COPPER.

THE COPPER MINES OF THE UNITED STATES IN 1905.

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INTRODUCTION.

Copper mining in the United States has had a marvelously rapid development in the last ten years, showing an increase of 150 per cent in that time. The production for 1905 broke all previous records and brought higher prices than at any time for ten years past. The greatest increase in production was in Arizona, and the greatest individual increase that of the Copper Queen mine at Bisbee, Ariz. The following table shows the production and relative rank of the different producing States, the figures for 1904 being those prepared and published by the Geological Survey,[a] while those for 1905 are compiled from estimates by various trustworthy authorities.[b]

Production of copper in the United States, 1904–5.

State or Territory.	1904.	1905.	State or Territory.	1904.	1905.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
Montana	298,314,804	319,179,885	Wyoming	3,565,629	2,393,201
Arizona	191,602,958	222,866,024	Alaska	2,043,586	4,703,600
Michigan	208,309,130	218,999,753	Idaho	4,518,034	6,661,400
Utah	47,062,889	51,950,789	Oregon and Washington.	.....	1,550,000
California	28,529,023	[a] 20,000,000	North Carolina	.....	700,000
Tennessee	15,211,086	14,507,982	Georgia	.....	10,000
Colorado	9,506,944	9,854,176	Total	814,035,719	879,015,652
New Mexico	5,368,666	5,638,842			

[a] Salt Lake Mining Review, Annual Review number, January, 1906.

The proportion furnished by the United States and the leading part it plays in the copper market of the world are shown in the following table, giving the production for 1904:

[a] Mineral Resources U. S. for 1904.

[b] Eng. and Min. Jour., April 28, 1906; Stevens, Horace J., Mining World, Jan. 27, 1905; and information furnished the writer by mine owners and managers.

Production of raw copper, 1904, including both native and foreign ores, smelted and intermediate products, raw copper to be refined, and supplies of refined, in metric tons.[a]

Germany		30,262
Great Britain		65,500
France		7,000
Austria-Hungary		1,463
Italy		3,700
Russia		10,900
Imported into Europe from United States		245,000
Imported into Europe from Chile		22,000
Imported into Europe from Japan		3,850
Imported into Europe from Australia		12,200
Imported into Europe from other countries (Mexico, East India, and Canada)		10,000
Imported into Asia from Japan and Australia		38,000
Imported into Asia from America and Europe		7,300
United States product		378,000
Less export to Europe	255,934	
Less export to America and Asia	6,800	
		262,734
United States supply, 1904		115,266

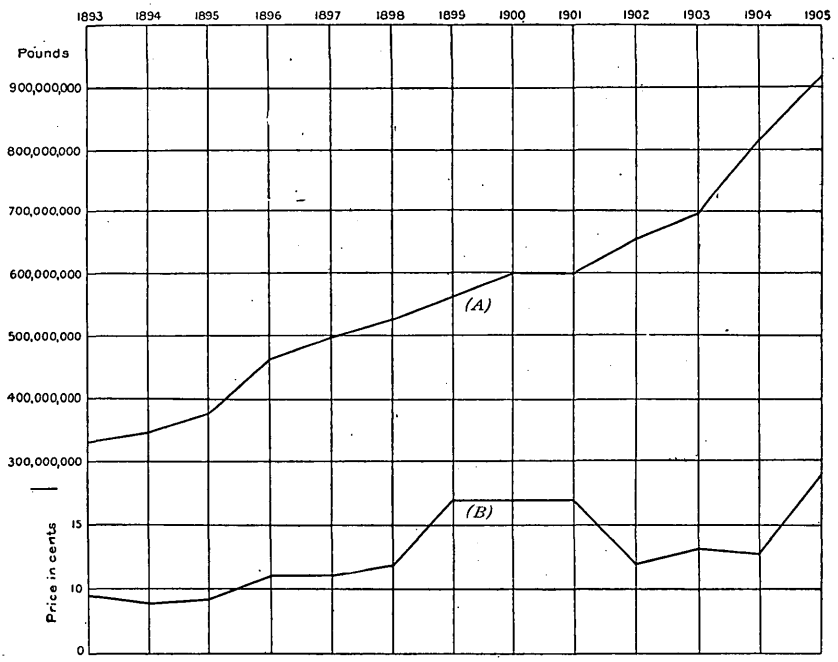
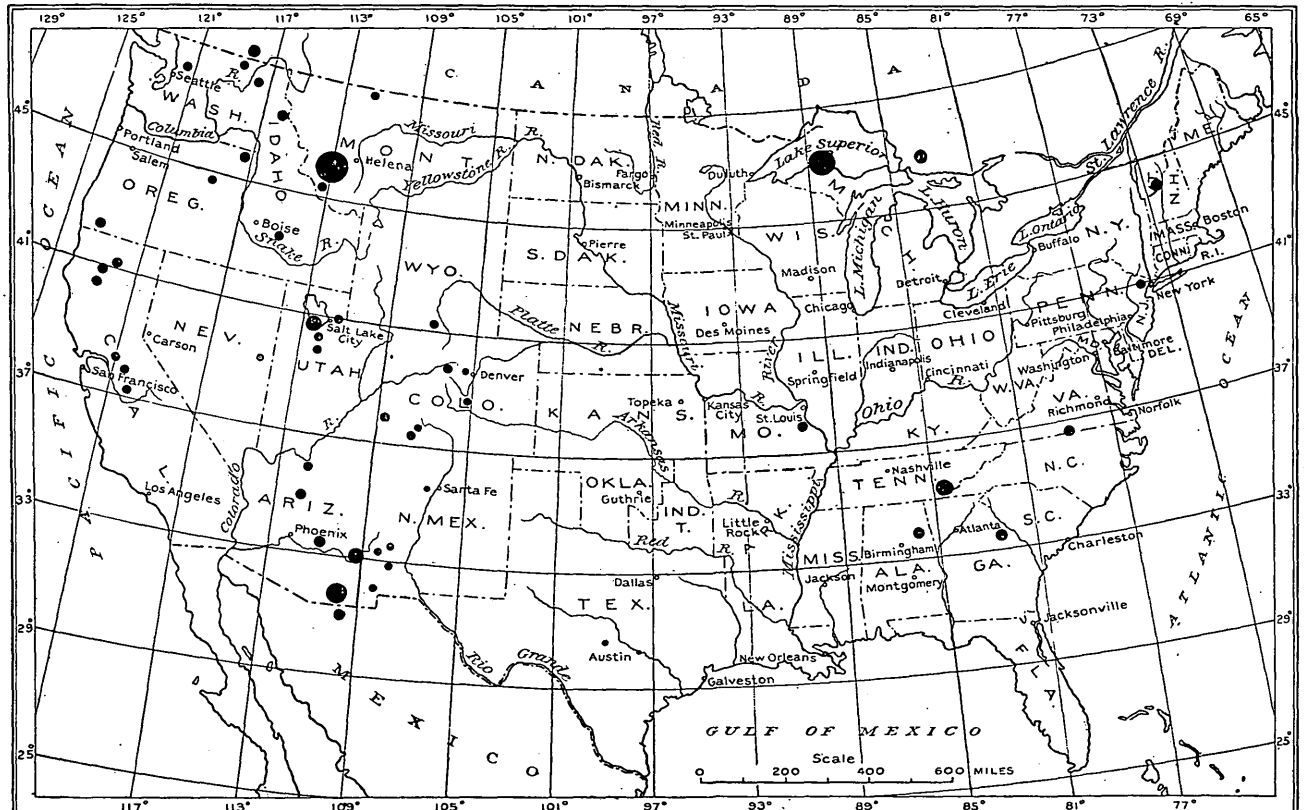


FIG. 5.—Diagram showing (*A*) production and (*B*) prices of copper in the United States from 1893 to 1905.

The copper mines of the United States yield gold and silver as by-products and many gold mines yield small amounts of copper. The total gold produced by the copper mines of the United States in 1904 was 237,116 ounces, distributed as shown in the table below:

[a] Metal. Gesell., 12th annual issue, October, 1905.



MAP SHOWING THE DISTRIBUTION OF THE PRODUCTIVE COPPER MINES OF THE UNITED STATES.

Size of dot represents approximately the relative importance and production.

Precious metals contained in the copper ores of each State.

	Gold.	Silver.		Gold.	Silver.
	Ounces.	*Ounces.*		*Ounces.*	*Ounces.*
Utah	109,968	2,572,582	Idaho	538	201,843
Arizona	47,563	1,464,731	Wyoming	326	4,601
Montana (Butte)	44,400	10,236,119	Oregon	326	11,677
California (Shasta)	24,727	844,265	South Dakota	145	789
New Mexico	4,137	79,369	Nevada	10	2,519
Colorado	3,288	131,695	Michigan		122,807
Appalachian States (estimated)	1,066	79,600	Total	237,116	15,768,307
Washington	582	16,710			

The distribution of the copper mines of the country is shown in Pl. III.

The Butte, Mont., copper district is the greatest silver-producing camp of the entire world, its production being 10,236,119 ounces in 1904. Utah leads in the amount of gold produced from its copper ores, Bingham and Tintic yielding 109,968 ounces, the ores also carrying 2,572,582 ounces of silver. The Arizona mines yield more gold than the Butte mines, but far less silver.

GENERAL CONDITIONS.

The marked change from lead to copper as a collector of precious metals in smelting practice is one of the notable features of recent years and has furnished a market for gold and silver ores whose copper content was not formerly paid for, 3 per cent copper being long considered the minimum.

The most striking feature of copper mining in the last two years is the complete success of experiments made in the treatment of the so-called disseminated ores, in which small particles of copper sulphides occur disseminated through altered porphyry. Enormous bodies of this class of ore occur at Morenci, Ariz., at Bingham, Utah, and at Ely, Nev., that were formerly considered of too low grade to work, but that have been proved to yield a handsome profit when treated in concentrating mills and concentrated 10 to 20 into 1.

The extent to which these great bodies of "disseminated" ore will contribute to the world's supply of copper can be estimated from the fact that preparations are being made to mine and mill 12,000 tons of this ore a day at Bingham and nearly as much at Ely, while the mills of both the companies at Morenci have been greatly enlarged. Although similar disseminations of glance and pyrite in altered granite alongside of and between the veins at Butte, Mont., have long been milled, it has been customary to regard a 3 per cent or even a 4 per cent ore as the lowest grade that could be profitably treated, whereas at the localities mentioned above the grade is much lower, as shown by the following table, after J. P. Channing:

Tenor of "disseminated" copper ores.

	Per cent.
Morenci, Ariz., Arizona Copper Company	2.6
Morenci, Ariz., Detroit Copper Company	3.0
Bingham, Utah, Utah Copper Company	1.9
Bingham, Utah, Boston Consolidated Copper Company	1.4
Ely, Nev., Nevada Consolidated Copper Company, Ruth mine	2.6
Ely, Nev., Nevada Consolidated Copper Company, Eureka mine	2.2

It is evident that the price of the metal will determine the minimum grade of copper ore that can be treated at a profit. The above ores can be made to pay with copper at 12 cents a pound.

The widespread adoption of so-called pyritic or raw-sulphide smelting, in which the fuel value of the sulphur is utilized, has had its effect on copper mining, as, indeed, have the

introduction of labor-saving devices at the smelters and the improved mechanical arrangements which have lowered the cost of treatment and so led to the mining of lower-grade ores. The cheapened smelting costs have added a long lease of life to various old properties by enabling bodies of lean and previously unworkable ores to be reckoned as ore reserves, while pyritic smelting has led to a demand for pyritic ores as a fuel flux to be added to siliceous ores.

If it be true, as an eminent metallurgist has epigrammatically expressed it, that "roasting is a crime and concentration a felony," the ores now concentrated will some day be treated direct in the blast furnace, mixed with pyritic ores, as is now being done at the Pittsmont smelter at Butte.

It has not been found practicable nor is it especially desirable to separate the production of milling and of smelting ores. At Butte, Mont., the smelting ores form from 6 to 10 per cent of the total amount mined, the proportion varying at the different mines. The entire production of the Utah and of the Boston companies of Bingham, Utah, will be milling ores, and at everyone of the Arizona camps the proportion of milling ores used is increasing each year.

The California ores, like those of Ducktown, Tenn., are basic sulphide ores, an ideal material for pyritic smelting.

Copper ores can be grouped commercially into smelting, concentrating, and leaching ores. All three kinds of ore often occur at the same mine, but the distinction holds good in a general way. Smelting ores may be either pyritic, with an excess of iron, or siliceous, carrying an excess of silica, though the lower-grade siliceous ores are often classed as concentrating ores. Pyritic ores are found at Ducktown, Tenn., and at the mines of Shasta County, Cal., while the smelting ores of Butte are well-known examples of siliceous ores which need basic flux added to them to insure successful treatment.

In some cases, owing to the physical character of the ore and the minute intergrowth of ore and gangue minerals, concentration is not feasible. In such cases direct smelting with the production of a low-grade matte is possible, provided basic ores can be obtained. In any case the loss in wet concentration is considerable, varying from 20 to 35 per cent.

In recent years self-fluxing ores have been found at a few localities—as, for example, at the Boundary Creek region in Canada and in the mines of the Saddle Mountain Company on Gila River, Arizona—and in such cases ores particularly low in copper may be treated at a profit, provided coke can be obtained at a reasonable figure. The utilization of low-grade garnetiferous contact-metamorphic ores is still a problem for the metallurgist, and although various attempts have been made to treat such ores, particularly in the San Pedro mines in New Mexico, success has not been attained.

The Lake Superior ores may be called ideal concentrating ores, as the native metal is tough and does not slime, as do the brittle sulphides when they are pulverized to liberate the metallic contents.

From a geological standpoint the producing copper deposits of the United States may be grouped as follows:

(*a*) Deposits in altered limestones, showing contact-metamorphic characters, and adjacent to eruptive rocks (Morenci type) in part characterized by deposits of group *b*.

(*b*) Deposits in fissured and altered igneous rocks, in part as veins, in part as dissemination and impregnation of shattered or porous rocks of other kinds (Morenci).

(*c*) Replacement veins in sheeted granitic rock (Butte type).

(*d*) Lenticular masses of solid, nearly pure, pyritic ore in shear zones in igneous rocks (Shasta County type).

(*e*) Lenticular deposits (similar to *d* in shape and mineral character) in metamorphic schists (Ducktown, Tenn.; Ely, Vt.).

(*f*) Deposits of native copper in altered amygdaloidal basic lava and interbedded conglomerates (Lake Superior).

(*g*) Normal fissure veins and impregnations of similar genesis.

Other types of scientific but slight economic importance also occur—as, for example, the deposits in the glance-impregnated quartzites of the Permian Red Beds, the impregnated shales adjacent to trap sheets in New Jersey, the Blue Ridge deposits of Virginia, etc.—but they need not be considered here.

The class first named, the contact-metamorphic deposits, yield about one-fifth of the total copper produced in this country. The allied disseminated ores yield about 50,000,000 pounds, excluding Butte's production. The Michigan production of 221,000,000 pounds for 1905 is all from one type of deposit, while the lenticular deposits (*d* and *e*) yield 36,000,000 pounds. The grouping given above is intended to express broad features and is not given as a satisfactory classification. Form is an important factor from the mining standpoint; mineral character of ore and of gangue from the smelter's point of view.

The first group, which for convenience may be called the Morenci type, should really include groups *a* and *b*. At each of the great mining centers—Morenci and Bisbee, Ariz.; Cananea, Mexico; Bingham, Utah, and Ely, Nev.—the distribution of the copper deposits is coextensive with a great porphyry stock and its dike systems. Areas devoid of intrusions are barren. The deposits are essentially copper deposits, with very minor amounts of gold and silver. The workable deposits of these localities occur either in the limestones or in the porphyry. In limestone they are confined to areas showing marked contact metamorphism, and the sulphides replace the original rock material, are intergrown with the contact minerals, and were introduced during the metamorphism of the limestone. The prevalent minerals are cupriferous pyrite and chalcopyrite.

The disseminated ores and associated fissure-vein deposits carry pyrite, with or without chalcopyrite and often with zinc blende and molybdenite, with but little quartz gangue, in altered porphyry. The ores are of low grade and in many cases workable only as far down as secondary reconcentration (enrichment) has occurred. The porphyry is altered, usually greatly so, by late hydrothermal action, in the latter case consisting of sericite, quartz, and pyrite. Where the fissures pass into other rocks alteration and ore deposition also occur, except in those already altered by contact action.

RECENT LITERATURE.

During the last few years several important papers describing copper deposits have been published. Among the Survey publications the monographs on Globe, Bingham, Bisbee, Encampment (Wyoming), and Morenci have appeared as Professional Papers.[a] Shorter papers in Bulletins Nos. 213, 225, and 260, Contributions to Economic Geology, 1902, 1903, and 1904, have contained descriptions of Butte, Mont., and the deposits of Shasta County, Cal. The rocks, but not the ore deposits, of Lake Superior have been described by Irving in Monograph V. The copper deposits of eastern Oregon are described in The Gold Belt of the Blue Mountains of Oregon, by Lindgren.[b] The copper deposits of the Cœur d'Alene district, near Mullan, are described by Ransome in a preliminary report in Bulletin No. 260, and a more detailed paper is soon to appear. The deposits of the eastern United States are described in a forthcoming bulletin.

