties of alkali-rich rocks. This mass is nearly circular and is about 6 miles in diameter. Some of the buttes near the outer rim of the mountains are also capped with porphyry which is separated by limestones from the main central mass. The intruding porphyry is limited so far as known to the crystalline schists and to the Cambrian beds. The horizon between the schist and the Cambrian quartzite and that at the top of the quartzite and below the Cambrian shales appear to have been planes of weakness which were especially favorable for the intruding rock.

As the structure of the mountains is that of a dome, with the dip away from the central axis, and as the porphyry is in the main a sheet intruded between the sedimentary beds, it also dips away from the center of the uplift. The highest peaks are capped with porphyry, but the crystalline schists also occur at some localities near the top of the divide and they are exposed at a large number of places in the hollows of the gulches which radiate from the center of the mountains. Small areas of both schists and limestones, some of them only a few feet in greatest diameter, are entirely surrounded by porphyry and appear to be isolated masses which were caught up in the intrusion. Other masses of limestones are probably remnants, not yet eroded, of the beds which lie upon the porphyry sheet. The porphyry appears to be thickest in the central portion of the mountains and to thin out near the margin, but its precise thickness has not been measured, as no favorable section was found. At some places it is at least 400 feet thick, and it may be thicker. The contact between the schist and porphyry shows irregularities or warpings other than the ordinary dip toward the margin of the mountains, and the distribution of the two rocks with respect to the topography as shown in fig. 3 is not such as could result if the contact were simply a tilted plane. The porphyry sheet is an intrusive rock and is younger than the rocks which inclose it. At some places it must have come up through the crystalline schists and at such places its contacts with that formation are probably steeply inclined or vertical. At the point where the porphyry rose it is likely to be found to extend downward to great depth. It is the opinion of Weed and Pirsson [a] that one of the vents through which the porphyry rose is near the Goldbug mine. It is possible that another vent is located in the vicinity of the Alabama and Mint mines, for vertical workings in the Alabama mine over 500 feet deep are said to have been entirely in porphyry. Moreover, the contacts between the porphyry and the crystalline schists, as shown on the map (fig. 3), strongly suggest crosscutting relations at this place.

The fresh unaltered porphyry is commonly light gray in color, and at some places light pink or purplish pink. The groundmass is even and fine grained and practically all the phenocrysts are feldspar. These vary in size and in some varieties of the porphyry they are half an inch long. No ferromagnesian minerals are present, though small dark specks show where biotite crystals have altered. At many places the porphyry is extensively brecciated and cemented by ma-

[a] Op. cit., p. 412.

terial which is of about the same composition as the fragments, but the cement is usually less porphyritic than the fragments which it

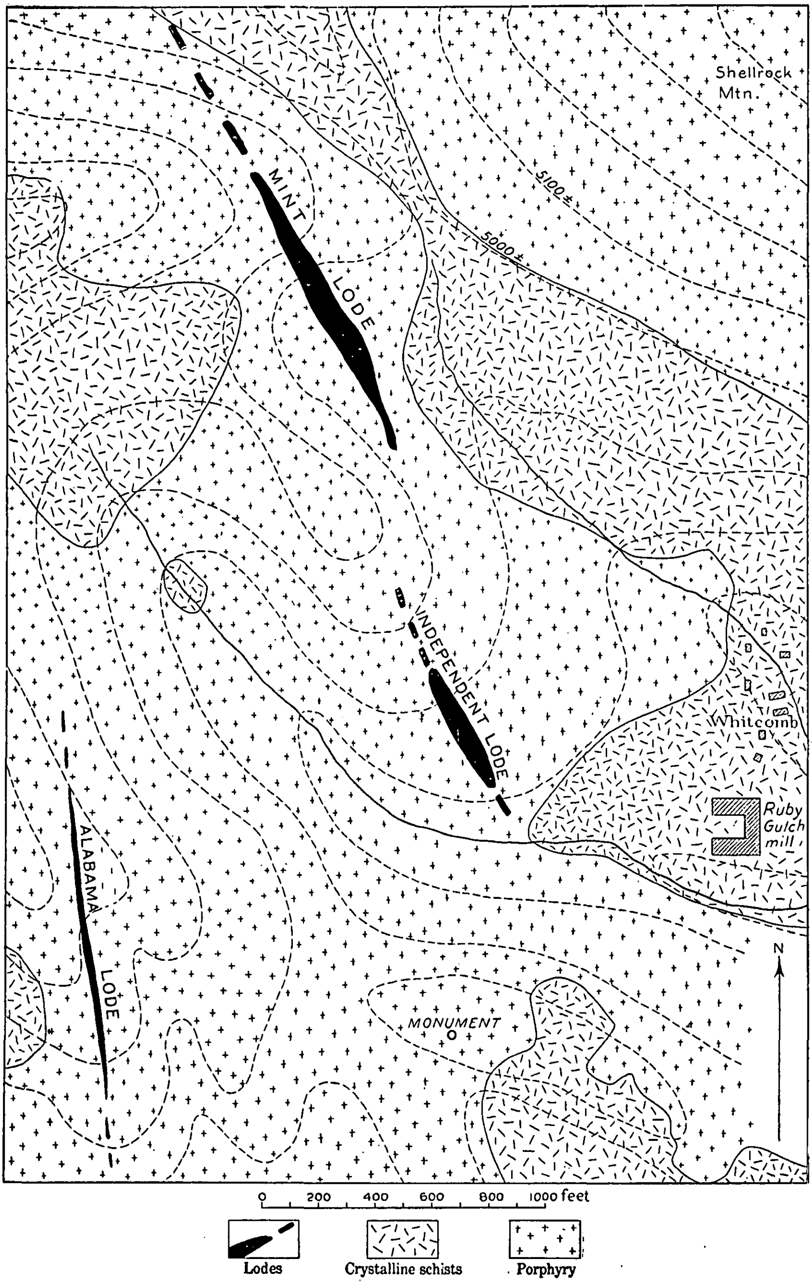


FIG. 3.—Sketch map of a portion of the Zortman mining district, Little Rocky Mountains, Montana.

surrounds. Under the microscope the phenocrysts are seen to be orthoclase and plagioclase, and in some varieties a few small quartz phenocrysts are present. The largest phenocrysts are orthoclase and zonally built forms made up of orthoclase and albite. A few striated plagioclase phenocrysts with the composition of acid oligoclase are usually present. The groundmass is microcrystalline and is composed of alkali feldspar and quartz, with fine particles of magnetite. The feldspars are slightly kaolinized; even in the freshest rocks some white mica has been developed, presumably as an alteration product of biotite. More extensive alterations which have occurred in the vicinity of the ore deposits are described on page 108.

The syenite porphyry, granite-syenite porphyry, and granite porphyry which make up the central igneous mass appear to grade one into another and have not been separated in the field. On Montana Creek a short distance north of Landusky, just below the Cambrian quartzite and between it and the main porphyry mass, a dark-green porphyry, possibly a contact phase, was examined by Weed and Pirsson and proved to be tinguaite, a variety of phonolite.

ORE DEPOSITS.

GENERAL CHARACTER AND STRUCTURAL RELATIONS.

The ore deposits of the Little Rocky Mountains are (1) zones of fractured porphyry replaced and cemented by quartz and pyrite and (2) replacement deposits in limestone near intruding porphyry. The ore carries as a rule from $3 to $7 in gold and about an ounce of silver to the ton. Here and there are small bodies of high-grade shipping ore. The most important deposits are in the porphyry and these fall naturally into two groups. One of these is the Zortman group, which includes the Mint, Independent, and Alabama lodes; the other is the Landusky group, which includes the Goldbug, August, and other lodes near by. The Landusky group is about 4 miles southwest of the Zortman group. All the lodes of the Zortman group, so far as known, trend west of north; those of the Landusky group trend east of north.

There is no evidence that the movements which resulted in the formation of openings that permitted the solutions to enter the porphyry and deposit their burden produced spaces of any considerable size. These movements resulted rather in shearing and in brecciation along fissured zones, with a large number of small openings rather than a single large open space. The stresses were in part of a compressive character, for some of the country rock near the Alabama lode is noticeably sheared. The irregular width, short length, and lack of definition of some of the deposits in the Landusky group may be attributed to this cause.

The lodes in porphyry range in width from a few inches to 70 feet. They are not everywhere of a grade to pay for working, but at both the Mint and Independent cuts it was found profitable to mill the lodes to a width of more than 50 feet for 200 or 300 feet along the strike of the deposit. As the lodes are replacement deposits and grade imperceptibly into the porphyry, it is at some places a very difficult matter to determine what is ore except by assaying. This is true especially where the barren porphyry in the mineralized area is slightly stained with iron oxide.

The lodes in the Zortman district appear to be fairly persistent in length. One of them has been followed continuously for 1,200 feet along its strike, and surface workings indicate that it is longer. Nearly all the lodes are cut by fissures, commonly called "walls." These are as a rule slickensided and grooved, indicating that they

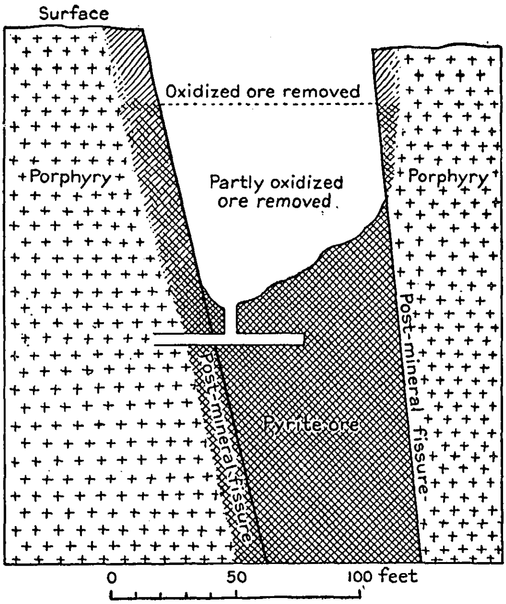


FIG. 4.—Vertical section through the Independent lode at open cut, near Whitcomb, Mont.

are planes of movement. At some places crushed quartz occurs along them, which shows that the movement was later than the deposition of the ore. They do not determine the limits of the ore body and are not walls in the strict sense of the term. At many places there is ore behind them, and some of them cut across the ore body, running at one place near the hanging-wall side and at another on the foot-wall side. Many of them split and inclose masses of ore and country rock, and some of them cross the vein at a considerable angle. Fig. 4 is a cross section at the Independent open cut, showing two such fissures crossing the ore body; followed along the strike these fissures intersect in the lode a short distance to the north of the line of the section. Some of the slickensided planes follow the lodes with singular persistence. One of them can be traced for 1,200 feet and in the entire distance does not completely cross the ore body. This parallelism of the lodes and the slickensided planes seems to indicate that the lodes are planes of weakness, and it is an illustration of the general fact that fissures have a strong tendency to follow planes along which movement has already taken place.

It is not good mining to follow these fissures or "walls" too closely, as they leave the lode at some places and strike out into the country rock, and as they do not everywhere limit the lodes. Good ore may be found beyond them or on both sides of them, and in many places frequent assaying is necessary to keep on the ore body.

The replacement deposits in limestone have not been developed sufficiently to determine their character. So far as known they all occur near the contact of the limestone with the porphyry, but they are not contact-metamorphic deposits, for the sedimentary rocks near the porhyry are not noticeably metamorphosed.

MINERALS OF THE DEPOSITS.

Gold.—Gold occurs in pyrite and in quartz and in the oxidation products of pyrite ore. It is so finely disseminated that the ores can not be successfully amalgamated. Small bodies of native gold the size of a pinhead have been found in oxidized ore from the Alabama mine, but most of the gold is not visible to the naked eye. A gold telluride occurs in several of the deposits.

Silver.—Most of the ore carries about an ounce of silver to the ton. A portion of the silver values are recovered by the cyanide process. The silver probably forms an alloy with the gold.

Quartz.—Quartz is an original constituent of the porphyry, where it occurs in the main as microcrystalline anhedra in the groundmass. Secondary quartz replaces both the phenocrysts and groundmass of the porphyry, and small veinlets of quartz, a fraction of a millimeter wide, are numerous in the porphyry near the deposits. The payable ore at some places is cut by small veinlets of milky quartz a centimeter wide, which do not carry gold.

Feldspars.—The phenocrysts of the porhyry are orthoclase and acid oligoclase and where the porphyry is not excessively altered these minerals are abundant constituents of the ore. Secondary orthoclase occurs as clear fresh crystals which have been deposited on the older altered orthoclase presumably by the vein-forming solutions.

Magnetite.—Magnetite is present as minute bodies which are primary constituents of the porphyry and as an alteration product of biotite. No magnetite was noted in the ore that replaces limestone.

Kaolin.—Kaolin is abundantly formed through the alteration of feldspar, and such alteration is not confined to the vicinity of the ore deposits.

Sericite.—Sericite, or white mica, is an abundant constituent of the ore. It occurs as minute foils replacing orthoclase and is extensively developed in the groundmass of the mineralized porphyry.

Pyrite.—Pyrite is the only sulphide which was noted in the ore and in depth is present in considerable quantity. It occurs as small irregular bodies and as well-formed crystals replacing porphyry, and in places in the Independent lode there are masses of pure pyrite of considerable size. It fills numerous small cracks which cut the replaced porphyry and commonly it coats the fragments of the crushed ore. Fibrous and globular pyrite, having the habit of marcasite but of brassy-yellow color, were noted in the Independent mine near the surface.

Fluorite.—Purple fluorite is present in all the producing mines and is a conspicuous mineral, though it forms only a small portion of the ore. It occurs as irregular bodies and as small tabular masses along planes of movement parallel to the lode and it is usually associated with the ore of high grade. It replaces both limestone and porphyry. In the porphyry it is as a rule a more or less earthy variety, and under the microscope some of it is colorless. Fine crystals of purple fluorite are present in the Pole Gulch deposit in limestone.

Calcite.—Calcite is an abundant constituent of the deposits which replace limestone. The country rock is more or less marmorized and is cut by the veinlets of white calcite, which are as a rule less than 1 inch wide. In these deposits crystals of calcite nearly half an inch in diameter are associated with quartz and fluorite. The oxidized ores of the lodes in porphyry carry a trace of calcite, but none could be found in the sulphide ore of such lodes.

Limonite.—Limonite is invariably present in the oxidized ores and some of the deposits carry a considerable quantity of this mineral. Most of it is the earthy amorphous variety, but here and there a pseudomorph after pyrite is present. Brecciated fragments of porphyry are cemented by limonite and it coats fragments of crushed ore.

Manganese oxide.—The dark-brown powder which is present in some of the ore is one of the oxides of manganese. The presence of this powder is regarded as a favorable indication of values, as it is commonly associated with the high-grade ore.

Copper carbonate.—Small bunches of green copper carbonate are present in the oxidized ore, but this mineral is rare.

REPLACEMENT PROCESSES.

The porphyry of Antoine Butte is a granite-syenite porphyry. The phenocrysts are up to 5 millimeters long and are evenly spaced through the rock. A specimen collected by Weed and Pirsson from Antoine Butte was analyzed by Dr. H. N. Stokes in the laboratory of the United States Geological Survey.[a] The theoretical composition or norm calculated from this analysis gives:

Norm of porphyry from Antoine Butte, Montana.