ALASKA.

The first commercial shipments of copper from Alaska were made in 1903, forming, it is hoped, the beginning of a great industry. At the present time the known copper mines of Alaska do not warrant definite estimates of future production.

On Prince of Wales Island two properties have been brought to a producing stage and are now reducing their own ores. The first is the Mamie mine at Hadley, operated by the New York Smelting and Refining Company. The ore is chalcopyrite, with pyrite, a very small amount of calcite, and much amphibole. The ore occurs in lenticular masses surrounded by black slickensided surfaces. It is understood that an arrangement has been

[a] Nos. 12, 38, 21, 25, and 43, respectively.
[b] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 551–776.

made by which the company exchanges ore with the Britannia Company, near Vancouver, sending it the basic ore and receiving in exchange the highly siliceous ores of the Britannia mine. The Coppermount smelter was also in operation in the latter part of 1905 and promises to be a steady producer in the future.

One mine on Prince William Sound was a steady producer during 1904, shipping ore to the Puget Sound smelter.

The Nikolai greenstone forms a remarkable body of igneous rock, extending along the Alaska Range for nearly 300 miles, lifted and upturned with the Carboniferous limestone about its borders, but not breaking through the rock or sending out dikes or arms into it. This great body of rocks, which consists mainly of intrusive masses, but in part contains amygdaloidal surface lavas, is cupriferous over a very extensive area, and in places, as at Bonanza Creek (Copper River) carries disseminated bornite and veins of glance in what appears to be fresh rock, together with associated magnetite and pyrrhotite.[a] According to Schrader and Spencer the Nikolai greenstone consists of volcanic flows varying laterally and vertically and constituting a unit compared with adjacent rocks. It is composed of green to red feldspar, with augite, a less amount of chlorite, a little serpentine, and some accessory magnetite. The rocks are mainly altered basalts. Locally they contain metallic copper, which is secondary. Both the greenstone and the adjacent sedimentaries are fractured and the fissures become veins. The copper occurs in the fissures in the greenstone or in the sedimentaries only near the contact with the greenstone.[b]

The best-known mines of the Prince William Sound or Copper River district are in the Bonanza Creek basin, which lies across the range from the coast and is reached by a two weeks' journey with saddle and pack mules. The ore occurs in a vein which crosses at 90° the contact between the Nikolai greenstone and Carboniferous limestones upturned about it. The vein shows a pay streak of 4 feet of 40 to 50 per cent ore, consisting of bornite and glance, the vein itself being about 11 feet wide, if the parallel fissuring is included. The fracture is distinctly traceable into the limestone, where, however, it is barren and filled with limestone fragments cemented by calcite. The vein was traced by H. V. Winchell for over half a mile into the limestone and, being above timber line, it is well exposed, particularly where it crosses a 70-foot cliff. Although carefully examined and sampled it does not show even a trace of copper throughout this extent in the limestone. The ore occurs only where the vein is incased in the greenstone, and a 40-foot shaft sunk in the greenstone shows this ore to be a surface enrichment.

ARIZONA.

Mining is Arizona's chief industry, and copper the principal product, the Territory being second in the United States and fourth in the world in the amount of its copper production.

Production of copper in Arizona, 1903 and 1904, by counties.

County.	1903.	1904.	County.	1903.	1904.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
Cochise	63,264,488	90,850,611	Pinal	84,000	186,638
Coconino and Maricopa	257,022	333,754	Santa Cruz	4,162	27,000
Gila	7,740,843	14,677,561	Yavapai	23,999,628	30,826,286
Graham	52,839,856	59,537,295	Yuma	9,043	1,200
Mohave	31,931	1,480	Total	148,245,973	199,481,044
Pima	15,000	3,039,219			

[a] For a description of the Nikolai greenstone see Schrader, F. C., and Spencer, A. C., Geology and mineral resources of a portion of the Copper River district, Alaska: House Doc. No. 546, 56th Cong., 2d sess., 1901.

[b] For details concerning the copper deposits of various localities see op. cit., pp. 82, 89.

Within the last decade the industry has shown an enormous increase. Copper ores occur in nearly every county of the Territory, but the production is almost entirely from four somewhat widely separated districts—Bisbee, Cochise County, 6 miles north of the Mexican border; Morenci and Metcalf (Clifton district), Graham County, on the southern border; Globe, Gila County, near the center of the Territory; and Jerome, Yavapai County, in the north-central portion.

There are about forty producing copper mines, situated in eleven out of the thirteen counties of the Territory. The largest production is from Bisbee, which has seven producing mines; the second largest from Morenci, with five producing mines, and the third largest from Jerome, with eight producing mines. The copper output is treated in eight smelting plants and there are several idle plants which were not in operation during the year.

The Territory has shown an increase both in the production of copper and in the number of properties developed during 1905. The production for 1905 was 230,000,000 pounds.[a]

The greatest activity has been in the Bisbee district, where the Copper Queen mines have maintained their supremacy, producing some 77,000,000 pounds of copper. The so-called Bonanza Circle group of mines has been successfully developed, the greatest production coming from the Calumet and Arizona, whose smelter produced approximately 34,000,000 pounds.[a]

The copper smelter at Douglas, situated on the line between Arizona and Sonora, has been increased in size and is now capable of handling about 3,000 tons a day, or 50 per cent more than heretofore. This increase in size has been for the purpose of doing custom work, and the smelter now handles ores from the Globe district, from the Imperial mine, and from various small mines situated in the Dragoon and Santa Rita mountains.

The United Verde smelter, which does very little custom work, yielded about 40,000,000 pounds of copper.

The Equator mine, which was equipped and entered the list of producers in 1905, is now (February, 1906) closed down. This mine is the property of Hon. W. A. Clark.

BISBEE DISTRICT.

The copper output of Cochise County is nearly equal to that of all the rest of the Territory, and the copper ores of the Bisbee camp contain most of the gold and silver credited to the county. The chief producers are the Copper Queen, Calumet and Arizona, and Lake Superior and Pittsburg companies. The Bisbee district, or, as it is officially known, the Warren district, is the great center of mining production, but the ores are shipped to Douglas, on the the Mexican boundary line, where they are treated, together with ores from Nacozari and from various small properties on both sides of the line. The gold and silver values of the Bisbee ores are rather low, though the total output is considerable.

The Bisbee district produced 378,047,240 pounds of copper up to the end of 1902, entirely from the Copper Queen mine. To this may be added about 2,000,000 pounds from other properties. The Copper Queen workings cover half a square mile and the ore is developed to a depth of 950 feet. The Calumet and Arizona is now 1,200 feet deep; the Lowell shaft 1,200 feet; the Cole shaft 1,200 feet; the Calumet and Pittsburg 950 feet; the Bisbee West 700 feet; the Junction shaft 1,000 feet; the Briggs shaft 1,140 feet; the Hoatson shaft 850 feet, all in limestone, and the Saginaw shaft 900 feet. The Cole shaft of the Lake Superior and Pittsburg Company is now yielding ore from the stopes above the 1,000-foot level which carries 15 to 35 per cent of copper. The Saginaw shaft encountered ore at 700 feet and sinking is still going on.

The extraordinary success in developing new ground in an old district attained by the Bonanza Circle group of mines makes a knowledge of the geology of the district and the mode of occurrence of the ore bodies of great interest. The following notes are abstracted from the report by F. L. Ransome: [b]

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[a] Douglas, James, Eng. and Min. Jour., Jan. 6, 1906.

[b] Prof. Paper U. S. Geol. Survey No. 21, 1904. See also Contributions to Economic Geology, 1902; Bull. U. S. Geol. Survey No. 213, 1903, p. 152.

The Bisbee district is in the central part of the Mule Mountains, a few miles north of the Mexican line.

The principal ore bodies lie south of and within a mile of Bisbee. They occur in Carboniferous limestone, on the southwest side of a great northeast-southwest fault, closely associated with a boss of granite-porphyry. The limestones form a synclinal basin cut across the center by the fault. The ore occurs in roughly sheet-like masses more or less parallel to the bedding of the limestone and mostly within 1,000 feet of the fault or the granite-porphyry intrusion. Under the town the ore comes to the surface and is worked down to 400 feet, but it occurs at increasing depth to the southeast, and in the Calumet and Arizona mine was first found at a depth of 800 feet, thus indicating that the depth of the ore increases toward the center of the local basin formed by the beds, though it is not confined to any one horizon.

Thus far all the ore bodies, save the extreme western ones of the Copper Queen, lie in the Carboniferous limestones. Though these flat ore bodies lie with the bedding, their occurrence is dependent on other features. Large masses of low-grade, partly oxidized pyrite ore occur along the contact between porphyry and limestone. Other large ore bodies turn down alongside porphyry dikes, and fissures in the limestone influence distribution of the ore. The disseminated pyritic ore of the main porphyry mass of Sacramento Hill has not so far proved workable.

The "cave" ores of malachite, azurite, etc., for which Bisbee was so long famous, are now exhausted. The ores now mined consist of pyrite, with variable amounts of chalcocite and chalcopyrite. There is an observed relation between permeability and good ore.

Ransome, in his report, pointed out the probable occurrence of the then unknown ore bodies south of the porphyry boss in the following words:

> It may be pointed out that less than half of the semicircular mineralized zone (Bonanza circle) about the porphyry mass of Sacramento Hill has been explored at all. * * * There still remains an extensive area of unknown but promising ground lying south of Sacramento Hill and extending eastward toward the southeastern continuation of the Dividend fault, an area here concealed by the Glance conglomerate.
>
> But, judging from surface indications, there has been considerable mineralization of the Naco limestone south of Sacramento Hill, and there is nothing improbable in the occurrence of high-grade ores in this limestone at stratigraphically higher horizons than those in which ore bodies have hitherto been found.

Recent work by the Copper Queen Company along the Czar fault, a feature not known prior to the work of Ransome for this Survey, has led to the discovery of new ore bodies.

Coconino County contains a small producing copper mine near the Grand Canyon. The geology of this mine was treated by S. F. Emmons in the Economic Bulletin for 1904.[a]

GLOBE DISTRICT.

The principal mines of the Globe district, Gila County, are the Old Dominion and United Globe properties, the Summit group, and the Buffalo Mountain. There were 11 producing properties in 1904. The mines produce about 3,400 tons a month, having an average value of about $18 a ton. The gold content is insignificant, amounting to but a few cents a ton, and the silver content but slightly more.

The mines of the Globe district have been further developed, the output for the year 1905 approximating 28,500,000 pounds, which includes some custom ore, and about 5,500,000 pounds of copper from the Copper Queen mine shipped to Globe as sulphide ore to mix with the oxidized ores. The change in smelting from the old method of treating oxidized ores direct to the modern practice of matte smelting and bessemerizing has led to an increased output and decreased costs. The concentrating mill built by the Old Dominion Company and put in operation in August, 1905, will add materially to the output, and the draining of the deeper levels will, according to Doctor Douglas, reopen rich ore bodies inaccessible for some time past.

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[a] Bull. U. S. Geol. Survey No. 260, 1905, pp. 230–231.

The production of the Globe copper camp comes mainly from one mine—the Old Dominion. According to Ransome,[a] who made a detailed study of the region, the chief production of the district is from ore bodies in limestone and shattered quartzite, with lesser amounts from stringer lodes in diabase (pyrite ores of the Old Dominion and the Grey mines) and replacements of dacite tuff (Black Copper mine).

The important ore bodies of the district are all in limestone and quartzite, and lie on the southeast side of the great displacement which separates the sediments from diabase and is known as the Old Dominion fault. The limestone is 350 to 550 feet thick and rests on the quartzite. The ore bodies in limestone are rudely lenticular in shape and roughly parallel with the level beds of the limestone. They occur at various horizons, but always alongside of or near the master fault. The largest ore body was 200 by 100 feet and 60 feet thick. The ore of these great masses is all oxidized. Other ore bodies consist of impregnations of shattered or permeable rock, quartzite, or tuff, the ore passing into sulphides in depth.

There is an evident association of the ores and faulting, and a genetic relation of ore and igneous rocks.

The Old Dominion shaft is 827 feet deep (1904). The Grey mine is on an extension of the Old Dominion fault.

In the Pinal district the Black Warrior and other mines have already increased their output and are expected to become important producers in the current year.

The Saddle Mountain Mining Company, whose property is located near Gila River, close to Dudleyville and near the San Carlos Indian Reserve, has entered the list of copper producers. Its smelter was blown in in August, 1905, and is now in successful operation, treating 250 tons a day. The property of this company includes a considerable acreage that shows large areas of oxidized ore occurring in altered limestones adjacent to igneous intrusions. The development close to the porphyry contact shows sulphide ores with masses rich in magnetite, this latter ore carrying approximately 8 per cent copper present as chalcopyrite. The company is expected to produce continuously during 1906, and as the combination of garnetiferous ore, magnetite ore, sulphide ore, and limestone affords a favorable fluxing mixture, an enlargement of the plant in the near future has been confidently predicted.

The main shaft is now 330 feet deep. The ore has an average of 3 per cent copper. The product for the year 1905 was 356.8 tons of matte, carrying 394,318 pounds of copper, 90.98 ounces of gold, and 3,527 ounces of silver, with a total value of $52,124.

CLIFTON-MORENCI DISTRICT.

The copper mines of Graham County yield relatively low-grade ores, having an average value for the year 1904 of but $7.84 per ton. The Clifton-Morenci district (Greenlee and Copper Mountain districts) is the only producer of importance. The Arizona, Detroit, Shannon, Federal, and Standard companies own the principal properties, the last named being the only one not having reduction works.

The Clifton district has not shown an increase in production, owing to serious interruption by floods. Both the companies operating in this district have had construction work under way to increase the capacity of the concentrators. The Arizona Copper Company and the Detroit Copper Company both show large ore reserves.

Morenci ranks next to Bisbee as a copper-producing center, the output for 1905 being about 60,000,000 pounds. The ores now mined average between 3 and 4 per cent copper. About 20 per cent is smelting ore, carrying 6 to 10 per cent copper, and the balance is concentrating ore. The Shannon and Arizona companies, operating at Metcalf, are mining both oxidized and concentrating sulphide ores. The bulk of the ore mined is, however, a sulphide. The workings are all comparatively shallow, the deepest shaft being but 400 feet (1903).

[a] Ransome, F. L., Geology of the Globe Copper district, Arizona; Prof. Paper U. S. Geol. Survey No. 12, 1903.

The copper deposits of Morenci and Clifton have been investigated in detail by Lindgren, from whose report [a] the following notes are extracted:

The geographical distribution of the copper deposits is practically coextensive with a great porphyry stock and its dike systems. The deposits occur either in the porphyry or close to its contacts, or along dikes of porphyry in some other rock. Areas without intrusives are practically barren. This intimate connection between porphyry and ore is as important here as it is at Cananea. The two important mining centers, Morenci and Metcalf, are situated on the main contact between a porphyry stock and Paleozoic limestones; elsewhere the porphyry adjoins granite or Cretaceous beds.

The ores consist mainly of chalcocite, malachite, azurite, chrysocolla, brochantite, cuprite, and native copper. Covellite and bornite are practically absent. Brochantite, the basic copper sulphate, is an important ore mineral present especially in oxidized veins in porphyry. It occurs intimately intergrown with malachite.

These deposits carry copper ores, gold and silver occurring only in minute quantities.

The great bodies of oxidized ores are in limestone, and occur along bedding planes and dike walls as irregular or rudely tabular masses. The ore bodies of this character which are derived by oxidation from low-grade contact-metamorphic limestones are now nearly worked out.

Both the porphyry and the contact zone about it are traversed by fissure veins, which carry pyrite with small amounts of chalcopyrite, zinc blende, and molybdenite. The principal ore mineral, however, is chalcocite, derived by secondary sulphide enrichment from the original pyritic ore.

The main output of the camp is now derived from these veins and chiefly from disseminated chalcocite occurring in the crushed and altered rock alongside of the veins, forming the so-called disseminated ore. An oxidized and almost barren zone extends usually from the surface to a depth of 100 to 200 feet. Below this occurs a zone of copper glance, which descends to a maximum depth of 500 or 600 feet below the surface. Underneath this enriched zone the original pyritic low-grade ore is found. The Humboldt is the most important vein, running northeast and southwest through Copper Mountain.

The chalcocite ores of these veins, though of low grade, are extensively worked by both the Arizona and the Detroit companies. The Coronado vein differs from the others, being a fault fissure with a 1,000-foot throw, between granite and quartzite, followed for part of the distance by a later diabase dike. There is little or no gangue mineral. The pyritic ores are contained in altered porphyry, and the upper few hundred feet of the vein contain an enriched zone with chalcocite ore.

These deposits are thus of economic importance only when secondary enrichment has taken place by the action of descending waters, and this enrichment zone is from 200 to 400 feet deep.