Quartz	0.20
Orthoclase	.28
Albite	.41
Anorthite	.05
Water and other constituents	.06
	1.00

The phenocrysts are made up of orthoclase and striated plagioclase—about the composition of acid oligoclase. The proportion of the plagioclase in the groundmass is very small. The action of the mineral solutions on this rock was as follows: Pyrite and quartz carrying more or less gold partly replaced both phenocrysts and groundmass; the feldspar phenocrysts were altered partly or entirely to sericite and kaolin and fresh clear orthoclase was deposited on the older feldspars. Locally the porphyry, especially where crushed, was partly replaced by fluorite; the finely powdered porphyry was almost completely replaced and this now consists of an intimate intergrowth of small square crystals of fluorite between the interstices of which are many minutely microscopic bodies of quartz.

OXIDATION OF THE ORE.

The primary ore is in the main a hard, brittle porphyry, carrying a notable amount of pyrite and secondary quartz. The fresh, unaltered porphyry is a light-colored rock with a dense, fine-grained groundmass showing practically no dark constituents. Where this has been finely crushed the powder has been completely replaced, and small angular fragments are now surrounded entirely by the quartz and pyrite. The sulphide ore is best exposed in the lower workings of the Independent lode, where at some places sulphide ore grades into the altered porphyry without any definite dividing line between.

Near the surface the pyritiferous ore has oxidized to a variable depth. As shot down in the pits the harder ore consists mainly of porphyry, broken as a rule to small angular fragments which are covered more or less completely with a thin coating of iron oxide and cut through with thin seams of the same material. The richer portion of the ore is, however, either a reddish-brown or black material almost as fine as dust.

The lower limit of the zone of oxidation is at some places 200 feet below the surface. On the Mint claim pyrite is just beginning to appear at that depth. In the Independent open cut, oxides mixed with

[a] Washington, H. S., Prof. Paper U. S. Geol. Survey No. 14, 1903, p. 147.

pyrite extend at some places to the surface and generally appear at a depth of 25 feet or less. In the Alabama mine the ore is partly oxidized at a depth of 400 feet and it contains a noticeable amount of pyrite at 100 feet. Exclusive of relatively small seams of finely powdered limonitic and manganitic ore, the gold values in the sulphides and in the oxides are said to be approximately equal.

GENESIS OF THE ORES.

The ores were deposited as sulphides and probably by ascending waters. There is a large amount of calcite in the ore of the replacement deposits in limestone, but no calcite or other carbonate could be found in the sulphide ore of the lodes in porphyry, by either chemical or microscopic examination, and there is only a trace of calcite in the oxidized ore of the lodes in porphyry. A great thickness of limestone has been eroded from above the deposits in porphyry, for residual masses of the limestone rest upon the porphyry and the porphyry mass is surrounded by a girdle of overlying limestone. If the solutions had been descending through some higher horizon now eroded, they should have passed through this limestone and would probably have dissolved lime carbonate and redeposited it with the ore. The absence of more than a trace of calcite in the oxidized ore further suggests that secondary enrichment by waters descending through the overlying limestone into the lodes or brecciated zones in porphyry was not a process of great importance.

FUTURE OF THE DISTRICT.

Owing to the great width of the lodes, their linear extent, and the depth to which oxidation has extended, the success of the camp in the immediate future does not seem to depend directly on the availability of sulphide ores. But when the oxidized ores shall have been exhausted the value and extent of the sulphide ores will be a question of first importance. Although sulphide ore of fair grade has been found in the Independent mine, this ore, because of the greater difficulty of saving the values, has not proved so attractive as the oxidized ores of the Mint claim, and the workings in sulphide ore are of small extent. The data at present available are insufficient to form a sound basis for prediction as to the extent of the sulphide ore in depth. In this connection, however, two features should be considered—(1) the character and extent of the mineralization of the crystalline schists below the porphyry; (2) the thickness of the intruding porphyry.

Concerning the character and extent of the mineralization of the crystalline schists few data are at hand. These rocks are, as already stated, of much greater age than the porphyry which contains the ore and as they were present when the ores were deposited it is quite likely that they will be found to carry sulphides where the lodes cross them. Near the head of Peoples Creek, in one of the tunnels of the Fergus Mining Company, the schists are locally replaced by pyrite. On the other hand, no important deposits have yet been discovered in the schists and they can hardly be regarded as affording a favorable ore horizon. The vertical extent of the porphyry, then, is a factor of economic importance. As already stated, the porphyry is in the main a sheet from 300 to 400 feet thick, intruded between the arched Cambrian rocks or at the base of these rocks above the crystalline schists. Necks through which the porphyry rose may extend downward through the crystalline schists and at such places the thickness of the porphyry may be considerably greater. It is possible that future developments will show this structure at the Alabama mine, where the thickness of the porphyry is known to be above the average.

On the whole the conditions on which costs depend are favorable. Owing to the isolation of the locality and the high cost of living, labor has been somewhat higher here than at most of the other camps in Montana. Power is expensive and the cost of transportation of mill supplies is heavy. Wood fuel, which has hitherto been the sole source of power, is not of the best quality and sells at a high price. Power plants can not be constructed as readily as is possible in larger mountain groups, as the streams which drain the Little Rockies are small. Good coal is said to occur on the plains to the south of the mountains and this seems to be the most available source of power. The form and character of the ore deposits themselves favor unusually low costs.

DETAILED DESCRIPTIONS.

MINT MINE.

The Mint mine is located near the head of Ruby Gulch, about 2,000 feet northwest of Whitcomb. It is owned by the Ruby Gulch Mining Company and is the most productive deposit in the Zortman district. It has yielded more than $350,000 worth of gold and silver. The lode followed northward crosses the crest of the mountains and ore has been discovered on both sides of the divide, but the main workings are on the southern slope. The lowest level is an adit driven westward about 150 feet to the lode. From the point of intersection the lode is followed southward from the adit for 200 feet and northward for about 800 feet. Several raises are turned from this adit and are used to draw ore from the open cut above, which at its highest point is about 180 feet above the level of the adit. The Carter tunnel is 175 feet higher than the main working tunnel and is driven northward along the ore body for 400 feet. What is presumably the same ore body is opened by surface workings at two or three places north of the north end of the adit.

The country rock is porphyry, which constitutes the main central axis of the mountains. The crystalline schists outcrop both to the west and to the east of the lode, only a few rods away on either side. Their position is shown in fig. 3 (p. 103). A broken line in this figure indicates that though the lode is known to be present its width is unknown at such places.

The lode is a zone of shattered, cemented, and replaced porphyry. Its average strike is N. 28° W. and it is approximately vertical. As mined it is from 20 to 70 feet wide.

The ore is highly oxidized throughout the explored portion of the lode. In a winze sunk in ore 75 feet below the level of the lowest tunnel, giving a depth of 200 feet below the surface, no sulphides whatever appear, and only small bunches of pyrite occur here and there at the north breast of the tunnel, which is about an equal distance below the surface. The ore as mined is in the main finely shattered and decomposed porphyry, covered with a thin coating of iron oxide. Some of the porphyry is highly silicified. The ore carries from $3 to $21 in gold and about 1 ounce of silver to the ton, the general average as shown by mill runs being $6.55. The richest parts of the lode are rudely tabular bodies of finely pulverized red or chocolate-brown ore, which when damp has the plasticity of clay. These bodies are approximately parallel to the lode and are from 6 inches to 6 feet wide. Generally they occur along planes of movement. Bunches of earthy fluorite occur here and there in the high-grade ore and some of them carry high values.

The open cut above the adit is 300 feet long and workable ore is said to extend beyond the cut at each end, making a shoot of workable ore which is altogether 600 feet long. North of this ore shoot is a block of ore which is of too low grade to be worked with profit, but still farther north the tunnel passes through another body of profitable ore whose dimensions have not been ascertained. The main adit is nearly everywhere driven along a slickensided plane which persistently follows the lode and which may be traced continuously for 1,000 feet. This plane of movement is east of the ore at most places and it dips to the west, hence it is regarded as the foot wall of the vein, though the ore occurs below it at many places. Another slickensided plane in the lower tunnel is crossed by slickensided slips at right angles. These slips do not displace the fissures, which run nearly parallel with the lode, nor are they displaced by them to a notable extent.

INDEPENDENT MINE.

The Independent mine, which is situated about 1,200 feet south of the Mint, is also owned by the Ruby Gulch Mining Company. The deposit closely resembles that of the Mint mine, and it is possible that the two mines are on the same lode, although the connection has not been definitely established. The ore is worked from an open cut, 225 feet long, 110 feet deep, and from 10 to 70 feet wide. An adit is driven to the bottom of this cut and another one 125 feet below it. The lower adit, driven northwestward, intersects the lode 250 feet from the portal and follows it for 300 feet. The ore is drawn through chutes to the lower tunnel and is hauled over a level tramway to the mill.

The lode is a shear zone in porphyry. Near the surface the ore is oxidized and is of the same general character as that of the Mint mine, but contains less fine material. The difference in the amount of oxidation of the two deposits is very noticeable. In the Independent open cut the pyrite extended at one place to the surface and it is generally encountered at a depth of not more than 25 feet. At 100 feet in depth the ore is essentially all pyrite. The mixed oxide and sulphide ore is said to carry about $6.50 in gold, and the unoxidized ore below the sulphide ore runs a little lower. Postmineral fissures cut the ore body, as in the Mint mine, but in the Independent they do not follow the lode so closely. Two such fissures which intersect at a large angle along their strike may be plainly seen on the surface above the open cut. There is ore on both sides of these fissures, as shown in fig. 4 (p. 105), which is a cross section of the Independent at the open cut.

ALABAMA MINE.

The Alabama mine is near the head of Ruby Gulch, about 1,500 feet west of the Independent mine. It is owned by the Alder Gulch Mining Company, and when visited in October, 1907, was under bond to the Little Rockies Exploration Company, which had a force of men engaged in exploration. The mine is said to have produced about $200,000 worth of ore, of which the richer portion was shipped to smelters and that of the lower grade was milled at the Zortman mill on Alder Gulch.

A crosscut tunnel reaches the lode some 300 feet from the portal and follows it northward for about 1,000 feet. From this tunnel a raise extends to the surface a distance of about 255 feet, and a winze is sunk near the bottom of the raise to a depth of 250 feet. Levels are turned in the lode at intervals of 50 feet. When the mine was visited the levels 150 feet below the adit were under water.

The lode is a shear zone in porphyry. The ore is a brecciated porphyry, replaced and cemented by quartz, pyrite, and other minerals. On the surface the ore is completely oxidized and at places it is partly oxidized 400 feet below the surface. A streak of rich ore composed in part of purple fluorite has furnished a large part of the shipping ore. Some of this ore shows specks of free gold, but part of the gold is a telluride and panning does not reveal its presence until after it has been roasted. The rich streak seems to have undergone more movement than the remainder of the lode and it is as a rule greatly crushed. It is from a few inches up to 2 feet wide, but it has not been found throughout the length of the ore body.

The average strike of the lode is N. 12° W. and it dips about 87° W. Its maximum width is 30 feet. The principal ore shoot is just north of the winze, and on some of the levels is about 250 feet long. It has been stoped downward to a depth of about 450 feet. To the north of this ore shoot workable ore has been found here and there in the adit tunnel, and at the north breast of this tunnel, which is 400 feet below the surface, the face carries 8 inches of dark sulphide ore that assays $14 in gold. Across the breast for a width of 5 feet the average value is $3, exclusive of the rich streak. In the raise from the adit to the surface, at a depth of 50 feet, the ore consists of mixed iron oxides and pyrite. The groundmass of the replaced porphyry is a black, flinty, pyritiferous ore, and large crystals of feldspar have been leached out, leaving distinct negative crystal forms, the largest of which are about half an inch long. Some of these are now filled with spongy reddish-brown silica, which carries high values in gold. Other feldspar cavities do not contain quartz but are partly filled with soft white kaolin. Postmineral fissures follow the vein closely, forming the so-called walls. Some of these are thin, knife-edge seams, grooved here and there and case-hardened on the sides. At some places the ore along them is much brecciated and locally reduced to a soft mass, cut through here and there by narrow veinlets of barren white quartz. One of the most persistent of the fissures appears to form the boundary of the lode on its east side. From the surface to the bottom of the 255-foot raise on the adit level it dips from 85° to 89° W. Near the adit level it rolls, the dip changing to 70° to 85° E. The richest ore occurs near this fissure.

On the surface above the mine, about 100 feet northwest of the top of the raise from the adit to the surface, a shaft has recently been sunk in iron-stained sheared and brecciated porphyry which is said to carry $20 to the ton in gold. This ore is apparently independent of that encountered in the older workings, but the present developments do not show the character or outlines of this ore body.

BIG CHIEF CLAIM.

The Big Chief claim is west of the Mint and north of the Alabama mine, near the crest of the main divide of the mountains. It has been prospected by several trenches, surface pits, and shallow shafts, some of which were inaccessible in 1907. A tunnel is driven westward 410 feet into the mountain, following a smooth plane of movement which strikes N. 73° W. and dips about 67° S. Eighty feet from the portal the tunnel is intersected by an incline which is also sunk on the slickensided plane.

The country rock is granite-syenite porphyry, sheeted and stained by iron oxide on fracture planes and locally silicified. The shattered porphyry is said to carry gold.

POLE GULCH MINE.

The Pole Gulch mine is 3,500 feet S. 10° E. of the Zortman mill, with which it is connected by a level tramway. The south end of the tramway is laid in an adit that is driven southward 800 feet to a point below the ore body. The country rock is limestone and all the mining has been done near the surface, mainly by the open-cut method. The caved stopes and open cuts are at most places continuous and make a large, shallow, irregular cavity about 200 feet wide and 325 feet long. The limestones encountered in the adit are grayish buff in color and dip about 15° SE. They are marmorized and to some extent replaced by quartz. When the mine was visited most of the underground workings below the ore body had caved and their relation to the structure could not be satisfactorily made out. At some places the deposits appeared to follow the bedding planes of the limestone and at other places to cut across the bedding. The ore is soft and partly decomposed limestone, locally silicified and stained with iron oxides. Bunches of earthy purple fluorite occur here and there and are regarded as indicative of good ore. The mill runs are said to have averaged from $3 to $4 a ton.

BEAVER CREEK DEPOSITS.

On Beaver Creek, 2 miles northeast of the Mint mine, there is a large body of limestone about a mile long which is nearly or entirely surrounded by porphyry. Where best exposed the limestone dips 34° NW. In several small excavations bodies of low-grade ore have been found. When the camp was visited in 1907 very little work had been done on these deposits, but they had recently been sold to the Ruby Gulch Company for $20,000 and this company was planning extensive developments in the near future. The principal deposit is near the north contact of the limestone and porphyry. It appears to strike westward and where developed is of considerable width. In the most extensive tunnel the ore body is 45 feet across and is said to average $5 in gold to the ton. What is possibly the same lode is encountered in two short tunnels about 800 and 1,400 feet to the west, where the altered country rock for 15 feet is said to carry $4 in gold to the ton. The ore consists of decomposed, iron-stained limestone, spongy brown silica, and black cherty silica. The deposits are probably not of contact-metamorphic origin, for the limestone near by does not show any marked effect of contact metamorphism.

CLAIMS OF THE FERGUS MINING COMPANY.

The Fergus Mining Company has a large group of claims near the head of Peoples Creek. They are for the most part in porphyry, but some of the workings are in the crystalline schists. The principal tunnel is driven into the hill N. 17° E. for 270 feet. At the breast a portion of the wall rock is a hard, glistening amphibole schist, carrying considerable pyrite. Higher on the hill several pits and short tunnels are driven along zones of fractured porphyry stained by iron oxide and said to carry gold.

GOLDBUG MINE.

The Goldbug mine is located about 1½ miles northwest of Landusky, on the ridge between Mill Creek and Montana Creek. It has been worked now and then since 1893 and small shipments of rich ore were made in 1904. In 1902 a 10-stamp amalgamating mill was built at Landusky to treat the lower-grade ore, but this process was apparently not successful, as only a small amount of ore was treated. Five gold-bearing lodes are said to have been discovered on the property. None of these, so far as developed, is extensive. The deposits are sheared and brecciated zones in porphyry and as a rule strike northeastward. They have been prospected at several places by short tunnels and open cuts and some stoping has been done. The stopes are short and range from a few inches to several feet in width. The ore consists of shattered porphyry and quartz cemented by quartz and limonite, and some of the porphyry is replaced by quartz. Fluorite, pyrite, and tellurium minerals occur here and there. At some places well-defined slickensided planes form the walls of the lodes.

AUGUST MINE.

The August mine is about three-fourths of a mile north of the Goldbug. It was worked secretly in the winter of 1893, while the ground was yet within the Fort Belknap Indian Reservation, and $32,000 worth of rich gold ore was taken out in sinking a shaft 65 feet deep. Since then it has produced very little ore. In 1907 it had the appearance of a mine which has long been idle. The deposit is similar to that of the Goldbug mine and the ore consists of brecciated porphyry cemented by quartz and highly stained by limonite. Northeast of the August mine a number of short tunnels have been driven on iron-stained sheeted zones of porphyry. These zones commonly show grooved, slickensided surfaces, the general trend of which is about N. 35° E.

ELLA C. CLAIM.

The Ella C. claim is situated between the Goldbug and August mines. The lode is a sheeted zone in porphyry which strikes N. 35° to 40° E. This zone is about 2 feet wide, is composed of fragments of porphyry cemented by quartz and limonite, and is said to carry $20 a ton in gold.

SUSIE CLAIM.

The Susie claim, which is a short distance southeast of the August mine, is owned by C. R. Liebert and Peter Sieh. The lode strikes northeastward and is explored in several shallow pits. It is a brecciated zone of altered porphyry that has been recemented by iron oxide and quartz, which carry gold. A slickensided fissure with hard, polished surfaces coincides approximately with the hanging wall of the lode. This fissure strikes N. 43° to 67° E. and dips about 47° SE. Below the fissure the lode is from 6 inches to 3 feet wide and is said to carry $15 in gold to the ton.

GEOLOGY AND MINERAL RESOURCES OF THE OSCEOLA MINING DISTRICT, WHITE PINE COUNTY, NEV.

By F. B. WEEKS.

INTRODUCTION.

As a part of the general reconnaissance of the Great Basin region the geology of the region was studied by J. E. Spurr [a] in the summer of 1899 and by the writer in 1900. The geologists of the Wheeler Survey [b] also published some general observations on the region. A portion of October, 1907, was spent by the writer in making a more detailed study of the geology and mineral resources of the Osceola mining district.

GENERAL DESCRIPTION OF THE SNAKE RANGE.

The Snake Range, in which is located the Osceola mining district, is one of the most prominent and extensive mountain ranges between the Wasatch and the Sierra Nevada. It extends between latitude 38° 30′ and 40° 30′, a distance of 135 miles parallel to and a little west of the Utah-Nevada boundary. (See fig. 5.) As an orographic feature it comprises the Deep Creek or Ibanpah Range and the connecting hills designated as Kern Mountains on the map of the Wheeler Survey. The Snake Range is about 10 miles in width. The interior portion has been eroded into sharp ridges trending in general with the range, and the east and west flanks descend in steep slopes or bold escarpments to the valleys below. Snake Valley occupies a broad depression on the east and opens into the southwest end of Great Salt Lake desert. Spring Valley, west of the Snake Range, extends from the Cedar Range on the south to the so-called Kern Mountains on the north. The difference in elevation between the valleys and the highest part of the range is about 6,000 feet. The rugged character of the range makes it a formidable barrier to east and west travel. There are only four natural passes which afford a

[a] Bull. U. S. Geol. Survey No 208, 1903, pp. 25–36.
[b] Rept. U. S. Geog. Surv. W. 100th Mer., vol. 3, 1875, pp. 240–242.

practicable route for wagon roads. The highest summit of the range is Wheeler Peak (locally known as Jeff Davis Peak), which has an elevation of 12,000 feet. In the region of the Osceola mining district the range presents an abrupt face to the west and a long, gentle slope to the east.

Upon a basement complex of granite and schist, only a small area of which is exposed, there has been deposited a series of Paleozoic

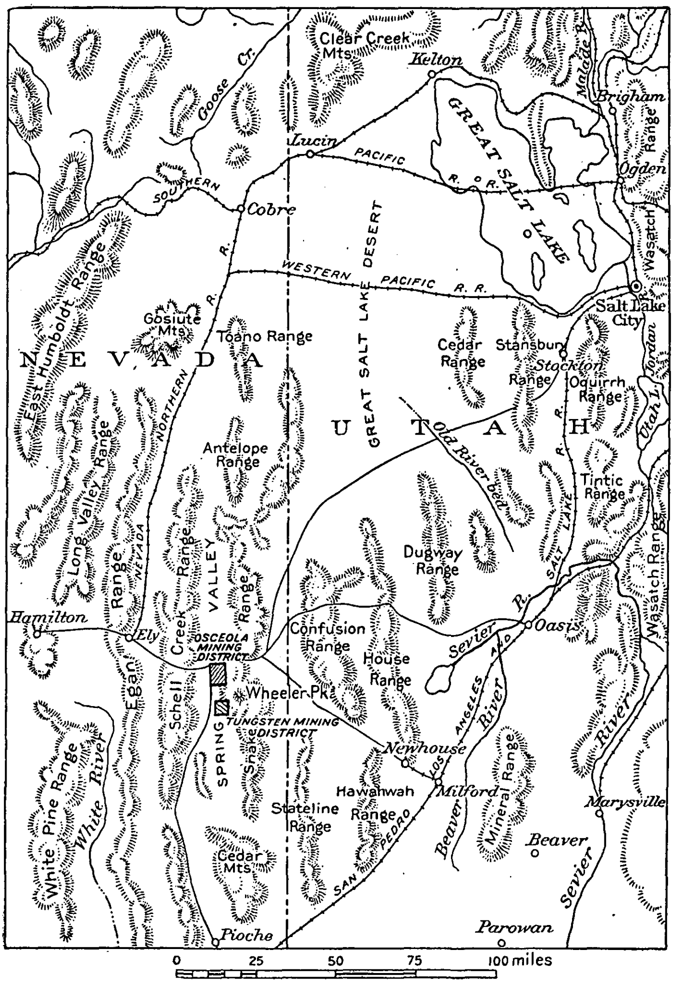


FIG. 5.—Map showing location of Osceola and Tungsten mining districts, White Pine County, Nev.

sediments from 8,000 to 10,000 feet in thickness. As shown by their fossils the strata were laid down in Cambrian, Ordovician, and Carboniferous time, a long interval of nondeposition occurring throughout the Silurian and Devonian periods. Some beds of unknown age may represent the Mesozoic era, but the evidence is inconclusive.

On the lower slope of the range in certain areas there are sands and gravels which lie above the Lake Bonneville beds and which were probably laid down in late Tertiary time. At the north end of the range terraces of the Pleistocene Lake Bonneville have been noted. It seems probable that from Carboniferous time to the present the greater part of this area has been subject to erosion.

Considerable bodies of igneous materials are exposed in the northern and central portions of the range. These igneous masses intruded Carboniferous strata and so, in part, at least, are Mesozoic or younger.

The prominent structural feature of the range is a dome in the region of Wheeler Peak, which both to the north and to the south passes into anticlinal folds whose axes in general trend with that of the range. This structure has been subsequently modified by compression and faulting and by the intrusion of igneous masses, so that the sedimentary beds generally have steep dips and are in many localities separated by considerable displacements. This is especially true in the region of the Osceola mining district.

OSCEOLA MINING DISTRICT.

SITUATION AND PHYSICAL FEATURES.

This mining district is about 35 miles east of Ely, Nev., the southern terminus of the Nevada Northern Railroad. It includes the crest and western slope of the Snake Range in the vicinity of Osceola. The east-west wagon road through the district is the principal route of travel between Utah and central Nevada. Near the summit on the eastern side the road forks, a branch leading over the Sacramento Pass and descending to Spring Valley on the west.

The principal drainage lines in the mining district are Dry Gulch and Mary Ann Canyon and along them and in their alluvial fans occur the most important placer deposits. The stream beds are dry during most of the year. About one-fourth mile above Osceola, near the wagon road, are several small springs and a small stream flows from the mouth of the New Moon mine. The elevatıon of the district ranges from 6,000 to 9,600 feet above sea level. The region is arid, the principal precipitation being in the form of snow.

GENERAL GEOLOGY.

The distribution of the rocks in this district is shown in the sketch map forming fig. 6, and a general section is given in the following table.

General geologic section of the Osceola mining district.

No. in fig. 7.	Age.	Character.	Thickness.
			Feet.
1	Recent	Gravel, coarse to fine, gold bearing	Up to 80
2	Upper and middle Cambrian	Gray to white, rather pure limestones and dark-blue crystalline limestones.	1,000
3	Lower Cambrian	Green sandy shales, *Olenellus* zone	150
4	do	White, blue, and purple quartzites, gold bearing	2,000
5	do	Purple argillite	750
6	do	Conglomerate	100 to 150
7	Archean (?)	Granites and schists, with intruded granite porphyry.	

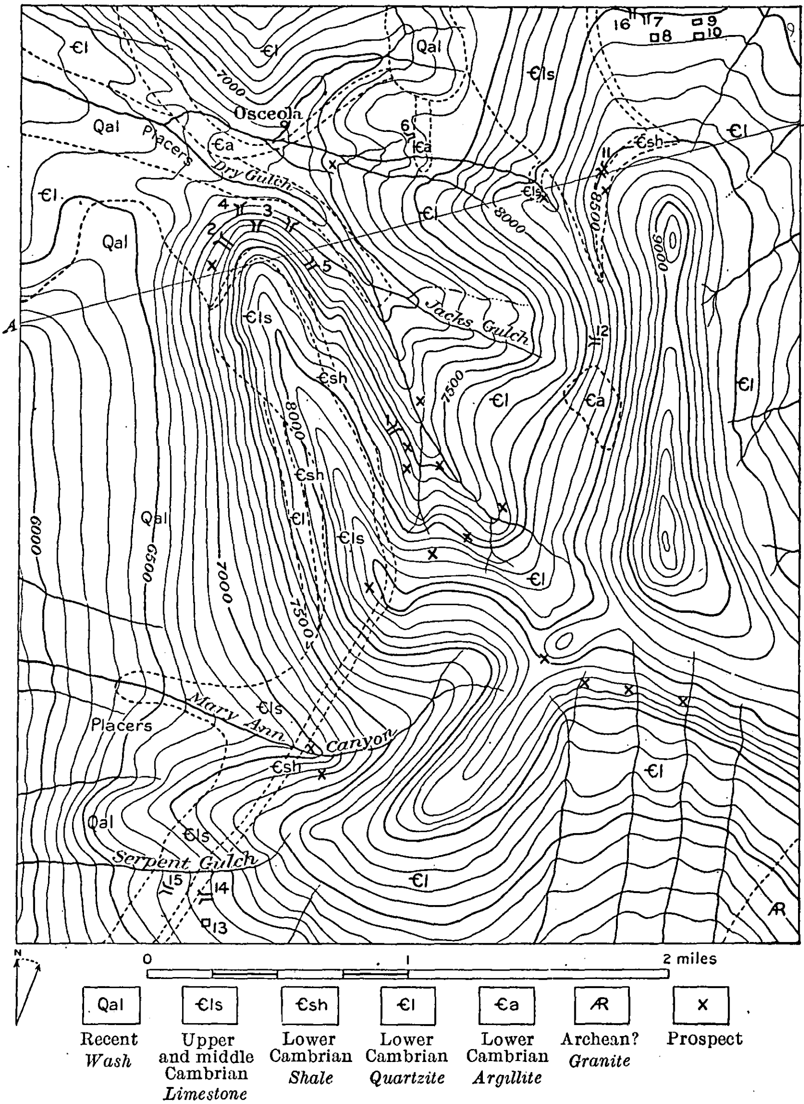


FIG. 6.—Sketch topographic and geologic map of the Osceola mining district. Contour interval 100 feet. Mines: 1, Cumberland; 2, Golden Eagle; 3, Crescent; 4, Time Check; 5, Exchange; 6, New Moon; 7, Gold Hill; 8, Gold Crown; 9, Queen; 10, King; 11, Whitney group; 12, Mulligan group; 13, Drummer shaft; 14, Mayday; 15, Serpent; 16, June. Dotted lines are boundaries of rock areas.

Fig. 7 is a cross section showing the structural relations along a line crossing Dry Gulch.

A short distance south of the mining district and near the crest of the range is an area of granite and schist overlain by a coarse conglomerate which grades into a compact argillaceous rock resembling argillite. The argillite is succeeded by a series of quartzites which pass into shales containing an *Olenellus* fauna. It appears from these observations that there is exposed here a small area of the basement complex rocks. Their structure has, however, been broken by an intrusive mass composed largely of gray and red granite porphyry which, north of the road crossing the range to Osceola, has penetrated through strata of possible Carboniferous age.[a] On the divide north of Wheeler Peak certain observations made in an area of poor rock exposures indicate that the granite porphyry cuts through the granites and schists of supposed Archean age.[b] These Archean rocks are much finer in grain and generally more basic than the intrusive rocks. By the presence of sheared zones and general

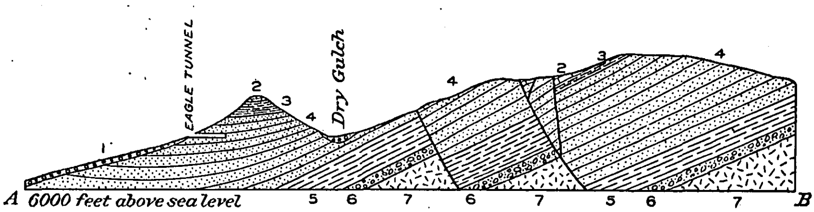


FIG. 7.—Structure section along line *A–B*, fig. 6. 1, Recent; 2, upper and middle Cambrian; 3 to 6, lower Cambrian; 7, Archean (?).

schistose structure they bear evidence of stresses and strains which were not observed in the intrusive granite porphyry.

The conglomerate which overlies the basement complex is about 100 feet thick and is formed of large subangular pebbles and bowlders derived from the older rocks. The conglomerate pebbles gradually become more rounded and smaller in size, argillaceous material forming a considerable portion of the rock, which passes into a massive bedded argillite. The argillaceous series is about 700 to 800 feet thick and is well exposed on the eastern slope of the high ridge that forms the crest of the range east of Osceola.