The Detroit Copper Company and the Arizona Copper Company are working the low-grade bodies underlying Copper Mountain, the ores carrying from 3 to 5 per cent copper and needing concentration before smelting. The mines of this character include the Humboldt, Yavapai, Arizona Central, Copper Mountain, and West Yankie. The mining costs range from $1.50 to $2 per ton. The ores are of the character mentioned above, being decomposed porphyry, with finely disseminated pyrite and glance.

Mohave County yields a small production of copper, but contains no large mines.

LESSER DISTRICTS.

Pima County has one large producer—the Imperial Copper Company, operating the Mammoth mine, formerly known as the "Old Boot." This mine is in the Silver Bell Mountains, an isolated range northwest of Tucson, having an elevation of about 3,000 feet above sea level. The ore bodies are said to be irregular lenses running northwestward in parallel shear planes. There are prominent gossan cappings, and the granite-porphyry is impreg-

[a] Prof. Paper U. S. Geol. Survey No. 43, 1905.

nated with copper sulphides along the limestone contact. The ores consist of pyrite, with chalcopyrite and occasional bornite, but there is also a copper-bearing silver-lead ore consisting of galena, zinc blende, and chalcopyrite, a combination difficult of reduction. The Mammoth mine is 500 feet deep and the Union shaft 350 feet deep. A railroad 21 miles in length has been built from Silver Bell to a connection with the Southern Pacific. Though the mine is equipped with a smelting plant, the production for the last year has been shipped mainly to the smelter at Douglas.

Yavapai County, which includes the Jerome district, with the famous United Verde mine and the various copper properties to the south of Jerome, has maintained its position as an important copper producer throughout the year. Unlike the other copper ores of the Territory, those of the Jerome district contain relatively high values in gold and silver. The average ore treated at the smelters had a value of $18.95 per ton, and the copper ores produced 3,854 ounces of gold in 1904. The ore body is supposed to be a columnar but wide mass of sulphides in a shear zone in diorite.

The Equator Mining and Smelting Company, whose smelter is situated 8 miles south of Jerome, was a regular producer for a few months only and is now shut down.

The Bradshaw Mountain Copper Company and the American Copper Company, with numerous adjacent properties, are in the Bradshaw Mountains district.

The results of the survey of the Bradshaw Mountains quadrangle are given in Folio No. 126 of the Geologic Atlas of the United States. The following extract from this folio relates to the copper deposits of this much-advertised region:

> No copper deposits of proved extent and value are yet known in this district, but several promising prospects were seen. Two types of copper deposit were recognized. One consists of distinct veins carrying chalcocite, chalcopyrite, tetrahedrite, and in some instances bournonite, with a gangue of quartz, fluorite, and barite.
>
> The sulphide minerals are largely altered at the surface to chrysocolla and malachite. These veins carry silver values, as well as copper.
>
> The second type consists of impregnation zones in schist, chalcopyrite, pyrite, and bornite, with more or less quartz, replaced chlorite schist or amphibolite, forming bodies of irregular and indefinite outline. Small stringer veins carrying the same minerals are also present in places, but the formation as a whole appears to be a direct replacement.
>
> The surface zones of such deposits are silicious schists, pitted and copper stained with films of native copper and sometimes of cuprite. Small gold values are also found in these deposits.

The Valverde smelter, which operates on ores from this district, was rebuilt in 1905.

The Big Bug district, also in the Bradshaw Mountains region, has a small but increasing production, and the ores contain considerable gold and silver. The 1904 production was 86.934 pounds.

Copper deposits [a] similar to those of the Kaibab Plateau [b] occur in the White Mesa, in the Navajo Indian Reservation, 125 miles north of Flagstaff and 50 miles east of the Kaibab Plateau. The Triassic red sandstone is here less than 200 feet thick and is overlain by 200 to 250 feet of white sandstone, forming the White Mesa. The white sandstone is cross-bedded. The color is white or gray, rarely red. The rock is composed of well-worn grains of quartz sand from which most of the cementing material has been leached out, leaving it soft and friable. The copper deposits consist of a replacement of the cement of one particular cross-bedded stratum of the sandstone by chrysocolla, with some tenorite in grains or masses. Specimens contain as much as 32 per cent of copper. Generally the copper deposits are a few hundred cubic feet in size, and no strict line of demarcation is shown between them and the surrounding sandstone, the bluish-green color of the chrysocolla gradually fading into the white of the sandstone. The ore is apparently associated with small vertical crevices or fissures. Some of the deposits show a distinct vein structure, while others do not. The source of the ore is not very clear.

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[a] Described by H. F. Lunt, Trans. Am. Inst. Min. Eng., 1903.
[b] Described by E. P. Jennings, Trans. Am. Inst. Min. Eng., 1903.

CALIFORNIA.

Nine out of the 57 counties of California contain producing copper mines. Their production for 1904 is shown in the following table:

Production of copper in California in 1904, by counties.

County.	Quantity.	Value.	Gold in copper ores.	Silver in copper ores.
	Pounds.			
Amador	14,000	$1,400	.....	.....
Calaveras	2,611,660	277,165	$74,702	$64,376
Inyo	8,408	850	50	100
Madera	10,300	1,300	.....	.....
Mariposa	9,500	1,140	40	20
Placer	600,000	72,000	16,000	9,120
San Bernardino	154,477	15,020	50,503	13,028
Shasta	26,438,145	3,402,517	369,813	394,590
Stanislaus	7,300	930	.....	.....
Unapportioned	107,800	13,700	.....	.....
	29,961,590	3,786,022	.....	.....

Two new smelters in Shasta County added to the output for 1905, while the Mountain Copper Company has built new reduction works at Martinez, on San Francisco Bay, at a cost of about $1,000,000. Calaveras County has seen the reopening of one of the most productive of the older copper mines of the State, and extensive reduction works begun in 1904 are now said to be nearly completed. Placer County gave a considerable return from the new property opened in 1904, and various other properties scattered throughout the copper belt, lying on the western flanks of the Sierra Nevada, are being equipped and developed, so that the outlook for an increased copper production is bright.

Nearly every county contains copper deposits, but the known deposits of economic importance are confined to four groups: (1) Shasta County, (2) the western flanks of the Sierra Nevada, (3) the Coast Range, and (4) the deserts of southeastern California. Up to the present time almost the entire production comes from Shasta County, in the north-central part of the State. The Foothill copper belt of the western flanks of the Sierra is nearly 400 miles long, and contains many old and formerly productive mines. One of these, at Copperopolis, has lately been reopened. The Coast Range deposits extend southward for 150 miles from the Oregon line, a number of old and formerly productive mines existing in Del Norte County.

The western or Iron Mountain belt of Shasta County lies 3 to 6 miles west of Sacramento River, between Redding and Kennett. The eastern or Bully Hill belt lies east of Sacramento River, north of Pit River, and west of Squaw Creek, near Copper City and Delamar. According to Aubury [a] the ore bodies of the western belt occur on or near the contact between granite-porphyry and metamorphic slates or schists. Those of the eastern belt lie partly in schists (Devonian metamorphic rocks), partly in porphyry, but mainly on the contact between the two.

The region has been geologically mapped by J. S. Diller, whose preliminary report on the geology of the copper deposits appeared in 1903.[b] He states that the ore deposits occur in two areas of ancient volcanic lavas, probably of Carboniferous age, mostly a metarhyolite rich in soda. The sedimentary rocks include Triassic shales and limestones in the Bully

[a] Bull. California State Mining Bureau No. 23.
[b] Contributions to Economic Geology, 1902; Bull. U. S. Geol. Survey No. 213, 1903, p. 123. See also Bull. U. S. Geol. Survey No. 225, 1904, p. 172.

Hill district and Devonian shales and limestones in the Iron Mountain belt. The dike rocks cutting the lavas are connected with granitic intrusions and may be genetically related to the ore deposits. The ore bodies occur in shear zones, the rock sheeting and crushing being due to mountain uplift which formed the Sierra Nevada and Klamath Mountains at the close of Jurassic time. The shear zones are of limited extent, less than a mile long and from a few inches to 20 feet wide, with vertical or steep westerly dip and a north-south course.

In the Bully Hill district there are three zones, two of them parallel, a few hundred feet apart, with valuable ore bodies. The westernmost is in the Bully Hill metarhyolite; the other is a metabasalt dike near the surface, following the dike contact to a known depth of 500 feet.

The Bully Hill ore is base, carrying zinc, antimony, etc. It is said to average 8 per cent and to carry $2 to $3 in gold and silver. The ore bodies are stoutly lenticular, varying from mere nodules to masses hundreds of feet long and wide. They occur regularly distributed in the crushed and mostly impregnated rock of a shear zone 4 to 100 feet wide, averaging about 30 feet. All gradations may be seen, from unmineralized crushed rock through partial replacements and impregnations to complete replacement. The ore bodies pitch to the north. They are usually, though not always, marked by outcrops of porous limonite or gossan ore, but sometimes by merely stained rock. The gossan retains its gold values.

The Bully Hill ores consist of chalcopyrite with bornite and chalcocite, a gangue of barite, so finely disseminated as to be invisible. Copper glance is common in the dark ore. There are three lodes—the Delamar, Anchor, and Copper City. The first named is developed by a tunnel 800 feet beneath the outcrop, and the "vein" is developed for 100 feet in length. The Anchor lode is 200 feet west of the Delamar, runs N. 10° E., is vertical, and lies in silicified rhyolite, locally called quartzite. Nothing is known of the Copper City lode.

The Iron Mountain district contains the mine of the same name, together with the Shasta King and Mammoth.

The copper production of California comes mainly from the workings of the Iron Mountain mine near Keswick, owned by the Mountain Copper Company. The sulphide ores of this mine, which contain much excess iron, have long been useful as affording a means of treatment for the dry gold and silver ores of the surrounding country. The damage caused by smelter fumes, however, led to numerous damage suits, and the reduction of the ore will be hereafter accomplished mainly at the new plant, where sulphuric acid will be manufactured and fertilizer made as a by-product.

The Mountain Copper Company's ores occur as great lenses lying in schists formed by the alteration of igneous rocks. A pronounced fault separates the eastern ore body from the western. The ores consist of pyrrhotite, with pyrite and chalcopyrite and considerable zinc. The production is approximately 1,300,000 pounds of copper a year, the ore averaging about 4 per cent.

The main ore body is said to be from 100 to 400 feet wide, 800 feet long, and 500 feet deep, and was covered with gossan cappings 100 to 300 feet thick. The ore averages about 5 per cent copper, with 2 ounces silver, or slightly less than $1 per ton.

The company also owns the Hornet mine, which is in a large body of pyritic ore, carrying 2 to 2½ per cent copper, but with 47 to 57 per cent sulphur. The Bessemer copper is shipped to the New Jersey Metal Refining Works at Elizabeth, N. J., owned by the company, where the metal is refined and the gold and silver extracted. The output for 1905 was somewhat less than for previous years, owing to the construction of the new reduction plant. The ore bodies occur in northeast-southwest shear zones.

The ore has declined from an average of 7.45 per cent copper in 1897 to 5 per cent in 1901, with 2 ounces silver and less than $1 gold per ton of ore. The ore is low in silica and free from arsenic, bismuth, etc. The more northern ore bodies of this copper belt are of lower grade than those of Iron Mountain.

The Mammoth lode trends N. 80° E. and is traceable for 300 feet in length and 200 feet in depth. The dip is 30° NW. The ore is chiefly pyrite, with disseminated chalcopyrite and zinc blende, and a little quartz. It is said to be owned by the General Electric Company.

The Shasta King (Trinity Copper Company) ore body is basin shaped, with a north-south course, and is delimited by fissures. The ore carries barite locally.

The Balaklala is said to belong now to the White Knob Copper Company. The deposit is marked by heavy gossan, and is the probable extension of the Shasta King. The ore is a low-grade mixture of pyrite, chalcopyrite, and a scanty quartz gangue. The main ore body is up to 20 feet thick, trends N. 70° E., dips northwest, and pitches northeast. The ore body is followed for 1,000 feet on the course and 500 feet on the dip.

The Spread Eagle, King Copper, and Lorraine properties are still prospects.

The Foothill copper belt is in part mapped and described in folio No. 11 of the Geologic Atlas of the United States. The chief interest in this region is in the two copper belts near Copperopolis, Calaveras County, where the Ione, Caledonia, Union, and Napoleon mines are found. The ore consists of chalcopyrite and quartz. The Napoleon-Camp Seco lode lies 3 miles west of the Copperopolis lode. At the Union mine the lode is a vein of black pyritous slate in a belt of amphibole schist, identical in age and character with the Mother Lode vein, 12 miles to the east. The Ione and Caledonia, with the Copperopolis mine, occur in a similar belt in the schist area just east of the western belt of Mariposa slates.

The Copperopolis vein is 3 to 40 feet wide. The Union or Keystone mine has an average width of 15 feet and carries a chain of lenticular masses of chalcopyrite, connected by ore stringers. Three ore bodies have been worked, the largest, at the Union mine, being 2 to 40 feet wide, 300 feet long, and 600 feet deep, and pitching to the north. [a]

The ore carries no gold or silver, and is exceptionally pure, varying from 3 to 5½ per cent, with some 11 per cent smelting ore. The property is 14 miles from a railway and 40 miles from tide water.

The second, or Camp Seco belt, contains the mines of the Penn Chemical Company, on Mokelumne River, 20 miles northwest of Copperopolis. The vein contains chalcopyrite and pyrite, with a trace of zinc and low values in gold and silver, in a gangue of talcose schist, clay, and quartz. A quartz-porphyry dike accompanies part of the vein. The deepest development is by a 550-foot shaft at the Union. A 100-ton pyritic smelter is intermittently in operation.

The Napoleon, the oldest copper mine of the State, is 9 miles southwest of Copperopolis. The vein channel is 100 feet wide, and consists of diabase and metadiabase down to talcose schist. The dip is 62° and the vein is developed to 250 feet in depth.

At Copperopolis the smelter was blown in during December, but closed for three weeks during January. The ore supplied is derived from the Copper King mine, but as the smelter is 15 miles from the railroad and the fuel is oil, hauled by traction engine, it was obliged to shut down on account of the bad roads.

COLORADO.

Colorado has few producing copper mines. The copper output is obtained mainly as a by-product of the precious-metal ores treated in custom smelters. The production comes from eleven different counties, one-third of it being, however, from Lake County. San Juan County is the next largest producer. At Pearl, an extension of the Encampment, Wyo., district, a small matte smelter erected in 1904 is idle and the property unproductive.

The production by counties for 1904–5 is given in the following table:

[a] See Copper Resources of California; also Mother Lode district: Geologic Atlas U. S., folio 63, U. S. Geol. Survey, 1900.

Production of copper in Colorado, 1904–5, by counties.

County.	1904.	1905.	County.	1904.	1905.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
Boulder	5,340	14,106	Larimer	3,780	4,336
Chaffee	456,556	869,507	Ouray	431,048	524,199
Clear Creek	369,778	355,740	Park		38,374
Custer	10,910	862	Pitkin	2,908	127,094
Dolores	12,201	71,122	Saguache	48,066	2,988
Eagle	27,042	65,179	San Juan	3,575,219	2,274,106
Gilpin	604,791	638,597	San Miguel	245,709	272,513
Gunnison	1,864	36,997	Summit		44,033
Hinsdale	10,530	24,532		9,435,962	9,850,827
Lake	3,627,846	4,486,117			
La Plata	2,374	425			

The smelter returns for 1905 indicate that the production of copper from Colorado amounted to 10,736,151 pounds for that year. This is after the product of other States has been excluded from the smelter returns. The greatest return is from the American Smelting and Refining Company, which had an output of 8,920,064 pounds, of a value of $1,382,750.

GEORGIA.

The copper product of Georgia is at present insignificant, amounting to 8,841 pounds in 1905, in the gold and silver bearing matte from the Seminole or Magruder mine in Wilkes County. This deposit was described by the writer in Bulletin No. 225, pages 180–183.[a]

The Ducktown (Tenn.) copper belt extends southward into Fannin County, Ga., where the Sallie Jane, Lot No. 20, and Mobile mines were worked many years ago. The second named has recently been reopened. The mine is about 4 miles south of Isabella Ferry, between Pierceville and Frytown, Ga. It is owned by J. T. Howe and is worked under the superintendence of John Quantrell. The development consists of a shaft 100 feet deep, with a drift driven 200 feet to the east and 900 feet to the west. At the end of the east drift there is a winze 100 feet deep, with a second drift 100 feet long at the bottom. These workings show the vein to average 20 feet in width. The ore is said to carry from 3 to 30 per cent of copper. In the upper levels green carbonates are found, with the usual black ore near the water level and the gray and so-called yellow ore below. The presence of feldspar in the ore is notable. No ore has as yet been smelted or shipped. The information concerning this property has been furnished by Mr. L. La Forge.

IDAHO.

The copper production of Idaho for the past three years is as follows: 1903, 569,480 pounds; 1904, 4,518,034 pounds; 1905 (official), 6,661,400 pounds. This production comes from six counties—Bannock, Boise, Custer, Lemhi, Shoshone, and Washington. The Snowshoe mine in Shoshone County is the chief producer, the balance coming mainly from gold-silver properties. Fremont County yielded copper ore in 1903, but not in 1904. The Washington and Custer county (Loon Creek and Alden Creek) districts yielded gold-bearing copper ores. The Cœur d'Alene ore goes to Butte and Tacoma smelters; that of the other counties is reduced in furnaces in other counties.