In this region the dip ranges from 25° to 40° NW.[c] and where the strata are cut by the intrusive porphyry they have been altered for the most part into a bluish-gray, generally schistose rock that has been called "silvery slate." This series is overlain by gray and white fine-grained quartzites. The beds have been thoroughly silicified and contain many veinlets of probably secondary quartz. They have

[a] Spurr, J. E., Bull. U. S. Geol. Survey No. 208, 1903, p. 32.
[b] Idem, pp. 26–27.
[c] Directions given in this paper are magnetic.

also been subjected to compression and numerous extensive belts of cross fracturing have been developed in which the quartzite has been broken into small angular fragments. The quartzite series has been estimated to be 2,500 feet in thickness. In the upper part of these beds occur the gold deposits and from the erosion of their outcropping edges the placer deposits in and along the sides of the gulches and in the alluvial fans have been formed.

The quartzite is succeeded by about 150 feet of green sandy and argillaceous shales. Where the outcrop of these beds crosses the south end of the ridge facing Spring Valley fossils of *Olenellus* type were found. These are the lowest beds in which fossils are known to occur, though careful search was made for them in the argillite.

Above the shale series occur dark-blue and gray limestones about 1,000 feet thick. The individual beds range from 1 to 3 feet in thickness, but in the crest of the ridge facing Spring Valley there are about 100 feet of thin-bedded and shaly blue limestones. The dark-blue limestones immediately overlie the shales and for the most part are crystalline or semicrystalline and contain numerous calcite veins. The gray limestone is comparatively pure and ranges from dark gray to white in color. Fossils have been collected at several horizons in the limestone series on the east and north slopes of the ridge facing Spring Valley and these have been determined as forms characteristic of the middle and upper Cambrian.[a]

Within the area of this mining district there are no other sedimentary rocks except the recent deposits in which occur the placers. These deposits are from a few inches to 80 feet thick. The gravel ranges from fine to coarse and contains few large bowlders.

HISTORY OF MINING DEVELOPMENT.

In 1877 work was begun on the placer deposits of Dry Gulch. A few quartz locations were made prior to that time. It is reported that 300 to 400 miners were working on the placers during 1877 to 1880 and during the latter year 400 placer and lode locations were on record. The important placer properties in Dry Gulch became the property of the Osceola Gravel Mining Company, subsequently known as the Osceola Placer Mining Company, in the early eighties. Prior to 1890 this company had constructed two ditches approximating 34 miles in length, at a cost of about $200,000. The operations of this company and of individuals continued until about 1900, when on account of light snowfall and the loss in efficiency of the ditch from leaky flumes and other causes work was discontinued.

The alluvial fan which spreads out from the mouth of Mary Ann Canyon, in the southern part of the district, is locally known as

[a] Fossils mentioned in this report have been determined by Mr. Charles D. Walcott.

Hogum. Here pay gravel was found several years after the discoveries in Dry Gulch and the deposits have been worked intermittently since that time.

Several attempts have been made to work the gold-quartz properties on a small scale. Three mills of 5, 10, and 20 stamps have been erected and operated, but none of them has been commercially successful. It is admitted that more than 50 per cent of the values went down the gulch with the tailings. Since field work was completed the 20-stamp mill has been partly repaired and a run of several hundred tons of ore from the Cumberland mine has been made. The results are not known.

From all accounts that have been obtained, it seems safe to estimate that the production of gold from this district approximates $2,000,000, of which about one-tenth was probably derived from the quartz mines.

MINING.

The slopes being steep, underground development is through tunnels, there being not more than half a dozen shafts in the district. In one or two mines an upper and lower tunnel have been connected by winzes. The quartzite is exceedingly hard and no timbering is required in the tunnels. In winzes and stopes a few stulls are all that is needed.

Some ore has been sacked and shipped to the smelters, but the greater part has been locally milled. Stamping and amalgamation constitute the principal method of treating the gold quartz. A small cyanide plant was constructed several years ago but was abandoned, apparently before receiving a satisfactory trial.

The Boston and Nevada Mining and Milling Company employs half a dozen men and about the same number are engaged from time to time in doing assessment work for nonresidents. The average wage for miners is $3.50 per day of eight hours.

All the mines and placers have been located by prospectors and working miners. No extensive consolidations have been made and the camp remains an aggregate of small mines and prospects on which, with the possible exception of the Osceola placers, but little outside money has been expended. The ores so far discovered have not been of high enough grade to attract lessees.

EXTENT OF PRODUCTIVE TERRITORY.

There seems to be no ground for assuming that the productive territory extends beyond the limits of the area shown on the map (fig. 6). So far developments indicate that the deposits are confined to fairly well defined zones in the quartzite. It has been thought by some that the same mineral belt extends northeastward to the recently opened

Black Horse district. It may be that the effects of the same dynamic forces which developed the lode systems in this district extended to the Black Horse district, but a slight examination of that region indicates that although the lithologic characters of the strata are in general similar, the beds at Black Horse were deposited during a later period and the ores are very different in character.

The fissures appear to be confined to the quartzite. They were not observed in the overlying shales and limestones and the underlying argillite has not been exposed in the underground workings. To the east and south of the area mapped the argillite series is well exposed and shearing with more or less movement along the bedding planes is a prominent feature, the beds being locally altered to a silvery slate.

DISTRIBUTION OF MINES.

The areas of greatest mineralization are (1) the ridge on the west and south sides of Dry Gulch, (2) the slopes of Mary Ann Canyon, and (3) the north end of the main mountain ridge. (See fig. 6.) In the Dry Gulch area are situated what is locally known as the Gold Exchange group, including the Woodman, Golden Eagle, Star, Time Check, Crescent, Exchange, and January. There also are the Butterfield and the Cumberland mines. In the region of Mary Ann Canyon are the Serpent, Mayday, Drummer, and other prospects. On the north end of the main ridge at an elevation of about 8,000 feet are the King, Queen, Gold Hill, June, and Gold Crown claims, locally known as the Summit group, and a little to the west are the Whitney and Mulligan groups.

UNDERGROUND DEVELOPMENT.

The most extensive underground workings are in the Gold Exchange group. The tunnels in these mines have a total length of about 1,000 feet, and connect with one or two shafts and several stopes and winzes. In Mary Ann Canyon several prospects have tunnels from 50 to 125 feet long. In the Summit group the tunnels range from 50 to 350 feet in length. The Whitney and Mulligan groups have about the same amount of development. The three tunnels in the Cumberland mine have a total length of approximately 1,700 feet.

STRUCTURE OF THE GOLD DEPOSITS.

There appear to be only two types of auriferous deposits in the district—(1) regular zones of fracturing or sheeting and (2) irregularly shattered masses of quartzite adjacent to these zones of fracture. In most places there is no distinct line of demarcation between the two types. There are no massive veins solidly filled with quartz such as are characteristic of many other regions.

The most characteristic structure is the sheeted zone. In this district these zones consist of narrow, nearly parallel fissures forming lodes ranging from several inches to 15 feet in width. In the wide belts, which may be considered as compound sheeted zones, there are generally one or more zones of closely spaced fissures. The sheeted zones contain some fracture planes which show slickensiding, but the displacement appears to be slight. This may be due to the brittle character of the fine-grained quartzite that forms the country rock. Beds which are broken into fine brecciated masses lie between massive beds of quartzite which apparently were not affected by the compressive stress.

Circulating waters carrying silica in solution have filled the fissures of the sheeted rock. The original openings were small, and they are as a rule completely filled. The most important exception is the Cumberland lode, in which the vein material contains many vugs lined with gold, fluorite, and other minerals.

The lodes are in places conspicuously exposed, forming bold outcrops of quartz. They are somewhat more resistant to erosion than the country rocks, but can not be followed on the surface for a very great distance. There are also lodes in the mines which do not appear at the surface. It is therefore impossible to describe in detail the lode systems, as there is a relatively small amount of underground work and the limits of the fracture zones have not been reached.

The Osceola lodes form two intersecting groups of approximately parallel fissures. In the northeastern part of the district the strike is northeast. In other parts of the area the strike varies but little from east and west, except that in the southwestern part there appears to be a northeast-southwest system of fracture zones which cut the east-west lodes. In general the lodes do not converge but maintain their direction until they can no longer be distinguished from the irregular jointing which occurs in all the rocks. The two systems seem to have formed simultaneously and they do not appear to fault each other. In Mary Ann Canyon the fissures intersect without noticeable displacement. The intersection is usually marked by an irregular broken zone, as may be seen on the outcrop and in the upper and lower tunnels of the Mayday mine.

The lodes are steeply inclined, nearly all being above 70° and many vertical. So far as the underground workings show they are fairly regular in dip. Adjacent fissures in general dip in the same direction. This is well shown in the Gold Exchange group. In many places the lodes for considerable distances are so ill defined that the dip can not be determined. It may be said in general that the east-west lodes are vertical and that the northeast-southwest lodes dip at high angles.

No systematic relation between dips, distribution of fissures, and general structure of the district has been found.

PERSISTENCE.

Very little can be said definitely regarding the persistence of the lodes in depth. The deepest underground workings are not more than 300 feet below the surface and the fissures extend to this depth. The ore shoots and sheeted zones are not necessarily coextensive, for the highly productive areas have generally proved to be moderate in extent. Detailed information concerning the length of the lodes is wanting. In the Gold Exchange group the principal lode has been fairly well traced for a distance of half a mile, the west end being cut off by erosion and the east end passing into undeveloped ground. In the Summit group not one but several fissures which appear to replace each other have been traced at irregular intervals for more than half a mile.

ORIGIN OF THE FISSURES.

The character of the stresses that fissured the strata is not easily determined. It is clear, however, that they were such as could be relieved by fracturing with only slight displacement. The hypothesis which seems to accord best with field observations is that in the readjustments, which followed the intrusion of the magma, stresses were set up that resulted in the shearing of the argillite and the fracturing of the fine-grained, brittle quartzites along vertical or highly inclined zones. Fissuring and the intrusion of the igneous magma appear to be genetically connected and were followed by ore deposition from circulating waters.

CHARACTER OF THE ORE.

The lodes of the Osceola district contain a relatively small amount of metallic or gangue minerals. Inasmuch as these minerals occur as the filling of narrow fissures or cracks in the fractured zone which usually constitutes a lode, or as the incomplete replacement of the country rock, the gangue of the ores is similar in character and composition to the rocks adjoining the fissures. Pyrite is very sparingly disseminated in grains so minute as scarcely to be distinguishable by the unaided eye. Ferruginous clays are common in the fissures. In certain lodes, particularly that in the Cumberland mine, the quartz is here and there honeycombed and contains many vugs lined with fluorite and other minerals as well as free gold. More commonly the gold occurs in flakes and also finely disseminated in quartz seams and veinlets.

So far as known gold is the only metal of commercial value in the Osceola ores. From the information available it is impracticable to estimate definitely the average gold content. Commercial assay returns show a wide range in value. Three samples taken by the writer gave assay values of $5, $32, and $77 per ton, the last representing the face of a tunnel about 4 by 6 feet. Other samples taken by the writer ranged in value from 80 cents to $4.50 per ton and represented portions of lodes not less than 3 feet in width. The return from a shipment of several tons of selected ore from the fractured country rock adjoining a fissure zone gave a value of $28 per ton. It is evident that the gold content of the lodes varies greatly, as in other known gold-bearing veins. It is not unlikely that careful prospecting will develop ore bodies of sufficient size and value to render their exploitation profitable.

OXIDATION.

The greatest depth of underground workings does not exceed 300 feet, and the sulphide zone has not been reached, so far as known. No water is found in any of the mines except in the New Moon tunnel, which crosses a fault in the argillite series. Under present climatic conditions there is very little precipitation, so that the mines are practically never wet. The district stands high above the adjacent valleys, and other conditions suggest unusual depth of ground water.

The greater number of lodes contain a considerable amount of material oxidized to a yellow or brown clay, that does not appear to be easily carried away. Oxidation, however, does not seem to have changed the composition or obliterated the structure of the lode materials to any marked degree. No evidence was obtained that there had been a secondary enrichment of the lodes from the surface downward by leaching of the ore. Such action, however, may have taken place under more humid climatic conditions, such as are believed to have existed in this region in recent geologic time.

ORIGIN OF THE ORES.

No extended discussion of the origin of the gold-bearing ores of the Osceola district can be presented here, as the examination of the mines was not made in sufficient detail to determine many questions that have an important bearing on their genesis, and it has not been possible to study the field collections prior to the preparation of this paper. From general analogy with other deposits it is considered that the ores were deposited from circulating waters within fissure zones formed by compressive stresses. If, as seems likely, the greater part of the mineralization occurred by deposition from ascending waters the silica and the fluorine in the fluor spar locally developed were derived from the originally molten magma that probably underlies the region at no great depth, in geologic terms. In an adjoining area tungsten-bearing veins in granite porphyry contain a considerable amount of fluorite. Evidence bearing on the source of the gold is inconclusive. That it was leached from the quartzite strata is not improbable, for there is some evidence that they are gold bearing. It may, on the other hand, have been separated from the intrusive magma and brought up through the fissures by magmatic waters.

DETAILED DESCRIPTION OF MINES.

GOLD EXCHANGE GROUP.

The Gold Exchange group comprises eleven lode claims, of which three are fractional. They extend from the west face of Pilot Knob Ridge around the north end, following the south and west slope of Dry Gulch. The slope is steep, but good mountain roads have been constructed to the several tunnel openings. A 20-stamp mill has been erected on the Star ground, which adjoins the Golden Eagle (No. 2 on map, fig. 6) on the west. Water from the west-side ditch has been used in operating this mill. The Star, Golden Eagle, Crescent (No. 3 on map), and Exchange (No. 5) are patented ground; the other claims are held by annual assessment work.

The underground workings on this group, except a portion of the lower tunnel on the Star ground, are in the upper part of the quartzite series. The average dip is 40° NW. and the strike is N. 10° E., but both dip and strike vary within short distances. There are many vertical or highly inclined fault planes, but the displacements observed do not exceed a few feet. The shale series overlies the quartzite and above the shales are the limestones capping the ridge. Near the mill a fault has thrown down the limestones and below these outcrops the slope is covered with débris.

The quartzite strata have been subjected to stresses resulting in two fracture zones, one having an east-west direction, the other northeast and southwest. The east-west zone is the principal one and within it occur many small displacements, the rocks showing well-marked slickensides. This zone can be traced on the surface as a succession of "blowouts." In some of the beds the fracturing extends beyond the usual limits of the lodes, but the other strata retain their massive character. The shattered beds were broken into small angular fragments.

There are two lode systems within this group, one within the Time Check and Crescent (Nos. 4 and 3 on map) and the other within the Golden Eagle (No. 2), Exchange (No. 5), and January ground. They are approximately parallel and are several hundred feet apart. The latter is apparently the more extensive and has produced the larger amount of ore.

The gold is concentrated within fissure zones of varying width and is also disseminated to a greater or less extent in the beds of finely shattered quartzite. It is not known to what extent these beds have been mineralized, as no drifts have been made in them. They evidently contain some pay ore, for in places chambers several feet in extent have been stoped. The gold is rarely visible, being very finely disseminated.

In accordance with the locally held idea that these ores are free-milling they have been treated in the ordinary stamp mill with amalgamation tables. These properties have not been worked since 1899 and at this time it is impossible to obtain definite information as to the average value of the material milled or the percentage saved. It is generally conceded, however, that there was considerable loss—possibly as much as 50 per cent of the assay values. On account of the high degree of fineness of the gold and the fact that it is not all in the free state it is believed by many that a much greater percentage of saving would result from cyanide treatment.

SUMMIT GROUP.

The Summit group of claims is situated on the crest of the range about 1 mile south of the wagon road which crosses the mountains from Osceola. Some underground work has been done on each of the claims which comprise this group.