In the Fort Hall mining district, Bannock County, the Pocatello Gold and Copper Mining Company is working a "well-defined fissure vein carrying disseminated bornite." In 1904 ore was shipped to the copper smelters of Mackay and Salt Lake. The Fort Hall

[a] Contributions to Economic Geology, 1904.

Mining and Milling Company has driven a crosscut tunnel 2,500 feet long to cut an auriferous copper vein.

Boise County produced but 500 pounds of copper in 1904, as a by-product of gold ores shipped to custom smelters.

Custer County was formerly the largest copper producer of the State, the production for 1904 being 2,734,489 pounds, valued at $341,811. This came from the mines of the White Knob Copper Company, of the Alden Creek district, now shut down, and from the Loon Creek district. The production for 1905 was 684,134 pounds.

The White Knob ore deposit [a] occurs on a contact between granite and limestone. The ore zone is 400 feet wide and 1,200 feet long, and contains chalcopyrite, pyrite, and a little galena, together with magnetite and hematite in an altered limestone composed of garnet and calcite. The oxidized zone is 600 feet deep. The White Knob smelter was shut down in 1905. Recent development has shown the existence of payable bodies of sulphide ore beneath the ore oxidized zone and the mine is again actively worked.

An important development of copper ore has been made at Loon Creek, where the Lost Packer Mining Company owns a fissure vein in granite and rhyolite. The vein is 10 to 15 feet wide and carries a pay streak about 2 feet wide that is clean and well defined. The ore consists of massive chalcopyrite, with 20 per cent of copper and about 2 ounces of gold. Outside of the pay streak the vein is of low grade, running, it is said, about 3 per cent of copper and $5 to $7 gold. A blast furnace capable of handling 100 tons daily has recently been installed.

The Paymaster copper mine, in the Skull Canyon district, Fremont County, works a deposit on a contact between limestone and quartzite.

Lemhi County produced about 5,000 pounds of copper in 1904, occurring in gold and silver ores.

Shoshone County produced 5,805,000 pounds of copper, of a value of $893,389, in 1905.

The only productive copper property of the Cœur d'Alene district is the Snowstorm mine, east of Mullan. The deposit occurs in Algonkian (Revett) quartzite, and is, according to Ransome, an impregnated cupriferous zone conforming to the bedding planes, the strike being N. 60° W. and the dip 65° SW. The ore body varies from 10 to 35 feet in width, and is reported to be 430 feet long. The ore carries chalcopyrite, bornite, and chalcocite in disseminated particles in the quartzite. The quartzite is not particularly fissured and does not appear to differ from the rock of the foot and hanging walls. The greater part of the mineralized quartzite contains about 4 per cent of copper, with 6 ounces of silver, and 0.1 ounce of gold per ton. The ore shipped is worth $9 to $10 per ton, the Butte and Tacoma smelters giving a freight and treatment rate of $5 when SiO_2=90 per cent. A leaching plant is reported to have been erected on the property in 1905.

Washington County produced 898,209 pounds of copper in 1904, valued at $112,276. This output came from the Seven Devils district, the Landore smelter of the Ladd Metal Company and the smelter at Sumpter, Oreg., treating the ore. The chief producing mines are those of the Blue Jacket Consolidated Copper Company and the Montana-Nebraska Copper Company, but small amounts were also produced by the Peacock, White Monument, Helena, Queen, Alaska, and Crescent. According to Lindgren, the ores occur as follows:

In the Seven Devils district and in the adjacent Snake River canyon copper deposits are very abundant. There is, in that vicinity, an extensive series of Triassic basic lavas, with intercalated layers of slate and limestone. There are also diorites, intrusive in these beds. All of these igneous rocks apparently contain copper which was easily concentrated into deposits of various kinds—some fissure veins, others zones of impregnation, others contact deposits.

In the locality of the original discovery in the Seven Devils the copper occurs in typical contact deposits. Small masses of limestone are embedded in a later, intrusive diorite; at the contact and usually in the limestone are found irregular bodies and bunches of bornite, chalcocite, and a little chalcopyrite, containing about 10 ounces of silver and a little gold per ton. The limestone at the contact is very crystalline and contains, associated with the ores, abundant garnet, epidote, quartz, calcite, and specularite. The copper sulphides, as shown by their intergrowth, were certainly formed at the same

[a] Lindgren, W., Character and genesis of certain contact deposits: Trans. Am. Inst. Min. Eng., 1901.

time as the gangue minerals. The epidote, specularite, and garnet, as described by Palache,[a] present clear evidence of simultaneous crystallization. At the Peacock mine a large body of medium-grade ore of this character was embedded in diorite. No limestone showed here, but I am informed that a lower tunnel has lately encountered limestone below the croppings.

Other claims in which the ore occurs on the contact of limestone and diorite are the White Monument, Alaska, Blue Jacket, Helena, and Decorah. Considerable masses of ore have been exposed at some contacts, though the distribution is extremely irregular. In the Blue Jacket a rich body of bornite and chalcocite was lately found, and it is reported that 500 tons of 40 per cent ore has been shipped from this mine during the past summer. During 1900 the Boston and Seven Devils Copper Company shipped from the Peacock and other claims 260 tons containing 23 per cent of copper besides 8 ounces of silver and 0.04 ounce of gold per ton.

Still another copper deposit in Idaho which appears to belong to this type is the White Knob mine, near Houston, in Lost River Valley. Mr. W. Darlington, the general manager of the company, has kindly furnished the following information: The ore occurs as a deposit between granite and limestone; the trend of the contact is north and south, the limestone lying to the east and the granite to the west. On the surface the ore-bearing zone is 1,200 feet in length and (as a maximum) 400 feet in width. The minerals are hematite, magnetite, chalcopyrite, pyrite, and a little galena, in a gangue of garnet and coarsely crystalline calcite. A porphyry dike also occurs on the contact, complicating the geological relations. The oxidized zone is very deep, water not having been encountered until the depth of 600 feet was reached in the shaft.

MICHIGAN.

The Lake Superior copper district has shown a larger production for 1905 than at any time in its previous history. There were nineteen regular producers, and the output for the year is estimated at 220,950,000 pounds, valued at about $35,000,000, an increase of nearly 12,600,000 pounds over that of the preceding year. As usual, the largest output and largest gain is made by the Calumet and Hecla Company, which furnished nearly 27 per cent of the total production for the year, the chief production coming from the "Calumet conglomerate," as in former years. The "Kearsarge amygdaloid belt" has also furnished part of the Calumet production. The only new producer is the Allouez, the ore from this mine being treated in the Centennial stamp mill. The Copper Range properties were extensively developed, insuring an increased output for the current year. Among the older properties there has been a marked revival of interest and many of the mines are now being reopened, owing to the high price of copper. Among the producers which may be expected to add to the output of the district in the near future may be mentioned the Keweenaw Copper Company, which is under the control of the Amalgamated Copper interests. The Resolute, owned by the same interests; the Delaware, recently purchased by the Calumet and Hecla; and the Cliff, owned by the Tamarack Company, have also been extensively developed during the year. The Erie-Ontario Development Company and the King Philip Mining Company are among the newer ventures. The Phoenix is the only mine abandoned, as the St. Clair vein proved too narrow to permit profitable working.

Eight mines paid dividends, the total being $9,014,600, of which $5,000,000 was paid out by the Calumet and Hecla.

The Lake Superior district is unique among the copper regions of the world. Somewhat similar deposits occur in other places, but they are small and as yet unworked. The copper occurs in a native state, and the extent of the ore-bearing beds, the nearly uniform dip of the beds, and the fact that the copper is present for long distances along a bed render mining a stable industry in this district. These conditions and well-established systems of transportation for ore and supplies permit such cheap mining that ores containing less than 1 per cent of copper are worked at a profit. The dividends paid by the different mines operating this district aggregate about $160,000,000, and are greater than those of any other mining district in the world. The annual production is about 15 per cent of the copper output of the world. The mining companies in operation are increasing their output year by year and new mines are being developed, and yet it may be confidently asserted that there is no present sign of exhaustion of the region.

[a] Am. Jour. Sci., 3d ser., vol. 8, October, 1899.

GEOLOGY.

The Keweenaw Peninsula, the site of the copper mine of Lake Superior, is 40 miles across from east to west and projects about 70 miles northeastward into the lake. The central portion of this peninsula is formed of a succession of lava beds interbedded with layers of sandstone and conglomerate. The lavas are of two kinds, the prevailing variety being a dark basaltic rock, having the texture of diabase and most conveniently designated as trap. The light-colored lavas are quartz-porphyries or rocks corresponding to andesite in composition. The conglomerates are composed of rounded fragments of igneous rock, the light-colored reddish-chocolate and yellowish quartz-porphyries predominating. The entire series has a thickness of from 25,000 to 30,000 feet and is flanked on both sides by conglomerate and sandstone. To the west these sediments appear to be conformable, dipping with the lava beds. To the east there is a fault and the sandstones are nearly horizontal.

Copper occurs native in these rocks. It was first found in fissures cutting across the rocks and later in veins which cut the bedded series at an acute angle to the dip. At the present time, however, the great production of the region comes from the amygdaloidal lava beds and the so-called "ash beds" of nearly similar character and from the copper-bearing conglomerate, the latter rock furnishing one-half of the total production.

The so-called "Copper Range" is a belt from 4 to 6 miles wide, lying on the eastern side of the series of bedded trap rocks. The different members of this series vary from a few feet to 100 feet in thickness. the individual lava flows or layers being distinguished by the amygdaloidal or vesicular nature of the upper portion and in many cases being separated by beds of conglomerate. The igneous rocks have been altered to dark-green rocks in which the original hornblende and augite have become chlorite and epidote and the holes or vesicles have been filled by quartz, calcite, and other minerals, including native copper Both the amygdaloids and the conglomerates are heavily impregnated with epidote. The copper occurs in crystalline form and as casts or fillings having the shape of the amygdule which it fills. The conglomerates often inclose seams of fine-grained sandstone, but in such cases the copper impregnation is confined to the conglomerate. The conglomerates consist largely of chocolate-colored and reddish porphyry, with a few fragments of diabase and amygdaloid. These beds outcrop as ledges having a general northeasterly course, but owing to glacial erosion and the covering of the country by drift long outcrops are seldom seen and exploration work consists largely in stripping off the superficial cover to find the underlying trap beds.

The chief ore production of the district comes from the "Calumet conglomerate." This bed is from 12 to 25 feet thick, and has a northwest dip of 36° to 39°. The ore is not continuous throughout the entire extent of the bed, but is confined to ore shoots of great length; thus the Calumet and Hecla property is productive for 2 miles in length, and in this distance there are but few lean spots.

The diabase beds have the characteristics of extrusive lava sheets whose upper surface is often scoriaceous, giving rise to the term "ash bed." In the uplifting of this great series of trap rocks there has been dislocation, and cross veins have been formed.

The distribution of the copper in the different ore-bearing beds is dependent on the structure of the rock. In the Quincy mine the hanging-wall rock is richest, this portion being the most permeable. In the Atlantic ore bed the copper is somewhat uniformly disseminated throughout the amygdaloid. In the Baltic mine the copper is irregularly distributed and the ore channel appears to be a sheared zone, the fracturing extending beyond the limits of the amygdaloid layer and into the incasing trap. Slip planes and flat cross joints indicate movements, a cross vein at No. 4 mine extending for 200 feet across the beds, and carrying copper with quartz and calcite. Cross veins, though frequent, do not extend beyond the limits of the ore bed and conform in strike to that of the main ore bed. The occurrence of copper in these cross veins and of sheet copper along cross joints in the foot wall indicates migration of material after the original ore deposition was

completed. Lump copper is common and can often be recognized by the light-colored patches of decomposed rock surrounding it.

Joints and long slip planes are of frequent occurrence and may mark a change in the copper content, the rock on one side being richer or poorer. As a rule the cross courses consist of bands from a few inches to 2 feet wide of crushed rock seamed with white calcite. They dislocate the copper lode but slightly and seldom contain copper. In general, the mineralization of the amygdaloidal lodes is diffused and irregular and the richer rock lies against the hanging wall.

The conglomerate lodes have been the richest in the history of the region. The bed known as the "Allouez," or as the "Albany and Boston conglomerate," is from 8 to 25 feet thick. It is underlain by 3 or 4 feet of sandstone, resting in turn upon trap rock, and it is overlain by a foot of clay gouge with 4 to 5 feet of shattered trap rock above it, and then the normal hard trap rock forming the hanging-wall bed. Like the amygdaloid, the conglomerate is also traversed by well-marked joints and slips. The pebbles range in size from a pigeon's egg to bowlders as large as a man's head. The rock composed of smaller pebbles is more favorable for copper, and the best ore occurs where the cementing material is less firm, the copper favoring the permeable rock. In the Franklin mine the foot-wall sandstone thins out in depth, and the copper extends from the conglomerate into the underlying amygdaloid. The dip is about 18°. The ore-bearing beds sometimes lie close together; for example, the "Osceola conglomerate" lies 800 feet east of the "Calumet conglomerate."

A knowledge of the geology of the region is essential to successful prospecting. The trap beds are so nearly alike that identification is ordinarily impossible, but occasionally some mineralogical characteristic will serve as a guide, as, for example, the foot wall of the "Kearsarge amygdaloid" is a bed marked by large feldspars. Usually the amygdaloid layers weather more readily than the compact trap incasing them, and hence show infrequent exposures and are covered with drift and soil. The conglomerate beds resist erosion and form occasional outcrops.

DEVELOPMENT.

The following lodes are worked: The Calumet conglomerate is developed by the Calumet and Hecla Company. The Kearsarge amygdaloid, which lies 2,130 feet east of the Calumet and Hecla conglomerate, is worked by the Calumet and Hecla, the Allouez (on the underlay), the Akmeek, and the Tecumseh companies. The Franklin and Rhode Island companies are both trying to locate ore in this lode. The Osceola amygdaloid, which lies 2,200 feet east of the Calumet conglomerate, is worked by the Calumet and Hecla Company and the Tamarack Company. The Baltic lode is worked by the Superior, the Baltic, and the Tri-Mountain companies, and has been prospected by the Rhode Island Company, but proved too lean in their ground to yield a profit. The ore in this lode is spotty, good ore alternating with lean. The Pewabic and Allouez lodes have proved too lean to work in the Rhode Island Company ground. The Knowlton and Butler lodes are worked by the Mass Copper Company. The Montreal River lode is worked by the Keweenaw Company, and the Calumet and Hecla Company is reopening the old Manitou property near Lac la Belle.

MONTANA.

The copper production of Montana continues to dominate the entire industry, amounting to the enormous total of 335,000,000 pounds in 1905. Although for many years past this State has furnished about 40 per cent of the copper production of the United States, it will not quite reach this figure for 1905, as the increase in Arizona has been extraordinarily rapid. The production of the State is almost entirely from the Butte mines, but a small amount is reported from Beaverhead County, mainly from the Indian Queen mine, and from Meagher, Jefferson, and Madison counties, these four counties yielding gold-copper ores. The copper ores of Montana furnish 18 per cent of the gold production of the State and 80

per cent of the silver production. The gold-copper ores of Beaverhead, Meagher, and Jefferson counties furnish a total of 17,300 ounces of silver out of a total of 10,250,000 ounces.

The statistics of the 1905 production of copper for the individual counties are not yet available; those for 1904 are as follows:

Production of copper in Montana, 1904, by counties.[a]

	Copper.		Gold in copper ores.	Silver in copper ores.
	Mint report.	U. S. G. S. report.		
	Pounds.	*Pounds.*	*Ounces.*	*Ounces.*
Beaverhead County	68,815	543,126	31.15	12,577
Meagher County	.....	75,000	50.00	2,000
Jefferson County	161,100	11,100	4.00	2,750
Lewis and Clarke County	17,067	7,067	.....	.....
Madison County	15,815	11,300	465.25	.....
Powell County	30,000	1,000	.....	.....
Silverbow County	283,070,422	290,032,979	43,889.90	10,218,792
Miscellaneous	587,111	.....	.....	.....
Total	283,945,330	290,681,572	44,440.30	10,236,119

[a] The figures in the last three columns are from the chapter on Gold and Silver Production of the United States in Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905. They differ materially from those of the Director of the Mint in his report on Precious Metals of the United States for 1904, p. 139, as shown in first column.

It will be seen that Silverbow County, according to these figures, yielded 99½ per cent of the copper product of the State.

GEOLOGY.

The geology of the Butte copper district has been somewhat fully presented by the writer in a previous bulletin (No. 213), and in Folio No. 39 of the Geologic Atlas of the United States. The main facts are as follows:

The Butte district is in southwestern Montana, in the central part of the Rocky Mountain region, within 2 miles of the continental watershed. The rocks of the region are all igneous, the prevailing form being a dark basic granite, or quartz-monzonite,[a] which is part of a great mass of granite forming the core of the mountainous area extending from Butte to Helena. This rock is cut by irregular and dike-like bodies of a lighter colored granite rock—an aplite called the "Bluebird" granite, largely used for building stone at Butte. This rock covers relatively small areas on the surface, but is more abundant in deep workings. Both the granites mentioned are cut by the "Modoc" porphyry, a light-colored quartz-porphyry, carrying large and well-formed crystals of quartz. The latest rocks are rhyolitic in nature and later than the veins in age.

The veins occur in the basic or Butte granite, but cut through the other rocks. They can be grouped into silver veins and copper veins, and the two classes occupy distinct areas, with but little overlapping. The copper area is about one-half mile by 1½ miles in extent.

The veins belong to four distinct systems. The largest veins, embracing the Anaconda and its dislocated segment the Parrot, the Syndicate ledge, and, in fact, all the greatest producers of the district, run east and west, and dip steeply to the south. These veins are faulted and displaced by a northwest-southeast series, including the Clear Grit, Blue, Skyrme, Gray Rock, and other important veins. A still later set has a direction east of northeast, and faults and displaces both the earlier vein systems; the veins of this set are in places heavily mineralized, as in the Stewart mine. The latest fracturing is by northeast-southwest faults which contain drag ore, but little if any newly formed ore.

[a] Granite Rocks of Butte, Montana, and vicinity: Jour. Geol., vol. 7, 1899, pp. 737–750.

The older veins are distinctively replacement veins, and consist of quartz and pyrite with secondary glance ores. They are surrounded by areas of granite altered by solfataric action.

The output consists of glance-pyrite-quartz ores, often of high grade, and of the altered granite impregnated with glance and pyrite. The bulk of the material mined is concentrating ore, carrying 3 to 4 per cent of copper, 55 per cent of silica, and 16 per cent of iron. Many of the lesser veins in the eastern part of the district consist of nearly solid enargite and pyrite. The Parrot and Original ores carry much bornite. The ores contain silver, the quantity varying from 1 ounce to 1 per cent of copper in the Trenton to one-fourth ounce to 1 per cent in the eastern part of the district. The ores average about 0.0375 ounce silver and $2.25 per ton of gold. The veins carry high-grade ores to exceptional depths. The Anaconda carries rich glance ore at 2,200 feet; the Original has enargite-bornite-glance ore at 2,000 feet; the Diamond, Mountain Con, and High Ore at 2,000 feet.[a]

DEVELOPMENT.

During the year 1905 the copper output for Montana reached the enormous total of 335,000,000 pounds. With the exception of a small production from scattered properties, this great output comes from the copper mines of the Butte district. During the year several important discoveries and developments have been made. The Pittsburg and Montana Copper Company, operating in the flat between the city of Butte and the East Ridge, has opened up four veins on the 1,200-foot level, and is now producing 5,000 tons of ore a month, and the furnaces are producing copper from the company's own ores. This company has, it is understood, abandoned the attempt to use the Garretson process, and is smelting its siliceous Butte ores with pyrrhotite from the Spring Hill mines situated south of Helena. In converting the matte raw siliceous ore is charged directly into a molten matte (Baggally process), a basic lining to the converter being used. This is a marked change from ordinary practice, in which siliceous linings are used.

The discovery of these veins in what has hitherto proved a barren portion of the district has greatly stimulated activity in the vicinity of the mines. Several new companies have been formed to take over properties in this part of the district, and active exploitation is promised in 1906.

The North Butte Copper Company was formed during 1905, and acquired the Speculator, Edith May, Jessie, and other properties. A crosscut driven north developed ore bodies of phenomenal size and richness in the Edith May and Jessie veins. These ore bodies mark the farthest known limit of the rich copper ores of the district, and, as noted later, occur under conditions which have awakened widespread interest in the possible extension of the copper-bearing zone to the north. In the western portion of the copper-producing section the Lexington mine, now controlled by the United Copper Company, has yielded considerable high-grade copper ore, but this has been of a different character from the ore of the copper belt, consisting mainly of chalcopyrite, an unusual mineral in the copper mines proper.

The Raven mine, which lies north of the Buffalo and is in the extreme northwestern part of the copper belt, has also yielded considerable amounts of copper ore, and the Snoozer claim of this company is being extensively prospected and developed from the crosscut on the 1,500-foot level driven from the Buffalo shaft.

In the great mines of the camp the workings have been deepened, with marked success. The most notable instance is in the Anaconda mine, where the shaft has been deepened to 2,400 feet and the crosscut from the 2,200-foot level encountered rich ore on the middle ledge. This "strike" has been widely heralded in the newspapers. On the 2,400-foot level the crosscut had not reached the vein at the beginning of 1906.

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[a] See description in Nature of Ore Deposits, a treatise on the Ore Deposits of the World, by Beck and Weed, p. 223.

In the other properties belonging to the Anaconda Copper Company production continues at an increasing rate, and development work thus far shows little change in conditions during the past year.

In the Boston and Montana properties the deeper levels have shown an ore body maintaining the full width encountered above, and tetrahedrite has been found in some of the ores, with an accompanying rise in gold values.

In the mines owned by Hon. W. A. Clark development work has been extremely fruitful, and the ore bodies have proved even larger and richer than they were in the upper levels. The Stewart shaft has been dismantled and abandoned, and the workings of this mine are entirely from the new shaft formerly known as the West Stewart, but now commonly called the Stewart. This shaft is 1,800 feet deep, and the ore body on the lower level is said to show 20 feet of ore, carrying 12 per cent or more of copper, developed for a distance of 400 feet in length.

In the Original mine the shaft is 1,800 feet deep, and on the 1,800-foot level an ore body 25 feet wide, said to average 18 per cent of copper, has been drifted on for 150 feet and its limit not yet reached.

For many years past this great copper camp has been stirred by litigation and the conflict incident to attempts to control the politics of the county. But few companies were formed and their success was doubtful. Within the last six months, however, many new companies have sprung into existence and the end is not yet in sight. This is probably largely the result of the boom in the price of copper and copper stocks, but it is also due in a great degree to the phenomenal success of the North Butte Company in developing the largest and richest ore bodies found in recent years. Among the older of the companies formed in the last few years is the Pittsburg and Montana Company, which has at last reached the production stage, its output now being about 300,000 pounds of copper per month from the company's own ores. But one blast furnace is run.

The Reins Copper Company, owning property east of the Boston and Montana, has opened up a good vein of copper ore on the 800-foot level, has sunk a shaft to a depth of 1,070 feet, and will cut a station at the 1,200-foot level in the near future. Though fairly rich ore has been encountered in this property, no stoping has yet been done and some difficulty has been experienced in handling the flow of water.

Among the newer companies organized may be mentioned the Butte and London Copper Company, which will develop the Greendale placer, north of and adjoining the Pittsburg and Montana ground.

The East Butte Company has bought up and is now mining ore from a number of small claims and city lots in the southern portion of the city.

The Columbia-Butte Company, controlling four claims in the copper-silver belt west of the Lexington mine, is reported to have found a 10-foot vein of ore carrying one-half to 1 per cent of copper on the Jennie Dell claim, at a depth of 358 feet, supposedly on the Lexington vein.

The owners of the Raven property, which has been extensively developed during the past three years, have incorporated the Raven Mining Company. The property owned by this company consists of the Raven and Snoozer claims, and is being developed at a depth of 1,500 feet by a crosscut from the Buffalo shaft of the Amalgamated Company. The Raven has been shipping ore for some years.

The J. I. C. mine is now being developed by the Amalgamated Company, as is also the Greenleaf claim, lying east of the flat, near the Great Northern tunnel.

The Berlin mine has recently been acquired by the North Butte Company, and work on the 400-foot shaft has been stopped, as the future development will be carried on from the deep levels of the company.

The United Copper Company is operating the Belmont and Glengary mines, the Belmont shaft being reported to have a depth of 900 feet and the Glengary of 800 feet. The Dutton shaft of the East Butte Company is to be sunk from 350 to 1,000 feet in depth.

The total production from the district is now approximately 15,500 tons a day. The Amalgamated Company is treating 8,350 tons a day at the Washoe smelter, of which 1,000 tons is North Butte ore and 550 tons from the W. A. Clark mines. This is the largest quantity treated at any individual copper plant in the world, the Calumet and Hecla Company coming next in point of production, with a daily treatment of 6,000 to 7,000 tons of ore. The Great Falls smelter, also belonging to the Amalgamated Copper Company, treats 3,700 tons a day. The properties belonging to Senator Clark yielded about 2,000 tons a day, treated partly in his own works and partly by the Amalgamated Company.

The Butte Copper Exploration Company, controlling eight claims east of the city, has begun development. The Golden Chief is reported (in the Engineering and Mining Journal) to show a 30-foot vein of 2½ per cent ore.

Daily and gross output of Butte copper mines, December, 1905.[a]

Mine.	Daily tonnage.	Pounds of copper per ton.	Pounds daily.	Tonnage for month.	Pounds for month.
Boston and Montana	3,100	73	226,300	96,100	7,015,300
Anaconda	4,125	64	264,000	127,875	8,184,000
Butte and Boston	530	63	33,390	16,430	1,035,090
Trenton	600	62	37,200	18,600	1,153,200
Washoe	420	68	28,560	13,020	885,360
Parrot	400	70	28,000	12,400	868,000
Clark's Original	1,250	72	90,000	38,750	2,790,000
Pittsburg	160	82	13,120	4,960	406,720
North Butte	625	138	86,250	19,375	2,673,750
United Copper	1,615	69	111,435	50,065	3,454,485
East Butte	180	160	28,800	5,580	892,800
Miscellaneous	400	65	26,000	12,400	806,000
	13,405	.....	973,055	415,555	30,164,705

[a] Mining World, Jan. 27, 1906, p. 145.

NORTH CAROLINA.

The copper production of North Carolina amounted to 700,000 pounds in 1905. This comes almost entirely from the mines of the Virgilina and Gold Hill districts.

In the Virgilina district the ores consist of bornite and copper glance in a gangue of white, coarsely crystalline quartz. The ore is sorted, the high-grade material being shipped and the low-grade ore treated in a concentrating mill. The mines owned by Person Consolidated Copper and Gold Mines Company were the only ones in operation in 1905.

The actual value of the Virgilina properties is dependent on several variable factors, the most important being, of course, the price of copper. The ores occur in a very hard quartz and carry from 70 to 80 per cent excess silica, while the copper minerals, though free, are extremely brittle. Wet concentration effects a saving of about 50 per cent of the value, and on a 2 per cent ore, with only an ounce or less of silver, is clearly unprofitable. Hand picking has been practiced at several mines, but is hardly profitable.

The cost of mining in this district is estimated at $1.75 to $2.25 per ton, including 35 to 65 cents per ton for development work. With these figures the problem of profitable working is one of freight rates to a smelter. Assuming a 2 per cent ore and copper worth 15 cents a pound, the gross value, including silver contents, is $6.50. Deducting $2 for mining costs leaves $4.50 for freight, smelter charges, and profit.

In Rowan County the Gold Hill district produced 840,000 pounds of copper in 1905 from the Union Copper Company mine. The property shows a number of well-defined veins of the usual Appalachian "schist" type, with gold values in the oxidized ore. The copper ore

occurs in shoots and consists of chalcopyrite intimately intergrown with quartz. Concentration is not effective owing to the fineness of the particles of chalcopyrite and the practical impossibility of a clean separation. The ore is highly siliceous and carries a low precious-metal content. One workable ore shoot has been developed in the Union Copper Company's workings, and this is open to a depth of 800 feet. The ore is shipped to New York, and to Ducktown, Tenn.

Besides the two districts mentioned North Carolina has many copper-bearing veins in the gold belt lying along the boundary between the old Algonkian (?) slates and the granite mass. The Crosby and Concord Hill mines, near Concord, are among the best known, the ore being chalcopyrite associated with siderite (carbonate of iron).

In the mountain region of Jackson County there are several copper veins, formerly worked, that carry copper pyrite. They are in metamorphic schists but usually occur associated with amphibolite bands. The only property recently worked is the Cullowee (Davies post-office), near Sylva, on the Murphy branch of the Southern Railway. The ores consist of chalcopyrite in a quartz gangue, occurring in a band of amphibolite. The development work on the various properties is not sufficient to warrant an estimate of the importance of the veins as future producers. The ore shoots so far known are not large, and though the veins are often traceable by their iron-stained outcrop for a mile or two, development work is limited to a few points. These properties are at present several miles from the railways, but branch lines could be easily and cheaply constructed and would serve the timber and clay industries as well.

The Rowan and Salisbury copper mines have been worked to some extent and the Mead mine has been developed.

NEVADA.

Nevada has as yet only a small annual production of copper. Six counties yielded a total of 29,317 pounds of copper in 1904, the largest production, 13,963 pounds, coming from Eureka County.

Elko County produced 7,200 pounds in 1904, from the high-grade gold-bearing ores of the Weston and Frank mines, in the Railroad district.

Esmeralda County gave the small amount of 300 pounds in 1904. The Sodaville copper belt occurs in this county, at the north end of the Pilot Mountains, about 18 miles east of Mina, a new town on the Carson and Colorado Railway. The copper ores occur in a contact zone 12 miles long, on the borders of a granite intrusion. On the east side of the range the Dunlap property is being developed by the Guggenheim interests. At the north end the copper-contact mine is shipping small amounts of ore, and at the south end the D'Arcy mine is also producing. On the west side of the mountains the Utavarda Copper Company, at Garnet, shows a vein said to be 13 feet wide, opened by a 70-foot shaft and proved for 2,700 feet horizontally.

Eureka County yielded 13,963 pounds, of a value of $1,380, mostly from the Tenabo Mining and Milling Company's mine in the Cortez district.

Lander County yielded 3,200 pounds of copper in 1904.

Nye County produced but 70 pounds of copper, from the gold-silver ores shipped to smelters.

White Pine County, whose great ore bodies are now being so actively and extensively developed, yielded but 4,584 pounds of copper in 1904. Within the last few years a great mining district has been quietly developed in this county, and its mines will soon take high rank among the world's great producers. The region, commonly known as the "Ely district," lies 6 miles west of Ely, the county seat, which is 140 miles distant from Toano, a station on the Southern Pacific Railroad. The place is officially known as the "Robinson mining district."

The mineral-bearing area consists of shales and limestones, intruded by an immense dike-like mass of monzonite-porphyry that is traceable for some miles in length, with a later intrusion of rhyolite-porphyry transversely cutting across the porphyry in the center. On

the northwestern border of the field an intrusion of granite occurs cutting the monzonite. The mineral-bearing porphyry is a white siliceous rock, with a brown weathered surface. In places it is so silicified that it forms hard masses which stand out in relief above the more gentle slopes of softer, leached rock.

The ore bodies are of enormous extent. That of the Eureka mine is 70 by 800 feet, and has been developed to a depth of 100 feet. That of the Ruth mine has a width of 50 to 250 feet, is developed for 400 to 900 feet in length, and has a known vertical thickness of 250 feet. According to Channing, from whose report on the Nevada Consolidated Copper Mining Company's properties these notes are taken, the rock is leached for 50 to 100 feet down, carrying not over one-half of 1 per cent of copper. Below this the ore is white and soft, and consists of decomposed porphyry carrying minute seams of pyrite and copper glance, with some quartz. This is typical "disseminated" ore, exactly analogous to the ores of Morenci and Bingham. At the Ruth mine there is a 640-foot inclined shaft, having an angle of 41°, equal to 420 feet vertical. Levels are driven at 200, 300, 500, and 650 feet on the incline, and the ground is blocked out by 200-foot crosscuts. The ore has a content of 2.6 per cent of copper at the Ruth mine and of 2.2 per cent of copper at the Eureka mine, with 40 cents per ton in gold. A large concentrating plant has already been planned, and with the completion of the railroad now being built by the company the property will have an estimated output of 3,000 tons a day. It is expected that a saving will be made of 77 to 79 per cent of the values of the ore. These properties are in the eastern or central portion of the belt. The western portion of the quartz-monzonite area is owned by the Giroux Copper Mining Company.

The quartz-monzonite mass is surrounded by contact-metamorphic limestones and shales, in which there are pockets of ore, but up to the present time no large ore bodies have been found in such rocks.

NEW MEXICO.

Copper mining in New Mexico during 1905 has not shown the same marked improvement in condition as in Arizona. The Territory contains a dozen or more areas of igneous rock surrounded by borders of limestone which has been altered by contact metamorphism and impregnated by copper ores. Various attempts have been made to work these low-grade ores, notably in the San Pedro Mountains, but thus far without marked success. There seems no question as to the abundance of low-grade garnetiferous ore at all these localities, but the future utilization of these ores is a metallurgical problem. The extension of railroad lines in 1904 has altered conditions materially, and with the assurance of cheaper coke the possibility of successful reduction seems more hopeful. The Santa Rita mines continue to produce the largest amount of ore.

The copper output of New Mexico for 1905 is estimated at 3,500,000 pounds, nearly all from Grant County. The returns for 1904[a] show the following production by counties:

Production of copper in New Mexico, 1904, by counties.