The Gold Hill tunnel (No. 7 on map) is 309 feet in length and its direction is south. It is entirely in the quartzite strata, which strike N. 10° E. and dip 45° NW. They are generally massive bedded and contain several clay seams and fractured zones about 6 inches in width. On the eastern side of this claim there is another tunnel about 100 feet in length, having a direction S. 60° W., with a drift to the south from the face of the tunnel about 100 feet long. In these workings is exposed a broad zone of fractured and brecciated rock whose limits are not known. Considerable ore from this tunnel is said to have been milled, but no satisfactory estimate of value could be obtained.

The June tunnel (No. 16 on map) varies in direction and has a total length of 240 feet. The tunnel cuts a fault trending N. 26° E. East of the fault, in the direction of the face of the tunnel, the beds show little disturbance but contain many soft seams from which gold can be obtained by panning. To the northwest, or toward the mouth of the tunnel, the quartzite is very finely brecciated. In this fracture zone assays ranging from $8 to $15 are said to have been obtained, but no definite statement as to the width of the zone furnishing such assay values could be given. This fracture zone appears to have a general direction of N. 30° E.

The Gold Crown, Queen, and King (Nos. 8, 9, and 10 on map) are developed to a small extent. Average assays of $14 are said to have been obtained from these claims.

Within the Summit group there appear to be at least three fracture zones separated by intervals in which the quartzites are relatively undisturbed. The amount of mineralization varies greatly within these zones and extensive prospecting will be necessary to determine the distribution of the values.

WHITNEY GROUP.

The Whitney group (No. 11 on map) has been prospected by several tunnels cutting the shale and quartzite nearly at right angles to the strike. The strata are in places much broken and shattered and in others are undisturbed. Certain fault planes, indicated by slickensided surfaces, have been followed as walls in the tunnels. These fault planes dip 60° S. Considerable ore has been mined and milled from these workings, but no satisfactory statement of its value could be obtained.

MULLIGAN GROUP.

At the north end of the Mulligan group (No. 12 on map) there is an incline following what appeared to be a fault fissure nearly filled with vein quartz. The fault strikes N. 80° E. and dips 65° S. About 600 feet south of this incline is a tunnel which at the time of visit was closed, but the material on the dump showed that there must be considerable underground work in a formation of very finely crushed white quartzite. At the south end of this group is a 200-foot tunnel entirely in a crushed white quartzite.

CUMBERLAND MINE.

The Cumberland mine (No. 1 on map) has three tunnels having a common direction of S. 80° W., at vertical intervals of 100 to 200 feet. The lower tunnel is 500 feet in length and follows a fault zone in which are many small fissures showing slickensided surfaces and dipping both to the north and south at high angles. In some places a fault plane dipping steeply to the south has been followed until it became nearly horizontal in the roof and then another steeply inclined fault plane farther on in the tunnel has been used as a wall. In some places, for distances of 10 to 20 feet, the quartzite strata are unbroken and have the normal strike and dip. Many beds not showing distinct fault planes have been crushed into confused masses of small fragments. Clay seams are abundant, and some of them follow bedding planes.

The second tunnel was not examined. The third and upper tunnel is 650 feet in length. At 450 feet from the entrance is a winze 50 feet in depth and an upraise to the surface. In this upraise there is an ore shoot 3 to 4 feet in width which pitches 75° S. The greater part of this ore shoot has been worked out. Its hanging wall is a well-defined fault plane. The lower edge of the shoot is cut in the back of the third tunnel, but its pitch carries it to the south of the first and second tunnels, and no prospecting has been done to determine its extension in this direction. It is reported that most of the ore mined and milled from the Cumberland came from this upraise, but no definite information as to its average value could be obtained. The ore contains much free gold, partly in vugs with fluorite. Many beautiful specimens have been found in these ores.

OTHER PROSPECTS.

In the southwestern part of the Osceola district, in the region about Mary Ann Canyon, there has been considerable prospecting since 1900. This area is locally known as Hogum. The granite porphyry is exposed on the western edge of this area and small veins, generally of quartz, extend from it into the adjoining sedimentary strata. The derivation of the vein filling from the intrusive mass is more clearly shown here than in the other parts of the district. Although the structural features of this area have been affected by the intrusion of the igneous magma, they nevertheless are closely connected with those of other parts of the district previously described.

The Mayday claim (No. 14 on map) is developed by a tunnel 130 feet in length following the strike of the vein, which is S. 70° E. The gangue material is nearly all quartz and it pitches to the southwest, or in the direction of the granite porphyry, which is exposed about one-eighth of a mile farther south. The vein contains many gouge seams and small displacements. In the area between this vein and the granite porphyry the quartzite is fractured and broken into small angular fragments.

The Drummer claim (No. 13 on map) is developed by a shaft 18 feet in depth following an offshoot from the granite porphyry. This vein is about 4 feet wide and is formed of fine-grained granite porphyry and quartz. Its general direction is N. 30° E.

The Serpent claim (No. 15 on map) has two tunnels 50 and 80 feet in length. The entrance to the upper tunnel is in the limestone, which dips 45° NW. and strikes N. 30° E. The vein strikes N. 50° E. and dips 45° SW. The ore-bearing portion ranges in width from a 10-inch vein to a thin parting. The best ore, said to have been found where the pay streak averaged 4 inches wide, assayed $400. Coarse gold was observed on exposed faces of the vein.

The lower tunnel is 25 feet below the upper tunnel and has a direction S. 80° E. The vein is from 6 to 8 inches in width and dips 25° SW. The returns from the milling of this ore were reported as $17 to $20 per ton. Considerable lead ore is found in a parallel vein.

PLACERS.

The placer deposits of Dry Gulch range from a thin covering of the edges of the quartzite strata in the upper part of the gulch to deposits 25 to 30 feet in depth in the lower part, below which the débris spreads out into an alluvial fan. Hydraulicking and ground-sluicing methods were employed to recover the gold. The values were more or less disseminated through the gravel, the principal pay deposits being as usual near bed rock. Large nuggets were rarely found, the gold being in general very fine. There still remains a considerable area of ground to be worked, but lack of water has thus far rendered further operations impracticable.

In the southwestern part of the district, in the area locally known as Hogum, the placer deposits occur in channels buried under the material of the alluvial fan below the mouth of Mary Ann Canyon. They usually occur in a stratum overlying a so-called cement or false bed rock, of which there appear to be several at different levels. The channels are worked by sinking and drifting. The material is raised by a whim, shoveled into sluice boxes, and washed with a small quantity of water from the ditch. Here, as in every other part of the district, the gold is fine and nuggets of much size are seldom found. Frequently small potholes are encountered in the false bed rock. These have the gold concentrated around their edges, but not within them. During the summer of 1907 the Gold Bar Placer Company employed from two to four men and the operations are said to have given a satisfactory return on the investment. The pay stratum was reported to have yielded from $6 to $8 per cubic yard.

Placer mining has also been carried on east of the divide, above the town of Osceola, in Mill and Weaver creeks. This area lies to the northeast of that shown on the map and was not studied in detail. The gold is derived from the erosion of the quartzite strata, as in all other parts of the district.

GENERAL SUMMARY.

The lode systems of the Osceola district are known to be extensive. All of them carry gold, but the values are irregularly distributed along the fissure zones. Systematic and extensive prospecting must be done to determine the average value of these lodes. It seems certain that the average product of the lodes will be a low-grade ore which must be worked at a small cost and in large quantity to be profitable.

Water for milling purposes and placer mining can be obtained from the several creeks heading around Wheeler Peak, which are also available for the generation of electricity. As it will require the waters of all these creeks to fully develop the resources of the district there should be such a combination of interests as would permit the development of the water and power for the use of the various mining companies. Future development and prosperity depend on a concentration of local interests on a basis that will attract capital.

MINES OF THE RIDDLES QUADRANGLE, OREGON.[a]

By J. S. Diller and G. F. Kay.

GOLD-QUARTZ MINES OF THE RIDDLES QUADRANGLE.

By G. F. Kay.

INTRODUCTION.

The Riddles quadrangle is situated in southwestern Oregon. It is a 30-minute area and embraces parts of Douglas, Jackson, and Josephine counties. It lies immediately south of the Roseburg quadrangle, which has been described in folio 49 of the Survey.

The geology and economic resources of this area were studied, for folio publication, by Mr. J. S. Diller and myself, during the summers of 1906 and 1907. In connection with this work, the placer deposits and gold-quartz mines were examined. It is the intention in this paper to describe only the latter, the former having been studied by Mr. Diller, who describes them on pages 147–151.

My thanks are due to many persons connected with the mines for information and other kindnesses, particularly to Capt. J. S. Buck, of the Greenback; Mr. S. G. Adams, manager and secretary-treasurer of the Baby mine; Mr. John Scribner, of the Silent Friend mine; and Mr. J. H. Beeman, of Gold Hill, owner of the Lucky Bart group. I am also much indebted to Mr. Diller for many valuable suggestions.

GEOGRAPHY AND HISTORY.

The Riddles quadrangle is of moderate relief, its elevation ranging from about 600 feet to 5,274 feet above sea level. In the northern part is South Umpqua River with its large tributary, Cow Creek. The chief streams of the southern part are Grave Creek, Jumpoff Joe Creek, and Evans Creek, all tributaries of Rogue River, which crosses the quadrangle only in the southwest corner.

The Southern Pacific Railroad passes through the northwestern part of the quadrangle, reenters it about the middle of the western

[a] The first paper of the group on the Riddles quadrangle (Nickel deposits of Nickel Mountain, Oregon, by G. F. Kay) was published in Bull. U. S. Geol. Survey No. 315, 1907, pp. 120–127.

side, and runs southward, keeping within the quadrangle to its southern boundary, which lies between Merlin and Grants Pass. There are wagon roads along almost all the main streams, and trails run over many of the more mountainous parts. Hence the region is, in general, fairly accessible.

Much of the higher ground is covered with forest, but in many of the valleys there are small ranches. The climate is such that quartz mining can be carried on, without much inconvenience, during all seasons of the year.

The history of gold mining in southwestern Oregon dates back for more than fifty years, the first discovery having been made about the middle of the last century. From that time to the present, this portion of the State has yielded a considerable percentage of the total gold production of Oregon. The two counties from which most of the gold has come are Josephine and Jackson, both of which lie partly within the Riddles quadrangle.

In the early days practically all of the output came from the placers. Between 1880 and 1890 there was a small but gradually increasing yield from the gold-quartz mines. During the succeeding ten years the production of the placers continued to decrease and that of the gold-quartz mines to increase. In 1905 [a] the value of the product of the placers of Josephine and Jackson counties was $165,793, whereas the value of the output of the quartz mines (including that of three quartz mines of Lane County and less than $2,000 worth of gold from copper ores) was $236,193. Of the latter amount the Greenback mine, which is in the Riddles quadrangle, contributed a large part. Since the fall of 1906, however, this mine, which was for several years the chief gold-producing mine and one of the best-equipped mines in Oregon, has been closed. Moreover, several prospects, which a few years ago were considered very promising, have proved disappointing and work on them has been suspended.

GEOLOGY.

The rocks of the Riddles quadrangle comprise both sedimentary and igneous rocks of various ages. The former belong mainly to the Mesozoic and the Tertiary, but in the southeastern part of the area are highly metamorphosed sedimentary rocks, in which, as yet, no fossils have been found, but which, owing to resemblances to fossiliferous rocks occurring farther southwest in California, are thought to be of Paleozoic age. The igneous rocks are in large part intrusive, but considerable areas show undoubted volcanic characters.

The sedimentary rocks which are thought to be Paleozoic consist chiefly of mica slates, mica schists, and micaceous quartzites. To the same system belong scattered lentils of crystalline limestone

[a] Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906, pp. 288–292.

found a short distance beyond the southern limits of the quadrangle. These rocks are widely separated from the Jurassic of the quadrangle by igneous rocks.

The Mesozoic rocks belong to the Jurassic and Cretaceous systems. The Jurassic sediments consist mainly of slates and sandstones with interbedded shales; conglomerates and cherts are subordinate. These rocks, particularly the sandstones, usually show quartz veining and pronounced induration. The Cretaceous beds consist chiefly of conglomerates, sandstones, and shales, and have been divided, on the basis of fossil evidence, into the Knoxville, Horsetown, and Chico formations. The Chico is now represented by but a few small remnants of the original widespread formation. The chief remnant within the area of the quadrangle is on Grave Creek about 6 miles above the small village of Placer. It is not underlain by the Horsetown or the Knoxville but by older slates and by igneous rocks. There is evidence of a slight unconformity between the Knoxville and the Horsetown. The Knoxville rocks are locally veined and indurated, but generally to a much less degree than those of the Jurassic.

The Tertiary rocks are of Eocene age. They consist of yellowish sandstones, shales, and conglomerates, the stratification being well preserved.

The evidence indicates a great unconformity between the Jurassic and the Cretaceous; a somewhat less important unconformity separates the Cretaceous from the Eocene.

The igneous rocks are of various kinds, including greenstones, peridotites, serpentines, granodiorites, dacite porphyries, and augite andesites.

The greenstones are widespread and are generally altered to such an extent as to be unsatisfactory for study. Under this name are included several kinds of rocks so related in the field that it is practically impossible to map them separately. What may be considered the normal type resembles, when fresh, a gabbro, consisting essentially of pyroxene and a lime-soda variety of feldspar. Some phases of the greenstone are dioritic, some diabasic, and some fine grained and compact, resembling basalt. Moreover, some of the rocks included as greenstone are of the nature of volcanic breccias; others show decidedly vesicular characters: All these types are, no doubt, closely related genetically, but they may vary considerably in age. All are of a more or less green color and almost everywhere they show marked evidence of extensive crushing and veining. Associated with the greenstones in the west-central part of the quadrangle are a few lens-shaped areas of rhyolite.

The peridotites consist chiefly of olivine and enstatite, the former usually predominating, but locally the pyroxene is so abundant that the rock is a pyroxenite.

The serpentines have resulted chiefly from the decomposition of the peridotites and the pyroxenites, but some areas of the serpentine are probably the result of the decomposition of basic phases of the greenstones. Much of the serpentine shows shear zones and slickensided surfaces.

The granodiorites are of granular texture and include rocks which vary considerably in composition. The more acidic approach the granites and the more basic include quartz diorites. These rocks are composed chiefly of feldspar, quartz, and hornblende or mica, or, as is more commonly the case, both hornblende and mica. The color varies, depending on the amount of dark-colored minerals present, but the prevailing color is dark gray. The feldspar is chiefly plagioclase which belongs to the acid end of the soda-lime series. It is usually present in greater amount than the quartz. The mica is generally biotite, but muscovite is also found, and in places both are present. Apatite, magnetite, and locally garnet are accessory minerals.

The dacite porphyries are thought to be closely related genetically to the granodiorites. They have a rather sparse distribution, occurring as small knoblike areas and as dikes. They are usually light colored and have as their chief constituents quartz and soda-lime feldspar, both of which minerals in much of the rock form distinct phenocrysts.

The augite andesites occur only in small dikes and have been found cutting greenstones, granodiorites, and the Horsetown formation of the Cretaceous. The dikes of this rock were found only in the eastern half of the quadrangle.

The relative ages of the igneous rocks have been fairly well worked out. The greenstones are the oldest, then come the peridotites, next the granodiorites and dacite porphyries, and finally the augite andesites. Except some of the greenstone, which is probably Paleozoic, none of the igneous rocks described are thought to be older than the Jurassic, some are younger than the Lower Cretaceous, and all, except the augite andesites, are older than the Eocene. The augite andesites are probably related to the volcanics of the Cascades, and if so related they are of Tertiary age.