County.	Quantity.	Value.	County.	Quantity.	Value.
	Pounds.			*Pounds.*	
Donna Ana	40,000	$5,200	Santa Fe	2,308	$300
Grant	4,428,508	575,706	Sierra	16,700	2,171
Luna	16,000	2,080	Socorro	425,508	55,316
Otero	14,400	1,872	Taos	3,000	390
Rio Arriba	846	110			
San Miguel	24,900	3,237	Total	4,972,170	646,382

[a] Lindgren, Waldemar, Production of gold and silver in 1904: Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905.

The copper ores yielded gold to the value of $85,525 and 79,369 ounces of silver.

Donna Ana County contains copper mines in the Organ district, in which the Torpedo, Memphis, Copper Bar, Excelsior, and other properties occur along a contact between altered limestone and igneous rocks, the conditions being somewhat similar to those observed at Clifton. The copper occurs in the central portion of the contact, where the limestone has been converted into garnet, vesuvianite, and epidote.

The Silver City district, Grant County, in which the Comanche Mining and Smelting Company's property is situated, furnishes the copper ores of this part of the Territory. This company owns the Hearst mine, which works a body of low-grade sulphide copper ore, developed to a depth of 800 feet. The ore is, however, refractory and contains a large amount of zinc. The company is actively developing its mines at Burro Mountain and Pinos Altos. The new concentrator has a 400-ton capacity to treat complex sulphide ores, with a 250-ton furnace, and is developing ground on the 200-foot level of the No. 8 shaft.

In the Burro district, in the same region, the 100-ton concentrating plant owned by the Burro Mountain Copper Company was in operation during the year, and has recently been remodeled.

In the Central district the Santa Rita mines continue to furnish the bulk of the copper output of the Territory. The Santa Rita property is said to show an underlying core of igneous rock, with an overlying bed of quartzite about 50 feet thick, which is impregnated with oxide ores. The quartzite lies at a gentle angle, and is overlain at some distance from the mines proper by an altered limestone, which has presumably been eroded off from the vicinity of the mines and during this erosion has furnished the solutions for the impregnation of the quartzite. Sulphide ores also occur in the underlying porphyry, extending downward as deep as the workings have been carried, about 300 feet below the surface.

In the Mogollon district bornite ores have been mined in small quantities and shipped to the custom smelters.

The "Red Beds" area of New Mexico covers a considerable portion of the Territory and contains extensive deposits of oxidized ore. The utilization of these low-grade ores has been attempted by various companies, but thus far without bringing in any large producers. The character of these deposits has been discussed elsewhere. The Blake mine of San Miguel County is the chief producer.

In the Virginia and Pyramid districts, which lie immediately south of Lordsburg, the Bonney Mining Company has developed complex copper ores carrying lead, with gold and silver values. The Robert E. Lee and Nellie Bly mines, of the Pyramid Peak district, have encountered bornite ore near the surface, with chalcopyrite ore carrying about 6 per cent of copper and 7 ounces of silver. The production from the Central district for 1905 shows a marked decrease from that for 1904.

Otero County yields a small production from the mines in the Jarilla Mountains.

Luna County contains the Apache mine, near Hachita, which is a small producer.

Sierra County contains a few small copper mines near Hillsboro.

The copper production of Socorro County comes from the mixed sulphide ores of the Magdalena Mountains.

Taos County has an insignificant production from small streaks of chalcopyrite in schist.

Sandoval County contains the Nacimiento district, where the ore occurs as fossil palm leaves and tree trunks, consisting of copper glance occurring in Triassic standstones. The deposits are not worked.

OREGON.

The northern extension of the copper belt of California passes into Josephine County, Oreg. Several properties have been developed and within the last year the Takilma Smelting Company, near Waldo, has been in operation. No returns for 1905 are yet available. In 1904 there were four producing counties in the State, but of the aggregate of 269,510 pounds all but 6,000 pounds came from the Takilma smelter. So far as information is available the ore bodies of this region consist of chalcopyrite ores, with a little bornite, in a gangue

of pyrite and pyrrhotite. They form lenticular masses inclosed in altered and schistose igneous rocks, but as the locality has not been visited by any member of the Survey no detailed information is available.

In eastern Oregon there are a number of copper properties which have attracted more or less attention for some years past. They occur in the Blue Mountain region, and most of the deposits are contained in Triassic lavas, mainly basaltic, interbedded with sedimentary rocks of the same age. Three types have been distinguished by Lindgren—the Seven Devils type, the Tourmaline type, and the Snake River type.

The first named includes contact deposits of irregular bodies of chalcopyrite and bornite, lying between limestone and diorite. The ores contain a gangue of garnet, epidote, and other contact minerals. The only example of this type occurs near Medical Springs.

The Tourmaline type is characterized by chalcopyrite and pyrite associated with a gangue of quartz and tourmaline, the ores occurring in fissure veins and irregular replacements. The Copperopolis mine, in the Quartzburg district, and the Jessie vein, in the Mineral district, are of this character.

The Snake River deposits occur in the canyon of that stream, southwest of Seven Devils, 80 miles from Baker City. The type consists of deposits, largely of metasomatic origin, of finely distributed copper glance, bornite, and rarely of chalcopyrite, in Triassic lavas or tuffs. The distribution of the sulphides is irregular, but commonly follows well-defined directions, probably determined by joint systems, though no sharply defined fissures could be observed. The gangue minerals are quartz, epidote, actinolite, or chlorite. At Copper Union and near Ballards Ferry, in the Snake River Canyon, the deposits are epidotic. In the Snowstorm mine, near Sanger, the rock is a diabase and the ore actinolitic. The Iron Dike and River Queen deposits are chloritic.

The Copper Butte district contains a number of deposits in basaltic rocks of Triassic age.

Among the copper deposits noted in the foregoing paragraphs there are no producing mines, though small shipments of high-grade ores have been made from one or two of the prospects. In general it may be said that the ores are of low grade and that the zones will not average more than 1 or 2 per cent of copper.

TENNESSEE.

The copper production of Tennessee comes entirely from the Ducktown district. The output for 1905 showed only a slight increase over that of 1904, as the four new furnaces were not put in commission. The Tennessee Company produced 7,977,982 pounds.

The production for the last six months of the year averaged about 1,000,000 pounds of copper per month, the recovery being 35 pounds of copper per ton of ore. The Burra Burra ore carries 2.3 per cent of copper, 0.33 ounce of silver, 0.001 ounce of gold, and 0.01 per cent of tellurium and selenium per ton. It is concentrated 50 to 1 by matting and converting to a pig copper carrying 99.4 per cent of copper, 12.5 ounces of silver, 0.025 ounce of gold, 0.01 per cent of tellurium and selenium, and 0.0007 per cent of arsenic.

GEOLOGY.

The Ducktown district is in the extreme southeast corner of the State, on one of the lines of the Louisville and Nashville Railroad. The deposits outcrop on a small upland plateau inclosed by higher mountains and trenched by stream channels. The country rock is a thinly foliated mica-schist with occasional intercalated layers of gneiss. The rocks are commonly regarded as part of the "Ocoee" series of Cambrian age, but they differ from the rocks of this series as exposed in the Hiwassee gorge. The foliation runs north-northeast and the beds dip 50° SE. Microscopic study by Kemp [a] shows the rocks to consist of biotite and quartz, indicating a sedimentary origin; the conclusions reached by Keith are in accord with this.

[a] Trans. Am. Inst. Min. Eng., vol. 31, 1901, p. 244.

The ore consists of massive pyrrhotite, containing interspersed particles and stringers of chalcopyrite and pyrite, together with minute quantities of galena and zinc. Calcite, zoisite, quartz, and occasional bunches of garnet occur, with actinolite in some deposits. The copper content averages about 2.12 per cent.

The deposits consist of long and exceptionally thick masses of solid ore, rarely with few included slivers or horses of country rock. These deposits occur on three lines of fracturing and probable faulting and rock crushing. They are classed as replacement veins, similar to those at Ore Knob, N. C., and the gossan lead of southwestern Virginia, but the ore bodies are larger. Diagonal faulting of the ore bodies has occurred.[a]

DEVELOPMENT.

The London and Burra Burra mines are on the westernmost vein, the Isabella on the middle, and the Polk County, Mary, and Calloway mines on the southeast vein of the district. The Tennessee vein lies west of the last mentioned and there are two smaller intermediate ore bodies.

The deposits are extensively worked by two companies—the Ducktown Sulphur, Copper and Iron Company (commonly known as the English company) and the Tennessee Copper Company. The Burra Burra mine of the latter company is now 560 feet deep, the ore body maintaining its nearly uniform dip (of 60°) and thickness to the lowest workings.

The Tennessee Company is preparing to erect an acid plant to make low-grade sulphuric acid out of the fumes from the blast furnaces.

The ore of the different mines has the following composition:[b]

Composition of Ducktown ores.

	1.	2.	3.	4.
Copper	2.744	2.79	2.2	3.0
Iron	36.519	43.26	37.5	31.0
Sulphur	24.848	29.18	30.0	21.0
Silica	18.548	10.01	10.3	26.3
Lime	7.294	6.32	6.2	6.1
Magnesia	2.672	1.39	1.9	2.5
Zinc	2.556	2.56	2.0	.8
Alumina	.911	1.00	3.9	4.4
Manganese	.770	.69	.....	.....
Carbon dioxid (by difference)	3.135	2.80	.....	.....
	100.000	100.00	.....	.....

The first two columns represent the ores smelted by the Ducktown Copper, Sulphur and Iron Company; the third and fourth columns the ores of the Burra Burra and London mines, respectively, both being from the same vein. It will be seen that there is considerable difference in the composition of the ores from the different parts of the same ore body.

The Ducktown ores are no longer roasted, but are smelted raw, in blast furnaces, with a concentration of about 7.3 into 1, forming a 12 to 20 per cent matte, which is resmelted with a small amount of raw ore, quartz, etc., and raised to a 50 per cent matte, which is in turn bessemerized.

[a] Henrich, Carl, Trans. Am. Inst. Min. Eng., vol. 25, 1895, p. 198.
[b] Channing, J. Parke, Pyrite Smelting, p. 254. Freeland, W. H., Raw sulphide smelting at Ducktown: Pyrite Smelting, p. 111.

UTAH.

The copper production of Utah for 1905 has been estimated at 57,267,000 pounds,[a] valued at $8,785,000. This output comes mainly from the copper mines of Bingham and Park City, the increase of over 13,000,000 pounds of copper over the production for 1904 being due to these two camps. The Utah Consolidated, of Bingham, has paid out over $1,000,000 in dividends during the past year, and the United States, another copper producer, $750,000 in dividends.

The Bingham camp has been successfully developed until it is now one of the greatest copper camps of the country. In addition to the production from the well-known flat ore bodies in the limestone, the copper-bearing monzonite ores have been proved to be of great economic value. The Utah Copper Company and the Boston Consolidated both work the so-called porphyry or disseminated ores, and as the ore bodies can be mined in places by steam shovels and a 3,000-ton mill is nearly completed by the Boston Company, a greatly increased output from this source may be expected in 1906. The Utah Copper Company has a plant of the same capacity now in process of erection, and it is said that these two companies have over 60,000,000 tons of ore available for extraction. A third group of mines on this porphyry belt is that known as the Starless group. All the companies operating in this vicinity have enlarged their plants, and the output will be greatly increased in 1906.

Park City, which produces copper as a by-product, has not been as prosperous as Bingham, though its output has been maintained at about the same point as in the previous year. The chief development has been in the Bonanza Flat section, where the West Quincy and Little Bell companies have carried on extensive development.

The Tintic district has shipped about 300,000 tons of ore from the 12 chief mines in operation, although there are 35 shipping properties. The Centennial-Eureka has, as usual, been the chief producer.

At Alta extensive development work has been done and new ore bodies opened up, and this once famous silver camp promises to become second to Bingham as a copper producer if present indications do not prove delusive.

The Cactus mine, in Beaver County, has been operated since March, 1905, producing about 10,000 tons of concentrates in 1905. The company expects to install steam shovels in 1906, which will greatly reduce the cost of mining.

The Utah and Eastern Copper Company has blown in its smelter, in Washington County, after some six months of idleness, and as the ore body has been cut by a deep drain tunnel, the outlook is hopeful for a continued production. A small smelter is also operated by the Paymaster Copper Company.

The production of the State for 1903 and 1904, by counties, is as follows:

Production of copper in Utah, 1903 and 1904, by counties.

County.	1903.	1904.
	Pounds.	*Pounds.*
Beaver and Piute	432,409	1,650,787
Juab and Utah	8,023,464	9,035,720
Salt Lake	18,604,989	30,864,666
Summit and Wasatch	3,297,101	2,118,452
Tooele	984,295	1,023,825
Washington, Millard, Sevier, Grand, and Boxelder	1,505,398	1,723,784
	32,847,656	46,417,234

[a] Beason, H. L., Eng. and Min. Jour., Jan. 6, 1906.

Bingham is the most important copper district of Utah. A monograph describing the district, by J. M. Boutwell, has recently been published by this Survey. The conclusions reached by Boutwell [a] as to the genesis of the Bingham deposits are as follows:

In Mesozoic or early Tertiary time intrusive bodies of monzonite invaded a mass of quartzites and limestones, producing contact metamorphism, with the intrusion of pyritous copper sulphides as replacement of marmorized limestone. After the cooling of the upper part of the intrusive monzonite to at least partial rigidity it and the inclosing sedimentary rocks were fractured by persistent northwest-southeast fissures. Heated aqueous solutions from the deeper unconsolidated portions of the magma ascended through these fissures, altering the fissure walls and introduced additional metallic material, adding to the deposits in the limestones, altering the monzonite and adding copper, gold, and silver as auriferous chalcopyrite, pyrite, and molybdenite to the monzonite. Two periods of mineralization are clearly defined—first, that of contact metamorphism, with intergrowth of ore, garnet, etc.; second, after actions, producing the disseminated ores and the lodes.

The site of the ore bodies was determined by selective preference of mineral solutions for deposition in certain beds, a preference quite as marked with different limestone beds as it is between limestone and quartzite.[b] The disseminated ores [c] were deposited by hydrothermal action subsequent to the date of the igneous intrusion, and the sulphides are now undergoing normal superficial alteration. The ores occur in the joints of the rock as a mossy coating of quartz and sulphides, but also in the body of the rock, especially associated with dark ores of ferromagnesian minerals, principally secondary (?) biotite. The productive ground was coextensive with monzonite exposures, as may be seen by comparison of the geologic and economic maps. All the monzonite was, however, not mineralized, and it was only where extensive fracturing permitted the access of the deep-seated solution that mineralization was extensive enough to form workable ore deposits. In the Utah Company's claims an average assay of 6,000 samples corresponds closely to the grade of ore now milled, showing 1.98 per cent of copper, 0.016 ounce of gold, and 0.15 ounce of silver per ton.

The Newhouse or Cactus mine, in Beaver County, is now one of the regular producers of the State. A description of this property, by S. F. Emmons, is given in Bulletin No. 260, page 242. The mine is 4½ miles northwest of Frisco, in the San Francisco Mountains, and is reached by a branch line of the San Pedro, Los Angeles and Salt Lake Railroad. The ore consists of coarsely crystalline pyrite, with a little chalcopyrite and rarely sooty sulphide. The deposit is a shear or crush zone in monzonite, 15 to 30 feet wide, the ore cementing fragments and filling cracks and crevices in the shattered rock. The ore zone is vertical and is developed to a depth of 600 feet by a shaft and a crosscut tunnel over a mile long. While the mine yields some smelting ore, the main product is concentrating ore treated in an 800-ton mill and concentrated 6 into 1. The shear zone is a strong fault zone, traceable for a mile or more across the mountain slopes running toward the Horn Silver fault.

The Park City district, though better known as a producer of argentiferous lead ores, yields an important and rapidly increasing output of copper ore. Copper is commonly present as tetrahedrite (gray copper), or fahlore, in the high-grade silver ores, the average of such ores carrying about 2.5 per cent of copper, 40 per cent of lead, and 60 ounces of silver per ton, while the crude ore sent to the concentrators carries 1.5 per cent of copper.

The ore occurs in fissure lodes and as masses in limestone, the bulk of the ore now extracted coming from the bedded ore bodies in limestone. The northeast-southwest fissures, with steep northwesterly dip, are wide and persistent veins, 2 to 35 feet wide, carrying narrow pay streaks of high-grade ore.

The "bedded" deposits are replacements of and occur in certain layers in Upper Carboniferous and Permian limestones, the ore-bearing layers being inclosed in quartzite. Both lodes and replacement bodies occur intimately associated with porphyry intrusions.

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[a] Prof. Paper U. S. Geol. Survey No. 38, 1905, p. 229. [b] P. 128. See fig. 2. [c] P. 172.

Development of these ore bodies has been very extensive. It is possible to walk for nearly 5 miles in one general direction underground, and the Ontario shaft is 2,000 feet deep. The Ontario, Daly West, Daly Judge, and Silver King are the largest companies.

Tintic produced 2,118,432 pounds of copper ore in 1904, carrying 59,213 ounces of gold and 1,655,139 ounces of silver, contained in 262,680 tons of ore and concentrates. The copper was about equal in value to the gold content of the ore, the combined value of gold and copper being $546,805, as against 6,126,332 ounces of silver and lead.

Bingham produced 705,792 tons of ore in 1904, of which 137,979 tons were milling ore, yielding 9,515 tons concentrates, valued at $510,291. The district yields practically no siliceous ore, and the copper produced carried 54,609 ounces of gold and 906,768 ounces of silver.

Mercur, Tooele County, yielded 1,023,825 pounds of copper in 1904, of a value of $127,978.

WASHINGTON.

The copper product of Washington comes chiefly from the mines situated in the eastern part of the State, though numerous prospects exist in the Lake Chelan region and in the Cascade Mountains near Index station, on the Great Northern Railway.

The production for 1904, by counties, is as follows:

Production of copper in Washington, 1904, by counties.

County.	Pounds.	Value.
Ferry	77,548	$8,948
Kittitas	329	46
Snohomish	77,850	8,991
Stevens	194,320	25,803
	350,047	43,788

The Copper King mine, a property situated 4 to 5 miles from Chewelah, Stevens County, is shipping ore to the Northport smelter. The ore consists of chalcopyrite and is said in occur in a schistose rock with granite near by. The ore is hauled to the railroad by a traction engine, which draws six cars of 10 tons each and makes three trips every two days.

At Chesaw, Ferry County, near the boundary line, northwest of Republic, the First Thought, Orient, and Belcher mines have been developed to a point where they are capable of making a steady output.

The Belcher mine was actively developed in 1905. The ore is a fine-grained, dense, banded mixture of pyrite and chalcopyrite. The district is underlain by diorite[a] and syenite-porphyry. The ore bodies occur in east-west fractures in the diorite with northerly dip. The ore occurs both in nearly pure bodies and with country rock. The largest shoot in Belcher No. 2 is of massive pyrite ore; it has an extreme width of 80 feet and is 100 feet long. Pyrrhotite is abundant in some veins and carries low gold values. The Belcher has five tunnels and several open cuts.

The ores at Index, Snohomish County, consist of granite impregnated with bornite and are quite siliceous, so that they can be treated only by mixing with the basic ores of other localities, the mixture of ore and gangue being too intimate to permit of cheap concentration by water.

WYOMING.

The principal copper-producing section of Wyoming is the Encampment district, which lies in the southern part of the State and extends from the Colorado boundary northward, on both sides of Platte River. Most of it is in southern Carbon County, and the remainder

[a] Mining World, Jan. 9, 1904, p. 86.

is in southern Albany County. A part of the same geographical section is the Pearl district of northern Colorado. Encampment, Carbon County, has the only large smelter in Wyoming, and an aerial tramway, 16 miles in length, the longest in the West, connects the smelter with the Ferris-Haggarty mine. The smelter, tramway, mine, and other property of the North American Copper Company were, after default in the payment of interest on bonds and a foreclosure, taken over by its successor, the Penn-Wyoming Copper Company.

The district has been fully described by Spencer,[a] from whose paper the following synopsis has been taken:

The region is one of quartzites and schists. The beds have a prevailing east-west course and dip steeply to the north and are intruded by igneous rocks. The ore bodies are reconcentration enrichments along channels, due to the netted fracturing of the rocks.

The ore is siliceous and needs an iron flux, gossan for this purpose being mined at a locality 9 miles away and hauled to the smelter.

The smelter is at the town of Encampment. The ore is carried by rope tramway 16 miles across the range, over two divides and two valleys. Coal is supplied from a locality 8 miles from the mines and hauled up grade in wagons to the furnaces. There are two producing mines—the Ferris-Haggarty and the Doane.

The Doane-Rambler mine is the second largest of the Encampment district. The shaft is now (1905) 600 feet deep, with several hundred feet of drifts cutting through both low-grade and high-grade ores. The property is equipped with a complete machinery plant and is said to have the largest ore reserves of any mine in the district.

The Ferris-Haggarty ore body lies between steeply dipping schists and quartzites, the schists lying above the ore. The ore consists of chalcocite and chalcopyrite impregnating and replacing crushed quartzite, which forms the gangue. Much of the ore requires concentration. The ore body is 250 to 300 feet long, and varies from a few inches in thickness at the end up to 30 feet in the middle. The schist hanging wall is very regular; the foot wall is very irregular, being governed by the amount of brecciation or fracturing of the quartzite. But one pipe of ore has as yet been found.

The Doane is of the same type. The ore is glance, with lesser amounts of chalcopyrite, bornite, and rarely of covellite. The ore body is an elliptical "pipe" lying in a bed of quartzite, dipping steeply to the north, the ore shoot having a wavy pitch to the west.

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[a] Prof. Paper U. S. Geol. Survey No. 25, 1904.

THE CASHIN MINE, MONTROSE COUNTY, COLO.

By W. H. Emmons.

INTRODUCTION.

The Cashin copper mine is situated at Cashin post-office, in the western part of Montrose County, southwestern Colorado, on La Sal Creek, about 4 miles west of its junction with Dolores River. In June, 1905, it was the writer's privilege to make a hasty visit to this property incidental to a geological reconnaissance under the direction of Mr. Whitman Cross. The nearest railroad station, Placerville, on the Rio Grande Southern, is about 70 miles to the east. The wagon road between the two points is said to be in very good condition and of moderate grade for a rugged topography.

The region is a portion of the plateau country which under various names constitutes a large part of southwestern Colorado and southeastern Utah and extends southward into New Mexico and Arizona. The country is traversed by deep and relatively narrow canyons, the steep, inaccessible walls of sedimentary rock presenting a picture similar to that of the Grand Canyon of the Colorado in Arizona, although the relief is much less. The climate is arid, but the La Sal Mountains, about 10 or 12 miles to the west, furnish an abundant supply of water and power.

The deposit was discovered in 1896, but active development did not begin until 1899. Since then it has been worked with varying success most of the time. According to the books of the La Sal Copper Mining Company, the present owners, it has produced altogether 363,778 ounces of silver and 732,740 pounds of copper.[a]

GEOLOGY.

The country is underlain by nearly horizontal sedimentary rocks, strongly fissured and faulted.

The generalized geologic section, as observed in Paradox and Sinbads valleys several miles north of Cashin, is as follows: [b]

Generalized section north of Cashin, Colo.

	Thickness in feet.
1. Dakota formation (Cretaceous): Sandstone, white or buff, often bearing abundant plant remains and thin coal seams	200-400
2. McElmo formation (Jurassic): Sandstone with shaly members, often massive; light pink or white	400
3. La Plata formation (Jurassic): Massive sandstones, with occasional thin-bedded or shaly layers; pink or nearly white	600-800
4. Dolores formation (Triassic): Fine-grained red sandstones, often thin bedded, alternating with sandy or calcareous red clay shales. Contains one or more beds of limestone conglomerate, usually bearing the remains of plants and small pieces of bone ("Saurian conglomerate"). Probably rests on Permian conglomerates	200-400

[a] These figures do not include the shipments of native copper, of which no record was available.

[b] The writer was unable to visit the country between the mine and Dolores River, where that portion of the section which comes below the present workings would probably be exposed. The thickness of the La Plata is exposed in the cliff above the mine, and the persistence of the limestone-conglomerate beds ("Saurian conglomerate") indicates that this limestone layer should appear not far from the present lower workings. It could probably be traced from its exposure south of the Paradox bridge up La Sal Creek and its position below Cashin determined with some degree of certainty. It would be interesting to know what change, if any, occurs in the ore body where the fissure crosses this limestone member.

In Sinbads Valley massive Carboniferous limestones, belonging below the Permian conglomerates, are exposed. It is probable, therefore, that considerable thicknesses of both of these strata would be crossed before the basal granite was reached.

The Dolores formation in its typical development of red sandy shales and limestone conglomerates was observed just south of the bridge crossing Dolores River at Paradox. It is the base of the section as there exposed. In the country to the north and west the Cutler formation (Permian) underlies the Dolores and consists of a great thickness of red sandstones and conglomerates, with occasional beds of red shale and lenses of gypsum. At several places the Cutler and Dolores are separated by an angular unconformity, showing that there was tilting and erosion between the periods of their deposition, but in Paradox Valley their dip appears to be uniform.

The La Plata formation occupies a large area in this region and often forms the "rim rock" of the valleys. The later formations generally occur as more or less isolated areas on the higher portions of the plateau. In Paradox and Sinbads valleys the rocks are complexly dislocated by faults of considerable throw—in some cases several hundred feet. A pronounced fissure trends northward from Cashin to Paradox Valley. The crushed sandstone along this fissure shows that it has been a plane of movement, though the beds show little displacement.

There are no igneous rocks in the immediate vicinity of the mine. A body of "porphyry" is reported to occur 6 miles southwest of Cashin, and the La Sal Mountains, a laccolithic group, are about 10 or 12 miles to the west.

To judge from the thickness of the La Plata sandstone above the mine, the tunnel must enter that formation near its base and the Triassic limestone conglomerate, if present, would appear near the lower workings. Mr. J. N. McBride states that the ore becomes very much richer in lime in that portion of the mine, and this may be because of the proximity of the limestone. There is so much crushed quartz, kaolin, and secondary calcite at this point that with the present limited development here, the country rock could not be determined with certainty.

ORE DEPOSITS.

The ore deposits occur along a fissure which cuts the La Plata sandstone. The dip of this fissure is 75° W. and, though it bends slightly, its general strike is about N. 20° E. According to Mr. Thomas L. Darby, the fissure may be traced on the surface northward to the rim of Paradox Valley, 2 or 3 miles distant, but the writer was unable to examine this portion of the lode, nor to observe its behavior in the formations above the La Plata. A tunnel with its portal about 30 feet above La Sal Creek has been driven northward on the lode for 700 feet. An inclined shaft connecting with the surface and extending 100 feet below the level of the tunnel crosses it about halfway to the breast, thus exposing 400 feet of beds. In places considerable ground above the tunnel has been stoped out and short drifts have been run on the vein at several levels.

The nonmetallic minerals are crushed quartz sand, kaolin, calcite, barite, and vein quartz. The metallic minerals are covellite, chalcocite, bornite, native copper, malachite, azurite, cuprite, and iron sulphate. Argentite and native silver occur near the surface in pockets of considerable size, but at the time of visit these had been removed.

The lode varies in width from 1 foot to 20 feet or more and is composed mainly of crushed sand and kaolin, containing small specks of copper sulphides. It is often stained green by copper carbonate and iron sulphate. There is not always a distinct line of demarcation between the lode and the wall rock, since the lode is made up largely of the material of the country rock, altered somewhat by movement and concomitant processes. The green discoloration sometimes extends beyond the fissure, a feature which is strikingly shown on the face of the cliff southwest of the portal of the tunnel.

Rich ore, composed largely of argentiferous covellite, chalcocite, and bornite and also carrying calcite and barite, occurs as veinlets in the fissure zone. These veinlets are from 1 inch to several inches wide and are sometimes composed entirely of the copper sulphides, the

brilliant blue of the covellite contrasting strongly with the dark chalcocite and making an ore of unusual beauty. The veinlets are generally approximately parallel to the direction of the fissure, but sometimes cut diagonally across it. Where the lode is widest, there are four or five of these veinlets. Frequently they play out along a narrow seam, perhaps to reappear beyond. Carload shipments of the rich ore have given returns as high as 512 ounces of silver to the ton. Large masses of the native copper occur embedded in the kaolin, especially in the lowest level. Most of them are irregular bodies about as thick as they are long, and one was found which weighed over 500 pounds. A sheet of leaf copper was observed on the dump. It was about a foot square and one-eighth of an inch thick, and was slickensided on both sides. Native copper also occurs in veinlets with calcite and barite, and one shipment averaged 89 per cent copper and 77 ounces of silver to the ton.

TREATMENT OF THE ORE.

On account of the excessive hauling charges, only the high-grade ore can be profitably shipped. Of this ore the mine has produced 2,067 tons, which averaged 12.5 per cent copper and 134 ounces of silver to the ton.

The Russel leaching process, by which the roasted and crushed ore was treated with a weak solution of hyposulphite of soda, proved successful so far as the silver was concerned, recovering 89 per cent of the values, but it was too expensive for the recovery of the copper. By this method 3,100 tons were treated at the mine, yielding an average of 3.5 per cent copper and 28 ounces of silver to the ton. A small smelter was also installed. Iron pyrite was shipped from Ophir, Colo., and coke from Dakota coal was obtained from ovens about 4 miles west of Naturita, or 28 miles east of the mine. The product was a copper matte running high in silver.

PROBABLE ORIGIN OF THE ORE.

S. F. Emmons,[a] in reviewing the occurrence of copper in the "Red Beds" of the Colorado Plateau, mentions a large number of deposits which are found in sedimentary rocks far from outcrops of contemporaneous or later igneous rocks. In regard to the origin of some of these occurences, his observations "favor the idea that the ore has been leached down from above and is of secondary origin, rather than that it is an original deposit from uprising solutions." F. L. Ransome,[b] in discussing the uranium and vanadium minerals, which occur in the La Plata sandstone of the Colorado Plateau near Placerville, Colo., and elsewhere, suggests that the deposits of these minerals "are local concentrations from the bulk of the sandstone." The ore deposits at Cashin probably belong generically to the same class, though they are distinctly fissure deposits. It is always possible that an igneous body may underlie any sedimentary rock, and the laccolith which formed the La Sal Mountains may have sent out thin intrusive sheets between the sediments to points much nearer Cashin than those at which these rocks now outcrop; but such intrusive sheets were not observed at any of the places where they should be revealed at points nearer the La Sal Mountains than the Cashin mine and at horizons lower in the sedimentary series.

The general occurrence of small bodies of low-grade copper minerals in the "Red Beds" of the Colorado Plateau suggests these formations as a possible source of the Cashin ores. The sedimentary rocks, consisting mainly of massive sandstones alternating with thin-bedded sandstones and shales, dip toward Cashin from the La Sal Mountains. Their higher outcrop is several thousand feet above their outcrop at Cashin, and the dip of the beds is approximately the slope of the surface. The water circulation is down the dip from the higher country, and where the rocks are cut through by erosion it manifests itself as springs in the deeper valleys. Often these springs are highly charged with salt or alkali, and some of them contain considerable quantities of hydrogen sulphide. Such springs were noted in Fisher Creek Canyon north of the La Sal Mountains. It is not known whether or not these waters carry a trace of copper, but some of them are at least capable of dissolving copper,

[a] Bull. U. S. Geol. Survey No. 260, 1905, p. 221. [b] Am. Jour. Sci., August, 1900, p. 120.

and others would precipitate the metal from dilute solutions. The solutions, moving down the dip in the various sandy beds, would rise when they reached the fissure and an artesian circulation would be established. In the fissure the mingling of solutions would cause a precipitation of metallic sulphides. The absorptive action of the kaolin, which is abundant in the zone of crushed quartz, may also have operated to deposit the ore.

The veinlets of argentiferous copper sulphides suggest that there has been a secondary concentration of the ore. All the metallic minerals belong either to the group which is commonly regarded as secondary or are those which usually occur in the oxidized zone. So far as the development has proceeded, there is nothing to indicate that the original ore was a copper-iron sulphide, for pyrite and chalcopyrite are almost entirely absent, and a complete analysis of the dump gave less than 2 per cent of iron.

ORE DEPOSITS IN THE ST. JOE RIVER BASIN, IDAHO.[a]

By ARTHUR J. COLLIER.

INTRODUCTION.

The region herein described lies south of and adjacent to the Cœur d'Alene mining districts of northern Idaho, which are the most important sources of argentiferous lead ore in the United States. It comprises parts of 30 townships, mostly unsurveyed, included within the limits of the Northern Pacific land grant. Though not very remote from railroads and populous mining towns, it is undeveloped and practically unexplored, since it is situated in the heart of the Cœur d'Alene Mountains. For this reason it has been included within the limits of the proposed Shoshone Forest Reservation. In 1899, 1900, and 1901 these lands were investigated by a United States mineral commission, appointed to examine lands within the Northern Pacific grant, and were by that commission classified as mineral lands.[b]

This classification being protested by the Northern Pacific Railway, F. M. Goodwin, special agent of the General Land Office, and the writer were detailed to make an examination of the lands in question preparatory to a hearing ordered for October 1, 1905, at the land office in Cœur d'Alene, Idaho. In accordance with instructions two months were spent in a rapid reconnaissance of the region in controversy, in the course of which a sketch map of the parts traversed was made and nearly all the reported prospects of valuable minerals were examined. Surface indications of silver, lead, copper, and gold ores were found to be widely distributed in the region, but there has been little development and, with one exception, no commercial ores have been produced. The following notes and maps, based on the writer's own investigations and the sworn testimony of many other witnesses, have been prepared in view of the fact that the region is practically unknown, either geologically or geographically, and because the surface indications of valuable ores seem to warrant investigation.

GEOGRAPHY.