THE ORE DEPOSITS.

The chief gold-quartz mines and prospects of the Riddles quadrangle are in Josephine and Jackson counties, mainly in the former, as indicated on the accompanying map (fig. 8). The gold quartz is found in small veins, veinlets, and stringers in several kinds of rock. Within Josephine County all the paying veins have been in greenstone; a few prospects but no mines have been located in serpentine.

A striking feature in connection with many of the gold-bearing veins found in the greenstones is their proximity to serpentine, but usually the veins are cut off sharply at the contact of the greenstone with the serpentine. This may indicate either that the rock from which the serpentine was derived was younger than the vein or that displacements have occurred at the contact of the greenstone and its decompo-

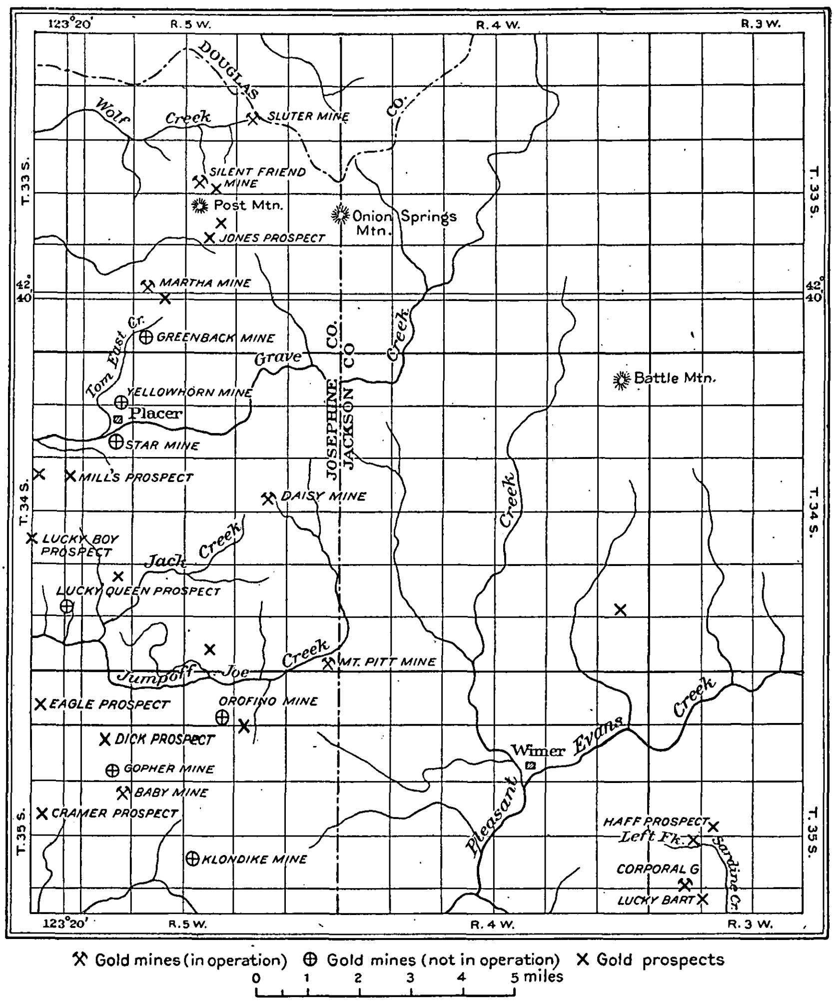


FIG. 8.—Map showing gold-quartz mines and prospects of Riddles quadrangle, Oregon.

sition product, the serpentine. In Jackson County the paying veins have been found in metamorphosed sediments, and usually they are within short distances of dikes or irregular areas of greenstone.

Quartz veinlets are also found in the granodiorites, but as yet no mine has been developed in these rocks within the area of the Riddles quadrangle. However, a few hundred yards south of the southern boundary, in the granodiorite, is the Granite Hill mine; which has been for several years an important producer of gold.

The evidence suggests that all the gold-bearing veins in the several kinds of rock are younger than the early Cretaceous and older than the Eocene. However, some of the veins in the metamorphosed sediments may be pre-Cretaceous.

The vein filling is chiefly quartz, calcite, and pyrite; here and there arsenopyrite, pyrrhotite, sphalerite, chalcopyrite, and galena are also present. The action of the mineral-bearing solutions on the country rock adjacent to the veins was such as to produce a strongly chloritized and, in places, talcose rock much of which contains carbonates or pyrite.

The gold-producing veins range in width from mere seams to veins more than 4 feet wide, but the average width of all the veins examined was less than 1 foot. In the best mine that has been found in the region, the Greenback, the average width of the vein was about 18 inches. In many places there are sheared and brecciated zones, in which occur several veinlets and stringers usually running parallel to one another, but locally irregular and running in various directions. In general, individual veins and veinlets are not continuous except for short distances, and in many localities, to further interfere with the continuity of veins, there has been a considerable amount of faulting along planes at various angles to one another. The walls of some of the veins are fairly well defined for short distances, but many of them show no distinct boundary between the vein material and the country rock.

Although gold-bearing veins and veinlets are found running in various directions, those which have been most productive trend in general east and west. For example, at the Greenback mine the vein has a direction nearly east and west; at the Martha mine, between northwest and west; at the Baby mine, northwest to nearly west; at the Corporal G mine, S. 85° W.; and the veins of the Lucky Bart group run almost west. The dips of the veins range from nearly horizontal to vertical, but usually they are at fairly high angles.

The values are found chiefly in the quartz of the veins and veinlets, but in the brecciated zones some gold is obtained in the fragments of chloritized rock which carries pyrite. The values are mostly in free gold, but the sulphides also carry gold, the amount varying considerably in different veins and in different parts of the same vein.

Some of the quartz veins which carry values are later in age than others which carry no values. This is well shown at the Baby mine, where the gold-bearing vein cuts a much wider barren vein. The barren vein appears not to have changed the strike, dip, or values of the Baby vein. In the neighborhood of the Corporal G are veins which are themselves barren, but where the younger gold-quartz veins intersect them the values are said to be enriched.

DESCRIPTIONS OF THE PRINCIPAL MINES.

Although there has been much prospecting for gold-quartz veins during the last fifteen years within the area of the Riddles quadrangle, comparatively few important discoveries have been made and some of the mines are no longer producing. Some of the most important mines are described below.

GREENBACK MINE.

The Greenback mine is situated on Tom East Creek, a branch of Grave Creek. It is worthy of note here that on the same stream, below the Greenback, is the Columbia placer mine, which is one of the most productive of southwestern Oregon.

The Greenback was discovered in 1897 by two prospectors, who lived in the vicinity of Placer on Grave Creek. They worked the deposit for about a year, treating the ore with an arrastre at Placer. They then sold the property for $30,000 to the Victor Junior Gold Mining Company, the chief owners of the stock being W. H. Brevort, of New York, and Messrs. Moffatt and Smith, of Denver. In 1902 more than 90 per cent of the stock was purchased by Mr. Brevort, and the corporation was named the Greenback Gold Mining and Milling Company. No transfer has since been made.

From the time when the property came into the possession of the Victor Junior Gold Mining Company until 1906 the development of the mine was rapid, more equipment being added each year. At first a 5-stamp mill was installed, later 5 stamps were added, and when, in 1902, Mr. Brevort became the chief owner, there were 15 stamps, besides a crusher, an air compressor, and three Wilfley tables for concentrating. Mr. Brevort's company soon began the construction of a new mill, about a quarter of a mile farther down the stream. At first 20 stamps were used in this mill. This number was increased until, in 1905, 40 stamps were being used. The new plant has three large Risdon crushers and 12 concentrating tables. There is also a cyanide plant consisting of four large tanks, with a capacity of 100 tons a day. For a while the mill was equipped with both steam and water power, but in 1905 a complete electric system was installed. The power was brought, by way of Grants Pass, from the Ray dam on Rogue River, a distance of about 30 miles. However, in the following year (August, 1906) all work at the mine was suspended and as yet it has not been resumed.

The workings of the mine are extensive, consisting chiefly of crosscut tunnels to the vein and drifts and shafts on the vein. Much of the ore has been stoped along the whole length of the vein to a depth of about 1,000 feet from the surface. The lowest of the workings are on the twelfth level. Below the ninth level the mine is filled with water.

The country rock is greenstone, which is considerably metamorphosed, but where most free from alteration it is of the nature of a gabbro. To the east and southeast of the mine there is a considerable area of serpentine, and a short distance to the north lies the southwestern limit of a band of siliceous slates which extends for some miles to the northeast.

The Greenback vein has a direction almost east and west, and dips, in general, about 60° N. It averages about 18 inches in width, but ranges from less than 6 inches to more than 4 feet. Where it is widest there is a crushed zone of quartz stringers and country rock, forming in places a beautiful breccia; the country rock of the breccia is strongly chloritized and contains sulphides which carry values. In many places the foot and hanging walls of the vein are fairly definite, but where considerable brecciation has occurred there is no distinct boundary between the vein material and the chloritized country rock. The vein is cut off sharply to the east against serpentine and to the west by a fault. The vein between the serpentine and the fault plane has an average length of more than 500 feet and within this distance there are only minor displacements. The vein has not been picked up to the west beyond the fault plane, nor has it been found in the serpentine to the east. This latter fact tends to prove that the rock from which this serpentine was derived was younger than the vein, rather than, as is indicated in some places in the quadrangle, that the present relations are due to displacements between the greenstone and its decomposition product, the serpentine.

The vein filling consists of quartz, calcite, and pyrite, which vary in amount in different parts of the vein. The average content of the ore mined from the first and second levels was between $8 and $9 to the ton; a few assays on these levels ran above $40 to the ton. Captain Buck states that over 75 per cent of the values of the ore was free-milling. The concentrates ran about $75 to the ton and after cyaniding the ores contained less than $1 to the ton. Within the mine there is but little evidence, except near the surface, of oxidation of the ores.

A short distance to the south of the Greenback vein and running almost parallel to it is the Irish Girl vein. On this very little work has been done.

MARTHA MINE.

The Martha mine is in the SW. ¼ sec. 28, T. 33 S., R. 5 W., about 1¼ miles north of the Greenback. It was purchased by the Greenback Company in 1904 and somewhat extensively developed. The electric power of the Greenback was extended to this property, and in 1906 an aerial tramway was constructed to connect the two mines and for a few months the ore of the Martha was conveyed by the tramway to the Greenback plant and treated there. The tramway is said to have cost $20,000. The company also installed a 75-horsepower air compressor. When the Greenback was closed the company also stopped all work at the Martha.

The mine was prospected by four tunnels whose length aggregates nearly 3,000 feet. At the time the property was examined (June, 1907) it was leased by J. M. Clarke, of Golden, Oreg., who had brought in five stamps and was treating the ore which had been mined by the Greenback Company but which had not been shipped to the mill.

The country rock is greenstone. The ores resemble those of the Greenback, but do not carry as high values in gold. They are found in narrow veinlets and stringers in zones of shearing and brecciation, which have a general trend between northwest and west and which range in width from a few inches to more than 4 feet.

BABY MINE.

The Baby mine is in the northwest corner of sec. 16, T. 35 S., R. 5 W., and is owned by the Capital City Gold Mining Company. The property was located in 1897 and since that time has been extensively developed by the present and the former owners. It is now leased by R. S. Moore, of Grants Pass. During the summer of 1907 three stamps were in operation. Mr. Adams, the manager of the company, says that the mine has yielded gold to the value of more than $20,000.

There is on the property a 5-stamp mill, two boilers, a concentrating table, and a small crusher. The development consists of more than 1,500 feet of tunnels, shafts, drifts, upraises, and crosscuts.

The vein occurs in greenstone and averages about 4 feet in width, but in places a fissured zone more than 10 feet wide has within it many parallel stringers of quartz which carries gold. The vein ranges in direction from northwest to nearly west and dips to the northeast, usually at high angles, although it is in some places almost vertical and in others almost flat.

A striking feature of the mine is the prevalence of faults. These are not only numerous, but they vary considerably in direction and in amount of displacement. One of the most prominent of the fault planes runs S. 80° W.

The vein material consists of a somewhat sugary-looking quartz, some calcite, and some pyrite. The values are carried chiefly by the quartz; in many parts of the vein free gold may be seen with the unaided eye. The sulphide varies in amount in different parts of the vein, and when concentrated yields about $75 worth of gold to the ton.

SILENT FRIEND MINE.

The Silent Friend property is in the southern part of sec. 15, T. 33 S., R. 5 W., on the north slope of Post Mountain. It is owned by the original locators, John Scribner and George Henderson, both of Speaker, Oreg. They discovered the vein in 1900, worked it until 1902, then leased it for eighteen months to Joseph Dysert. From the expiration of this lease until August, 1906, no development was carried on, but from that date to the present the owners have been working the mine on a small scale. Mr. Scribner states that from the oxidized material on the surface overlying a network of small stringers he has taken gold to the value of more than $7,000.

The chief development has been by two tunnels. The lower of these is 320 feet in length and crosscuts several small stringers. The upper is 75 feet in length, with an upraise to the surface.

The country rock is greenstone, which is strongly chloritized adjacent to the veins. The chloritization is, no doubt, due to the action of the mineral-bearing solutions. The ores are found in veinlets and stringers which run in various directions, but the majority of them have a general trend between southwest and west.

The filling consists of quartz, calcite, pyrite, arsenopyrite, and, locally, chalcopyrite. Some specimens of ore, which were found to consist largely of calcite, chlorite, and arsenopyrite, showed considerable free gold visible to the unaided eye. These specimens, which were taken from the bottom of one of the drifts, appeared to represent in the mine the ore of an 18-inch brecciated zone, which could be followed for several feet.

DAISY MINE.

The Daisy mine, which is on the divide at the head of Jack Creek, is on one of six claims constituting the Oregon Mohawk gold mines, owned by G. R. Smith, of Grants Pass. It was discovered in 1890 and for a time was worked under the name of the Hammersly mine. Then the stock was acquired by Morton Lindley, of San Francisco, who later disposed of it to the present owner.

Preparations were being made during the summer of 1907 to pump the water from the mine, which had been idle for some time, and mining operations were to be resumed. Mr. Smith stated that the mine had produced gold to the value of more than $200,000.

The workings consist of an inclined shaft 175 feet in depth, from which, at a distance of 115 feet below the surface, there is a drift along the vein for 350 feet to the west and 50 feet to the east. All the ore above has been stoped. From the bottom of the shaft there is a drift running eastward on the vein for 140 feet and westward for 243 feet.

The veinlets of gold-bearing quartz carrying pyrite run about east and west and are in a chloritized greenstone. The ore-bearing zone has a width of about 3 feet.

MOUNT PITT MINE.

The following notes were obtained from J. S. Diller, who examined the Mount Pitt property.

The mine is situated in the southeast corner of sec. 36, T. 34 S., R. 5 W. It was located by H. G. Rice, of Grants Pass, the present superintendent. The property is owned by A. C. Hooper, of Portland.

The present workings consist of an entrance tunnel of 225 feet to cut the vein, a drift of 100 feet along the vein, and an upraise of 200 feet from the drift to the surface. A mill has recently been erected containing a crusher, an automatic feeder, 5 stamps, and a concentrating table.

The ore is found in small, irregular veins in sheared greenstone, the sheared zone being usually about 3 feet wide. The quartz veins are rarely well marked, the greatest width of quartz seen being 4 inches and this is not persistent for more than a yard or so. The quartz veinlets are in general parallel to the plane of shearing, but some of them are small cross gash veins nearly horizontal.

OROFINO MINE.

The Orofino property, which is located in sec. 3, T. 35 S., R. 5 W., has been closed for several months and the workings are beginning to cave. The present owners are Messrs. Monahan and Mason, of Seattle. The last work was done by B. F. Chase, of Portland, who had a lease.

C. D. Crane, of Grants Pass, stated that there had been nearly 2,000 feet of work done on this property. Fourteen carloads of ore have been shipped to smelters at Tacoma, Wash., and Ashland, Oreg. The mine had at one time considerable equipment, including a 2-stamp mill, cyanide tanks, rock crushers, boilers, and hoists, but much of this material has been sold and shipped away.

The ore occurs in veinlets and stringers in a much fractured, brecciated, and chloritized greenstone. Many of the fragments of country rock of the breccia contain considerable pyrite. The vein filling consists chiefly of quartz and calcite, and, as shown by the relations of the two, the calcite was deposited later than the quartz. Sulphides are also present in some parts of the vein in considerable amounts, but in other parts they are almost entirely absent. A large amount of ore is now lying on the dump and many sacks of ore are ready for shipment.

OTHER MINES IN THE GREENSTONE AREAS.

All the mines thus far described are associated with greenstones and the descriptions indicate that the characters of the ores of the mines and their modes of occurrence are very similar. Many other mines and prospects associated with the greenstones might be described, but they would show few new features. Some of these are now being developed; some have been extensively prospected but have never produced; others have, in the past, produced small amounts but are no longer being worked. Among such mines and prospects may be mentioned the Lucky Queen, Mill's prospect, Star mine, Olympic prospect, Spotted Fawn prospect, Blalock & Howe mine, Eagle prospect, Cramer prospect, Gopher mine, and Dick prospect, most of which are indicated on the map (fig. 8). To the north of the area shown on the map are the Gold Bluff and Levens Ledge mines, both near Canyonville.

CORPORAL G MINE.

Of the mines which are not associated with the greenstones but with metamorphosed sediments the chief are the Corporal G mine and the Lucky Bart group, which lie west of the Left Fork of Sardine Creek.

The Corporal G mine is located in the southern part of sec. 19, T. 35 S., R. 3 W. It was discovered in 1904 by J. R. McKay, who, after taking out considerable rich ore, sold it to Mrs. Nina M. Smith, of Gold Hill, the present owner. The property is now leased by J. E. Kirk.

The workings consist of three tunnels, one above another on the vein. The longest tunnel is 92 feet in length, the shortest 63 feet. The ore occurs in a small vein with fairly definite walls of micaceous quartzite and mica slate. The average width of the vein is about 7 inches; it runs S. 85° W. and dips steeply to the north. The filling consists chiefly of quartz and calcite, but pyrite, pyrrhotite, chalcopyrite, bornite, sphalerite, and galena are also present. A few of the hand specimens show free gold.

Close to the Corporal G is the Volunteer claim on which a stringer running parallel to the Corporal G was followed by a drift for 135 feet, when it pinched out. This stringer intersects a barren cross vein running about N. 30° E.; at the intersection the values in the stringer are said to have been enriched.

LUCKY BART GROUP.

The Lucky Bart group consists of eleven claims in the NW. ¼ sec. 29 and the SE. ¼ sec. 30, T. 35 S., R. 3 W. The chief claim, the Buckskin or Lucky Bart, was discovered by Joseph Cox, who sold it in 1892 for $15,000. This amount he had to share with his partner, Bart Signoretti, who had had no part in the discovery, hence the name Lucky Bart. The company which bought the property worked it for four years when one of the shareholders, J. H. Beeman, of Gold Hill, purchased the rights of his associates and became the owner. About the same time Mr. Beeman purchased adjoining claims until he had title to all the property included in the Lucky Bart group. At present mining operations are being carried on at only one of the claims, the Yours Truly. The workings on the other claims, but mainly on the Lucky Bart, are in such condition that it is unsafe to enter them. The only workings examined were those of the Yours Truly. Information with regard to the other workings of the group was obtained from J. H. Beeman and J. E. Kirk.

Ore has been mined from five veins which run in a general direction a little south of west. These veins have an average width of less than 2 feet; the country rock is metamorphosed sediment, mainly mica slates and micaceous quartzites. The general strike of these rocks in this vicinity is somewhat east of north; the dip is to the southeast and is usually at fairly high angles. The total amount of ore that has been milled exceeds 14,000 tons, which gave values ranging from $4.80 to $100 a ton of free-milling ore. The ore from the Lucky Bart claim carried an average of 3 per cent of sulphides, which ran from 4 to 8 ounces of gold to the ton and a like amount in silver. Nine tons of ore from the deepest workings of this claim were shipped to the Tacoma smelter and gave returns of $130 to the ton. Practically all the ores from the group have been treated at a mill on Sardine Creek; the sulphides were shipped to the smelters at Tacoma, Wash., and Selby, Cal.

At the Yours Truly, where work is now being done by J. E. Kirk, who has a lease on the property, the workings consist of an entrance tunnel of 75 feet to the vein, 100 feet of drifting on the vein, and a shaft of 30 feet. The country rock is mica slate. The vein has an average width of about 1 foot and runs S. 85° W. At the end of the drift there are two veinlets of 8 inches and 4 inches in width and also a small seam. Within the workings there is evidence of considerable faulting; the directions of the fault planes observed were somewhat east of north. Mr. Kirk states that the veins carry more values adjacent to the fault planes than elsewhere. The ores of the Yours Truly are highly oxidized and carry an average value of more than $30 to the ton.

CONCLUSIONS.

Of the many veins and veinlets within the Riddles quadrangle on which work has been done, comparatively few have developed into profitable mines. The chief reason is to be found in the structural features of the rocks in which the ores occur. The Paleozoic and early Mesozoic sediments, with their associated igneous rocks, were, previous to the mineralization of the region, subjected to earth movements of such a nature that no definite, continuous fissures were formed, but rather, in general, innumerable minute and irregular fractures running in various directions. Later, when the mineral-bearing solutions, which may have been connected with one or more of the igneous intrusions, passed through these rocks and deposition therefrom took place, the gold was not concentrated in definite lodes but was widely distributed through the rocks in small veins, veinlets, and stringers, few of which are continuous except for short distances. Furthermore, in those places where fairly distinct and rich veins were formed, subsequent faulting has frequently been so prevalent that it is difficult and costly to follow the values. Notwithstanding these unfavorable conditions, however, the gold-quartz veins have produced and will probably continue to produce considerable amounts of gold. But the hope of finding vein deposits which will develop into large and profitable mines is not encouraging.

The veins and veinlets have been subjected to erosion for many thousands of years, during which time an immense amount of material has been freed of its gold. Much of this gold has been deposited in the neighboring streams, from which it has been and is being mined as placer gold.

PLACER MINES OF THE RIDDLES QUADRANGLE.

By J. S. Diller.

INTRODUCTION.

Placer mining is one of the most important industries of the Riddles quadrangle. There are 54 placer mines; 10 are in the northern half of the quadrangle in Douglas County; the remainder are in the southern half—18 in Jackson County and 26 in Josephine County. The total output of placer gold in the quadrangle up to date has been approximately $725,000. In 1906, according to the returns of Mr. Yale, of the Geological Survey, the output was $69,395, a considerable increase over that of the previous year.

The placer mines are all in gravel closely associated with the present streams. By far the greater portion of the mines are in the present stream beds or low terraces. Only a few are in gravel of the higher terraces, which rise from 100 to 400 feet above the stream.

No definite trace of ancient high-level gravels such as occur in the gold belt of the Sierra Nevada of California has yet been found in the Riddles quadrangle.

The gravels vary much in the form of the pebbles. On the higher terraces and the steeper grades of the larger streams they are generally well rounded, though some may be subangular, but in the gentler grades and especially also on the smaller lateral branches the gravel is subangular to angular. The contrast may be seen in comparing the well-rounded gravel of the Steam Beer mine on Grave Creek near Leland with the subangular gravel of the Columbia on Tom East Creek, near Placer.

The grades of the present streams range from 10 to 333 feet per mile, as made out approximately from the contour map. The major part of the placer mines are on grades not over 100 feet per mile. A smaller number are on grades between 100 and 200 feet per mile, and a few have grades greater than 200 feet per mile.

The highest terrace records are few, but if they may be depended on they seem to indicate that the grade of the streams when the gravels of the highest terrace were formed was probably lower than that of the present streams; moreover, the gravel of the highest terraces is on the whole not so coarse as that of the lower terraces and the present stream.

RIDDLES DISTRICT.

The placers of the northern part of the quadrangle are widely scattered, generally small, and for the most part unimportant. They lie on Rattlesnake, Middle, Catching, Mitchell, Jordan, Canyon and Shively creeks. The Ash mine, which covers about 3½ acres near Mitchell Creek, is peculiar in that the material washed is chiefly slope waste of slates and sandstones. On Shively Creek extensive preparations were in progress in 1906 for mining at the forks, but later returns have not been received.

COW CREEK DISTRICT.

Starvout Creek is a tributary of Cow Creek that drains the northern slope of Green Mountain. Three of the mines on this creek, the Harrah, Booth, and Curtis Brothers, have lately been in operation, but the Mizer and O'Shea only keep up assessment work. A large tract has been covered by these placers near the present stream level, and they are reported to have been fabulously rich in the early days. The bed rock is slate except in the Curtis Brothers mine, which is near the contact of the slates, greenstone, and serpentine.

Just beyond the western limit of the Riddles quadrangle, in Cow Creek canyon, are the Victory and Gold Flat placers, or terraces, about 150 feet above the stream. A dozen miles farther down are the Cain and the Cracker Jack, on terraces over 500 feet above the creek. All these are important placers formed under conditions in strong contrast with the gentle grade of Cow Creek above Glendale.

WOLF CREEK DISTRICT.

The Wolf Creek district includes not only the three placers more or less active on the main stream above the railroad station but also the four on Coyote Creek, which joins Wolf Creek at the post-office.

In Payne's mine, near Foley Gulch, a rusty rotten gravel is well exposed. The greenstone pebbles are completely rotten; those of slate are not so thoroughly decomposed. This gravel has the aspect of great age, but this illusion is dispelled by the freshness of the dark-gray gravel upon which it rests. The mine stretches up from the creek level to the terrace nearly 100 feet above. Coyote Creek has but little fall and the Ruble elevator has been used to advantage.

Near the mouth of Bear Gulch the bed of Coyote Creek has been mined for nearly half a mile. Its richness is due to the fact that Bear Gulch drains the slope from the Martha mine and the west end of the Greenback.

GRAVE CREEK DISTRICT.

Grave Creek is not only the most important placer stream in the Riddles quadrangle, but considering its size it is one of the most important in the State. Almost a score of placers, old and new, occur along the part of its course lying in this quadrangle, and half of them are still active during the good water season.

In the vicinity of Leland the lower Lewis and the Goff mines have not been worked lately. The water of their main ditch is now used in the Columbia. A small test of one-fourth acre in 20 feet of gravel was made last winter on the Klum property. The Steam Beer, owned by H. K. Miller, has continued in full operation for a number of years and there is more ground ahead. The ditch is about 9 miles in length and supplies a head of 200 feet. The gravel terrace is 50 feet above Grave Creek, which affords excellent dumping ground. The mine exposes 25 feet of gravel, generally coarse below, and made up largely of pebbles of greenstone with scarcely any quartz. The bed rock is slate.

On Brimstone Creek the gravel mined some years ago includes much quartz that appears to come from residual material on a terrace 300 feet above the creek.

The Columbia mine, near Placer post-office, is owned by L. A. Lewis, of Portland. It is the largest placer mine of the region and is supplied with water by two ditches from Grave Creek, one giving a head of 100 feet and the other of 600 feet. The mine occupies the valley of Tom East Creek, which drains the vicinity of the celebrated Greenback mine and is advancing in that direction. The gravel ranges from 4 to 30 feet in depth and is coarsest below, with bowlders a few of which reach 3 feet in diameter. The fragments are in general subangular and almost wholly greenstone. A few are rotten, but most are solid. The gold is fine, and nuggets are rare. With three 5-inch giants nearly 6 acres are mined over annually. The grade is low and to keep the sluice clear the tailings are washed aside from the end of the sluice by a powerful side stream which piles up the gravel in a prominent heap.

Near the headwaters of Grave Creek there are a number of active placers. Most of them are on the present stream bed, which has been washed for miles, but a few are on terraces up to 150 feet above the level of the creek.

JUMPOFF JOE DISTRICT.

The lower portion of Jumpoff Joe Creek traverses an area of granodiorite and has no placers, but above the forks placers occur among the greenstone hills on both Jack Creek and the main branch. The principal mine is the Swastika, under the management of A. B. Call. It occupies a low terrace in the forks at the mouth of Jack Creek. The Swastika property is said to include a large part of Jack Creek, and prospects have been made nearly 2 miles above its mouth toward the Daisy quartz mine. The Swastika has been operated by the present company for about a year. Two 18-inch pipes were used, one with a head of 150 feet and the other about 75 feet. The sluice dump was disposed of by a strong side stream.

The gravel is from 15 to 30 feet deep and is composed of greenstone pebbles. It is coarsest below, with bowlders up to 2 feet in diameter. In many places the whole mass is rotten, so that many of the bowlders go to pieces under the stream from the giant. The bed rock of the Swastika mine and throughout the slopes of Jack Creek is greenstone.

On the main fork of Jumpoff Joe Creek there are a number of small placers near its head and a larger one 5 miles below, where Cook & Howland have stripped the shallow bed of the stream, exposing the slates for half a mile to a width of 100 to 200 feet. The slope being gentle, an elevator was used.

EVANS CREEK DISTRICT.

Pleasant Creek, a branch of Evans Creek, heads against Grave Creek and has several active placers. For over 3 miles the bed of Pleasant Creek was almost completely mined out years ago, and later efforts have been directed to the benches rising up to 100 feet. The largest amount of work has been done at Harris Gulch, where an area of rotten gravel about 8 acres in extent has lately been removed. A smaller cut has been made in a well-marked terrace at Jamison Gulch, and farther up, between the forks, Thompson Brothers have washed off the residual material of a serpentine point 200 feet above the streams.

All the placers on Pleasant Creek except the one last mentioned are on granodiorite but near the contact with both slate and greenstone, which may be the source of the gold.

SOURCE OF THE PLACER GOLD.

The source of the placer gold is in the auriferous quartz veins, which are most abundant in the greenstones, though they occur in the slates also. The larger veins at many places are worked in quartz mines, but all the veins, both large and small, have contributed gold to the placer gravels. The greater number of placers are on slate bed rock. This does not necessarily indicate that the slates have been the chief source of the gold in the placers, but that in the process of stream erosion the slates are more readily terraced so as to preserve the gravels for mining.

PRODUCTION OF THE PLACER MINES.

Where data have been available for estimates the yield of the placers per cubic yard of gravel has ranged from 10 to 25 cents. Much of the gravel must have averaged 50 cents and in exceptional cases run as high as $1.50. To state it in another form, a number of the mines appear to have yielded from $4,000 to $6,000 per acre.

As already stated, the total production of the placers in the Riddles quadrangle has been approximately $725,000, of which considerably more than half has come from Grave Creek. A still larger proportion of the present annual output is from Grave Creek, for it has not only the greatest number of mines but includes the two largest producers. The approximate production by districts is as follows:

Total production of placer gold in Riddles quadrangle to 1907, by districts.

Riddles and Cow Creek districts	$100, 000
Wolf Creek district	75, 000
Grave Creek district	400, 000
Jumpoff Joe district	50, 000
Evans Creek district	100, 000

These estimates are more likely to be below than above the truth, for little is really known of the yield of the early placers.

NOTES ON COPPER PROSPECTS OF THE RIDDLES QUADRANGLE.

By G. F. Kay.

Copper minerals have been found at several places within the Riddles quadrangle, but as yet no paying mine of copper has been developed. During the summer of 1907 work was being done on two prospects which are of sufficient interest to merit a brief description.

The Joseph Ball mine is situated in the NW. ¼ sec. 36, T. 32 S., R. 4 W., which is on the southwest slope of Cedar Springs Mountain. The elevation at the mine is about 4,250 feet. Some ore has been carried by pack train to Glendale, on the Southern Pacific Railroad, a distance of more than 20 miles. The country rock is serpentine, which has been greatly fractured and sheared, and locally, where it has been decomposed, magnesite with some strontianite is present. The ores consist of native copper, copper glance, cuprite, and the copper carbonates. They are in a faulted zone in the serpentine, which shows numerous slickensided surfaces on which are vertical striæ. Within the workings the faulted zone varies in direction and the plane of shearing is very irregular. On this plane have been found flat pieces of native copper as large as the hand; the copper glance and cuprite have also been found on this plane as nodular masses and as scattered fragments. The workings consist of an upper tunnel of 150 feet along the fault zone and a lower tunnel of 145 feet from which there is an upraise of 60 feet to the upper tunnel. At the time the mine was examined the company was preparing to sink, from the lower tunnel, a shaft on the fault plane.

The Oak mine, in the SW. ¼ sec. 4, T. 35 S., R. 5 W., was located in 1905. It is owned by the Oak Consolidated Mining and Milling Company. Copper was found on this property while a gold-quartz vein was being developed. A tunnel was being run to crosscut some quartz stringers in a fractured zone, when copper pyrites was found. The mineral occurs as small irregular masses in a fractured and chloritized greenstone. During the summer of 1907 the company was installing an air compressor, hoists, and machine drills and plans were being made to prospect the property thoroughly.

Some prospects of copper occur in greenstone near Glendale and A. D. Leroy, of Merlin, has done some work on a quartz vein carrying copper in the N. ½ sec. 8, T. 35 S., R. 6 W.

SURVEY PUBLICATIONS ON GOLD AND SILVER.

The following list includes the more important publications by the United States Geological Survey, exclusive of those on Alaska, on precious metals and mining districts. Certain mining camps, while principally copper or lead producers, yield also smaller amounts of gold and silver. Publications on such districts are listed in the bibliographies for copper and for lead and zinc. When two metals are of importance in a particular district, references may be duplicated. For names of recent geologic folios in which gold and silver deposits are mapped and described, reference should be made to the table in the " Introduction " to this volume. Gold and silver, when the most important products in the area mapped, are indicated by italics in that table.

ARNOLD, RALPH. Gold placers of the coast of Washington. In Bulletin No. 260, pp. 154–157. 1905.

BAIN, H. F. Reported gold deposits of the Wichita Mountains [Okla.]. In Bulletin No. 225, pp. 120–122. 1904.

BALL, S. H. Geological reconnaissance in southwestern Nevada and eastern California. In Bulletin No. 285, pp. 53–73. 1906. Also Bulletin No. 308. 218 pp. 1907.

BARRELL, JOSEPH. Geology of the Marysville mining district, Montana. Professional Paper No. 57. 178 pp. 1907.

——— (See also Weed, W. H., and Barrell, J.)

BECKER, G. F. Geology of the Comstock lode and the Washoe district; with atlas. Monograph III. 422 pp. 1882.

——— Gold fields of the southern Appalachians. In Sixteenth Ann. Rept., pt. 3, pp. 251–331. 1895.

——— Witwatersrand banket, with notes on other gold-bearing pudding stones. In Eighteenth Ann. Rept., pt. 5, pp. 153–184. 1897.

——— Brief memorandum on the geology of the Philippine Islands. In Twentieth Ann. Rept., pt. 2, pp. 3–7. 1900.

BOUTWELL, J. M. Economic geology of the Bingham mining district, Utah. Professional Paper No. 38, pp. 73–385. 1905.

——— Progress report on Park City mining district, Utah. In Bulletins No. 213, pp. 31–40; No. 225, pp. 141–150; No. 260, pp. 150–153.

CALKINS, F. C. (See Ransome, F. L., and Calkins, F. C.)

COLLIER, A. J. Gold-bearing river sands of northeastern Washington. In Bulletin No. 315, pp. 56–70. 1907.

CROSS, WHITMAN. General geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 13–109. 1895.

——— Geology of Silver Cliff and the Rosita Hills, Colorado. In Seventeenth Ann. Rept., pt. 2, pp. 269–403. 1896.

CROSS, WHITMAN, and SPENCER, A. C. Geology of the Rico Mountains, Colorado. In Twenty-first Ann. Rept., pt. 2, pp. 15–165. 1900.

CURTIS, J. S. Silver-lead deposits of Eureka, Nev. Monograph VII. 200 pp. 1884.

DILLER, J. S. The Bohemia mining region of western Oregon, with notes on the Blue River mining region. In Twentieth Ann. Rept., pt. 3, pp. 7–36. 1900.

——— Mineral resources of the Indian Valley region, California. In Bulletin No. 260, pp. 45–49. 1905.

——— Geology of the Taylorsville region, California. Bulletin No. —. In preparation.

ECKEL, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin No. 213, pp. 57–63. 1903.

EMMONS, S. F. Geology and mining industry of Leadville, Colo.; with atlas. Monograph XII. 870 pp. 1886.

——— Progress of the precious-metal industry in the United States since 1880. In Mineral Resources U. S. for 1891, pp. 46–94. 1892.

——— Economic geology of the Mercur mining district, Utah. In Sixteenth Ann Rept., pt. 2, pp. 349–369. 1895.

——— The mines of Custer County, Colo. In Seventeenth Ann. Rept., pt. 2, pp. 411–472. 1896.

——— (See also Irving, J. D., and Emmons, S. F.)

EMMONS, S. F., and IRVING, J. D. Downtown district of Leadville, Colo. Bulletin No. 320. 72 pp. 1907.

EMMONS, W. H. The Neglected mine and near-by properties, Colorado. In Bulletin No. 260, pp. 121–127. 1905.

——— Ore deposits of Bear Creek, near Silverton, Colo. In Bulletin No. 285, pp. 25–27. 1906.

——— The Granite-Bimetallic and Cable mines, Phillipsburg quadrangle, Montana. In Bulletin No. 315, pp. 31–55. 1907.

EMMONS, W. H., and GARREY, G. H. Notes on the Manhattan district, Nevada. In Bulletin No. 303, pp. 84–93. 1907.

GALE, H. S. The Hahns Peak gold field. In Bulletin No. 285, pp. 28–34. 1906.

GARREY, G. H. (See Emmons, W. H., and Garrey, G. H.; Spurr, J. E., and Garrey, G. H.)

GRATON, L. C. Reconnaissance of some gold and tin deposits of the southern Appalachians; with notes on the Dahlonega mines, by Waldemar Lindgren. Bulletin No. 293. 134 pp. 1906.

——— (See also Lindgren, W., and Graton, L. C.)

HAGUE, ARNOLD. Geology of the Eureka district, Nevada. Monograph XX. 419 pp. 1892.

HAHN, O. H. The smelting of argentiferous lead ores in the Far West. In Mineral Resources U. S. for 1882, pp. 324–345. 1883.

IRVING, J. D. Ore deposits of the northern Black Hills. In Bulletin No. 225, pp. 123–140. 1904.

——— Ore deposits of the Ouray district, Colorado. In Bulletin No. 260, pp. 50–77. 1905.

——— Ore deposits in the vicinity of Lake City, Colo. In Bulletin No. 260, pp. 78–84. 1905.

——— (See also Emmons, S. F., and Irving, J. D.)

IRVING, J. D., AND EMMONS, S. F. Economic resources of northern Black Hills. Professional Paper No. 26, pp. 53–212. 1904.

LINDGREN, WALDEMAR. The gold-silver mines of Ophir, Cal. In Fourteenth Ann. Rept., pt. 2, pp. 243–284. 1894.

LINDGREN, WALDEMAR. The gold-quartz veins of Nevada City and Grass Valley districts, California. In Seventeenth Ann. Rept., pt. 2, pp. 1–262. 1896.

——— The mining districts of the Idaho Basin and the Boise Ridge, Idaho. In Eighteenth Ann. Rept., pt. 3, pp. 625–736. 1898.

——— The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho. In Twentieth Ann. Rept., pt. 3, pp. 75–256. 1900.

——— The gold belt of the Blue Mountains of Oregon. In Twenty-second Ann. Rept., pt. 2, pp. 551–776. 1902

——— Neocene rivers of the Sierra Nevada. In Bulletin No. 213, pp. 64–65. 1903.

——— Mineral deposits of the Bitterroot Range and the Clearwater Mountains, Montana. In Bulletin No. 213, pp. 66–70. 1903.

——— Tests for gold and silver in shales from western Kansas. Bulletin No. 202. 21 pp. 1902.

——— The production of gold in the United States in 1904. In Bulletin No. 260, pp. 32–38. 1905.

——— The production of silver in the United States in 1904. In Bulletin No. 260, pp. 39–44. 1905.

——— The Annie Laurie mine, Piute County, Utah. In Bulletin No. 285, pp. 87–90. 1906.

——— Notes on the Dahlonega mines. In Bulletin No. 293, pp. 119–128. 1906.

LINDGREN, WALDEMAR, and GRATON, L. C. Mineral deposits of New Mexico. In Bulletin No. 285, pp. 74–86. 1906.

LINDGREN, WALDEMAR, and RANSOME, F. L. The geological resurvey of the Cripple Creek district. Bulletin No. 254. 36 pp. 1905.

——— ——— Geology and gold deposits of the Cripple Creek district, Colorado. Professional Paper No. 54. 516 pp. 1906.

LINDGREN, WALDEMAR, and others. Gold and silver. In Mineral Resources U. S. for 1906, pp. 111–371. 1907.

LORD, E. Comstock mining and miners. Monograph IV. 451 pp. 1883.

MACDONALD, D. F. Economic features of northern Idaho and northeastern Montana. In Bulletin No. 285, pp. 41–52. 1906.

NITZE, H. B. C. History of gold mining and metallurgy in the Southern States. In Twentieth Ann. Rept., pt. 6, pp. 111–123. 1899.

PENROSE, R. A. F., jr. Mining geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 111–209. 1895.

PIRSSON, L. V. (See Weed, W. H., and Pirsson, L. V.)

PURINGTON, C. W. Preliminary report on the mining industries of the Telluride quadrangle, Colorado. In Eighteenth Ann. Rept., pt. 3, pp. 745–850. 1898.

RANSOME, F. L. Report on the economic geology of the Silverton quadrangle, Colorado. Bulletin No. 182. 265 pp. 1901.

——— The ore deposits of the Rico Mountains, Colorado. In Twenty-second Ann. Rept., pt. 2, pp. 229–398. 1902.

——— Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada. In Bulletin No. 303, pp. 7–83. 1907.

——— (See also Lindgren, W., and Ransome, F. L.)

RANSOME, F. L., and CALKINS, F. C. Geology and ore deposits of the Coeur d'Alene district, Idaho. Professional Paper No. 62. In press.

SCHULTZ, A. R. Gold developments in central Uinta County, Wyo., and at other points on Snake River. In Bulletin No. 315, pp. 71–88. 1907.

SMITH, G. O. Gold mining in central Washington. In Bulletin No. 213, pp. 76–80. 1903.

——— Quartz veins in Maine and Vermont. In Bulletin No. 225, pp. 81–88. 1904.

SMITH, G. O. (See also Tower, G. W., and Smith, G. O.)

SPENCER, A. C. (See Cross, Whitman, and Spencer, A. C.)

SPURR, J. E. Economic geology of the Mercur mining district, Utah. In Sixteenth Ann. Rept., pt. 2, pp. 343–455. 1895.

——— Geology of the Aspen mining district, Colorado; with atlas. Monograph XXXI. 260 pp. 1898.

——— The ore deposits of Monte Cristo, Washington. In Twenty-second Ann. Rept., pt. 2, pp. 777–866. 1902.

——— Ore deposits of Tonopah and neighboring districts, Nevada. In Bulletin No. 213, pp. 81–87. 1903.

——— Preliminary report on the ore deposits of Tonopah. In Bulletin No. 225, pp. 89–110. 1904.

——— Ore deposits of the Silver Creek quadrangle, Nevada. In Bulletin No. 225, pp. 111–117. 1904.

——— Notes on the geology of the Goldfields district, Nevada. In Bulletin No. 225, pp. 118–129. 1904.

——— Geology of the Tonopah mining district, Nevada. Professional Paper No. 42. 295 pp. 1905.

——— The ores of Goldfield, Nev. In Bulletin No. 260, pp. 132–139. 1905.

——— Development at Tonopah during 1904. In Bulletin No. 260, pp. 140–149. 1905.

——— Ore deposits of the Silver Peak quadrangle, Nevada. Professional Paper No. 55. 174 pp. 1906.

SPURR, J. E., and GARREY, G. H. Preliminary report on the ore deposits of the Georgetown mining district, Colorado. In Bulletin No. 260, pp. 99–120. 1905.

——— ——— The Idaho Springs mining district, Colorado. In Bulletin No. 285, pp. 35–40. 1906.

——— ——— Economic geology of the Georgetown quadrangle (together with the Empire district), Colorado, with general geology by S. H. Ball. Professional Paper No. 63. In preparation.

TOWER, G. W., and SMITH, G. O. Geology and mining industry of the Tintic district, Utah. In Nineteenth Ann. Rept., pt. 3, pp. 601–767. 1899.

WEED, W. H. Geology of the Little Belt Mountains, Montana, with notes on the mineral deposits of the Neihart, Barker, Yogo, and other districts. In Twentieth Ann. Rept., pt. 3, pp. 271–461. 1900.

——— Gold mines of the Marysville district, Montana. In Bulletin No. 213, pp. 88–89. 1903.

——— Notes on the gold veins near Great Falls, Md. In Bulletin No. 260, pp. 128–131. 1905.

WEED, W. H., and BARRELL, J. Geology and ore deposits of the Elkhorn mining district, Jefferson County, Mont. In Twenty-second Ann. Rept., pt. 2, pp. 399–550. 1902.

WEED, W. H., and PIRSSON, L. V. Geology of the Castle Mountain mining district, Montana. Bulletin No. 139. 164 pp. 1896.

——— ——— Geology and mining resources of the Judith Mountains of Montana. In Eighteenth Ann. Rept., pt. 3, pp. 446–616. 1898.

WILLIAMS, A. Popular fallacies regarding precious-metal ore deposits. In Fourth Ann. Rept., pp. 253–271. 1884.

WOOLSEY, L. H. Lake Fork extension of the Silverton mining area, Colorado. In Bulletin No. 315, pp. 26–30. 1907.