Nearly all these lands (see Pl. IV) lie within the drainage basin of St. Joe River, a tributary of Lake Cœur d'Alene. A small part along the southern border is drained by Little North Fork of the Clearwater. The western limit of the area is near meridian 116° 10′, and it extends eastward to the Montana-Idaho boundary, which in a sinuous line follows the summit of the Cœur d'Alene Range. This district (see sketch map, fig. 6) lies south of and adjacent to the area which was covered by the Cœur d'Alene special map of the United States Geological Survey and whose geologic and economic features have been

[a] This river has appeared on nearly all published maps as the St. Joseph. The name as written above, however, conforms with local usage and has recently been approved by the Board on Geographic Names.

[b] The act creating this commission provides in part "That all said lands shall be classified as mineral which by reason of valuable mineral deposits are open to exploration, occupation, and purchase under the provisions of the United States mining laws, and the commissioners in making the classification herein provided for shall take into consideration the mineral discovered or developed on or adjacent to such lands, and the geological formation of all lands to be examined and classified, or the lands adjacent thereto, and the reasonable probabilities of such land containing valuable mineral deposits because of its said formation, location, or character." (Sec. 3, act of February 26, 1895, 28 Stat. L., 683.)

described by Ransome.[a] Its southern boundary is about 20 miles north of the northern limit of the area covered in Lindgren's reconnaissance across the Bitterroot Range.[b]

This region is traversed by few lines of travel. Steamboats on St. Joe River can approach within 15 miles, and above the head of such navigation canoes can be poled up the swift water well into the heart of the district here described. There are, consequently, a few scattered settlements along the river. Along the main divides old, well-beaten trails, often referred to as parts of the "Lolo" trail, have been traveled by the Indians since prehistoric times. There are also two trails made by hunters and trappers, which start from Wallace and De Borgia, respectively, and cross the St. Joe drainage basin from north to south, joining the "Lolo" trail on the Clearwater divide. The northeastern border of the district is crossed for half a mile by a wagon road built from Saltese, Mont., a station on the Northern Pacific Railway, but with this exception there are no wagon roads, though a contract has been let for building one along the Wallace trail to the St. Joe.

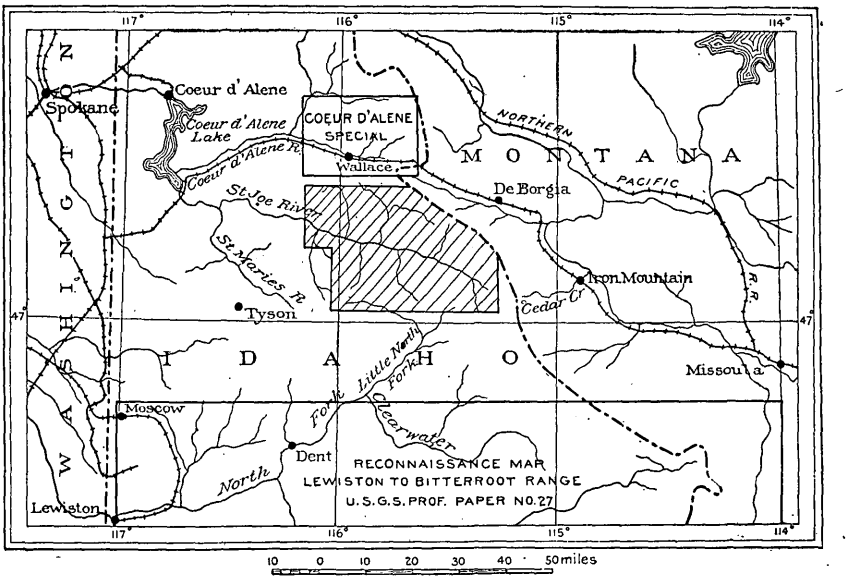

FIG. 6.—Map showing location of St. Joe River basin.

TIMBER AND AGRICULTURAL LANDS.

The whole region has been more or less heavily timbered, but forest fires occurring at intervals during the last twenty years have burned over large areas. About 15 per cent of the land, distributed in small patches, carries merchantable timber. Nearly all of the remainder is covered by a thick growth of underbrush and small trees, some of which are large enough for mining purposes. For this reason prospecting and travel away from the trails are difficult. All the mountains and ridges which rise above an elevation of 5,000 feet are timbered with "balsam fir" and hemlock, reported to be of little value, but at lower elevations the timber consists of red fir, white pine, tamarack, and cedar, all of which are valuable.

The agricultural lands are confined to the narrow bottoms along the creeks and rivers. It has been estimated that there may be as much as 400 acres of land suitable for agriculture along St. Joe River within the district and 200 to 400 acres more distributed along some of the tributary streams. On account of the heavy undergrowth and timber only a small part of this land is suitable for grazing at the present time.

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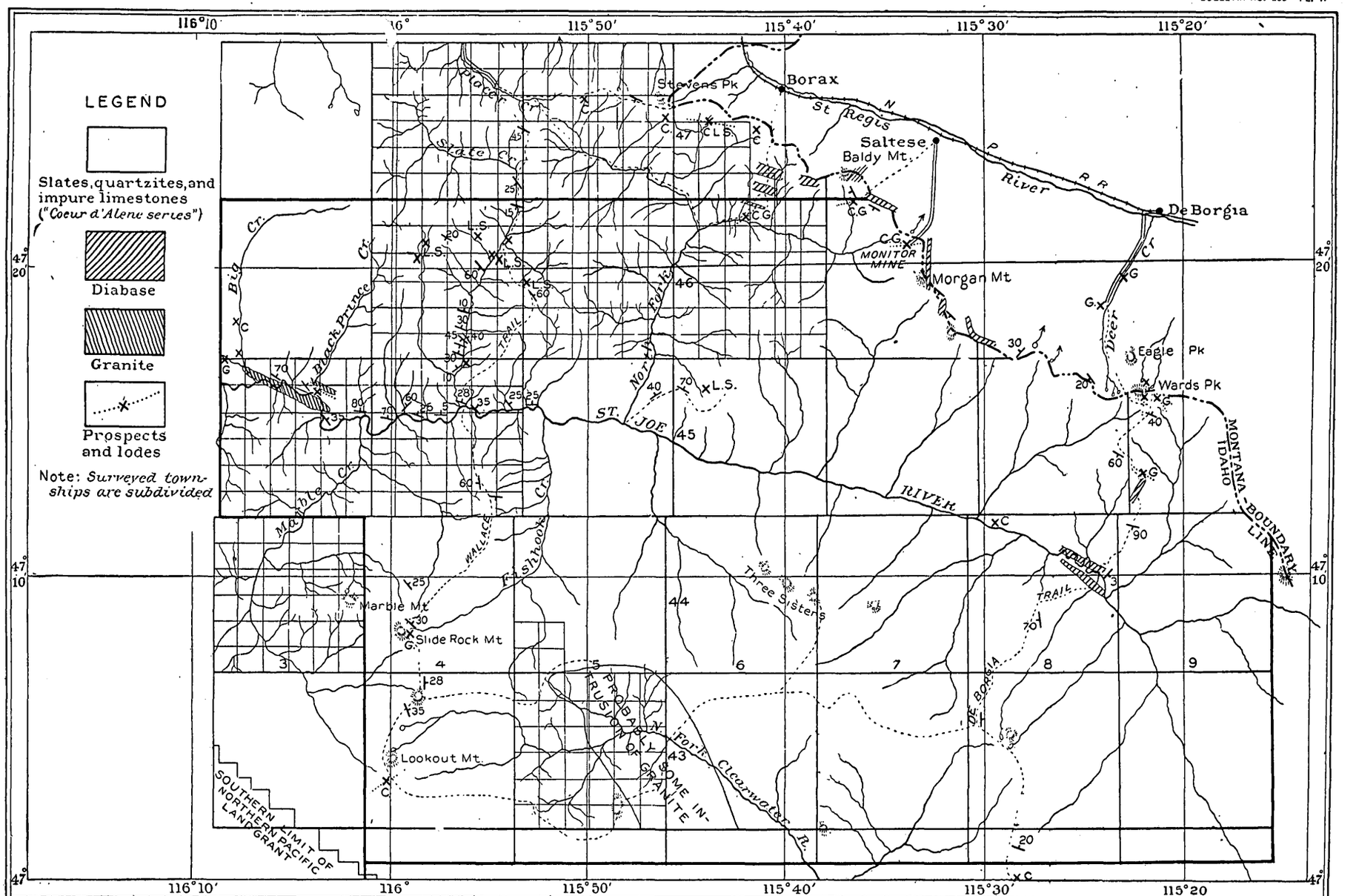
[a] Ransome, F. L., Ore deposits of the Cœur d'Alene district, Idaho: Bull. U. S. Geol. Survey No. 260, 1904, pp. 274–303.

[b] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, Pl. I.



MAP OF THE ST. JOE RIVER DISTRICT, IDAHO.

RELIEF AND DRAINAGE.

The relief and general topographic features are similar to those of the Cœur d'Alene mining district. The elevations range from about 7,000 feet at Wards Peak to about 2,100 feet at the lowest point within the district, on St. Joe River. Seen from the mountain tops the region has the aspect of a rolling plateau dissected by canyons to a depth of 1,000 to 3,000 feet. This plateau is regarded as a peneplain produced by the erosive action of streams and rivers when the land surface stood at a lower elevation. At that time the principle drainage channel was in a broad valley having about the same general position as St. Joe River. After the formation of this old surface the whole region for many miles both north and south of this district was elevated as a great block, from which the Cœur d'Alene Mountains have been carved.

The floor of the old valley, which in places was deeply gravel covered, has been elevated to an average height of 1,000 feet above the present river bed and dissected with the remainder of the plateau, leaving a series of gravel-capped hills. All the rivers and creeks lie in narrow canyons. They are characterized by steep gradients and comparatively large volumes of water. St. Joe River, the large trunk stream of the district, has a broad bowlder-strewn bed through most of its length, with occasional narrow flood plains and gravel benches. At two points the walls of the valley contract, forming what are locally called "box" canyons. The upper of these canyons, which lies just west of the crossing of the De Borgia trail, contains several waterfalls and marks the head of canoe navigation. Many of the tributary streams head in small glacial lakes on the flanks of the higher mountains at elevations above 5,000 feet. Their canyons contain few deposits of gravel or sand and in them the bed rocks are usually exposed. Owing to their high gradients and volumes many of the streams could be used for water power, and a few water-right locations have been made, though in no case has a power plant been installed.

GEOLOGY.

The prevailing rocks of this district comprise a series of arenaceous and argillaceous sediments, which as a whole show little contrast. Nearly all the beds are characterized by shallow-water features. The rocks are identical with those making up the series exposed in the Cœur d'Alene district, which have been examined with great care by Ransome and Calkins.[a] They are of Algonkian age and, as exposed in the area of the Cœur d'Alene special map, have a thickness of about 15,000 feet. The series comprises six formations, differing slightly from each other, which, arranged in order from the top of the series down, are called the Striped Peak, Wallace, and St. Regis formations, Revett quartzite, Burke formation, and Prichard slate. Although in the St. Joe region the rocks have been examined only in hasty reconnaissances, it seems probable from the observations made that all the formations distinguished by Ransome and Calkins in the Cœur d'Alene district are represented. The structures also are nearly if not fully as complex. The rocks are intensely folded, the dips varying from nothing to 90° and the prevailing strikes being about west-northwest. Overturned folds have been noted in a few instances and faulting is a common feature. Most of the faults strike approximately west-northwest and east-southeast, parallel with the prevailing strikes of the bed rock, though some having an approximate north-south direction have also been recognized, and in a number of instances a well-developed joint system also striking northwest and southeast was observed. In the northern part of the district the rocks are unaltered, and only the softer beds are affected by slaty cleavage. In the southern part, however, from St. Joe River to the southern limit of the region examined, the rocks become progressively more schistose, the softer beds especially being altered to mica-schists, often studded with garnet and staurolite. All gradations between the unaltered sediments of the northern part of the district and these schists can be observed.

[a] Ransome, F. L., Ore deposits of the Cœur d'Alene district, Idaho: Bull. U. S. Geol. Survey No. 260, 1905, pp. 277–285.

Lindgren [a] has mapped a great batholith of granite, covering an area as great as 5,000 square miles, which forms the whole mass of the Bitterroot Range south of this district. The increasing schistosity of these rocks to the south is probably to be accounted for by the proximity of this great intrusive mass, the northern limits of which have not been determined.

Igneous rocks occur as dikes, sills, and stocks intruded in these sediments at various places. They fall into the two groups, diabases and granites, which are of about equal importance as regards distribution. Diabases occur as dikes and sills cutting the sedimentary rocks, more commonly in the northeastern part of the district, though some smaller dikes occur in the southern and western parts. Some of the larger areas of diabase are shown on the map, Pl. IV. The largest mass observed is cut by St. Joe River at the upper box canyon. Several smaller masses, which were observed near the Cœur d'Alene divide, between Stevens Peak and Wards Peak, appear sometimes as dikes, but more often as sills. As far as observed their outcrops either extend north and south or northwest and southeast. This rock has a granitic texture; it consists essentially of plagioclase and augite, with quartz as an accessory mineral and magnetite and ilmenite as important constituents.

The granites are more local in their distribution and have been observed by the writer only along St. Joe River in T. 45 N., Rs. 2 and 3 E. Mr. Thomas Cooney, a mining engineer employed by the Northern Pacific Railway, reports that they also occur in the E. ½ of T. 43 N., R. 5 E. Although examined only cursorily these rocks seem to be intrusive masses in quartzites of the Cœur d'Alene series, which near the contacts are changed to hornfels. They consist essentially of quartz, orthoclase and plagioclase feldspars, and biotite. All of the minerals show more or less crushing and distortion, indicating disturbances subsequent to the intrusion of the granite.

In the Cœur d'Alene district two types of igneous rock have been recognized.[b] The most important of these is a coarse-grained syenite, which has a tendency toward porphyritic development of the dominant feldspar. These rocks occur as irregular stocks and dikes and find their greatest development in the vicinity of the most productive group of lead and silver mines, though no causal relation between them and the ore deposits has been established. The rocks of the second type occur in dark-colored dikes near the southern edge of the Cœur d'Alene area, and are of minor importance in that district. They are diabases consisting essentially of plagioclase feldspar and augite, with quartz as an important accessory. The granites of the great batholith of the Bitterroot Range are described by Lindgren [c] as quartz-monzonite, a variety of granite containing both orthoclase and plagioclase feldspars.

By a comparison of the igneous rocks found in this region with those described from the Cœur d'Alene district on the north and the Bitterroot Range on the south, it seems evident that the granites of the St. Joe Valley differ considerably from the syenites of the Cœur d'Alene district and are more nearly like the quartz-monzonites of the Bitterroot batholith. The diabases are probably of almost identical character with those from the Cœur d'Alene district, but they occur in much larger masses and are therefore of more importance.

ECONOMIC GEOLOGY.

Lead-silver, copper, and gold ores have been found, and some attempts to develop valuable deposits of these minerals have been made at many places within the area under investigation, but most of the prospecting and development have been unsystematic and desultory. The region is difficult of access and devoid of means of transportation. Most of the reported mineral discoveries and prospects are situated along the northern and eastern boundaries, which are fairly accessible from the line of the Northern Pacific Rail-

[a] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 18.
[b] Ransome, F. L., op. cit., p. 282.
[c] Lingren, Waldemar, op. cit., p. 18.

way, near the few trails which cross the district from north to south, or adjacent to canoe navigation on St. Joe River. From the evidence adduced it appears that placer gold was discovered on the headwaters of St. Joe River at what is called the St. Joe Basin as early as 1870 by prospectors crossing the divide from Iron Mountain, Montana. This district, however, is so remote from transportation and the placers are of such low grade that the ground has not yet been systematically worked, though small amounts of gold have been obtained. The search for lead-silver and copper ores was inaugurated in 1884 or 1885, after the discovery of the valuable lead-silver deposits of the Cœur d'Alenes.

LEAD-SILVER DEPOSITS.

Croppings of rock containing galena were examined in prospect holes at several points along Slate Creek, near the trail from Wallace to St. Joe River, in T. 46 N., Rs. 4 and 5 E.; also east of North Fork of St. Joe River in T. 45 N., R. 6 E. Similar mineral indications on which considerable time and money have been spent occur in the northern part of T. 46 N., Rs. 1 and 2 E., just outside the area under investigation. The occurrence of galena-bearing rock at a number of other localities not personally examined was indicated by the testimony of various witnesses adduced at the hearing. Most of the prospects examined lie within a belt a few miles wide extending from T. 45 N., R. 6 E., in a west-northwest direction to and beyond the limits of the district under investigation. In some instances the galena-bearing rock consists of so-called "iron cap" or gossam, a mixture of hematite, limonite, and quartz containing some unaltered galena which can easily be recognized when the specimens are newly broken. In many of the prospect holes, however, the galena is found to be disseminated in small grains and veinlets through the country rock, which on the surface is yellowish brown from iron stains. In such cases the galena is associated with more or less siderite and sphalerite, together with some pyrite and chalcopyrite. This association of minerals resembles that in the ores from some of the mines of the Cœur d'Alene district,[a] which have replaced the country rock in proximity to mineralized fissures or fractures.

In sec. 14, T. 46 N., R. 5 E., gossan, consisting largely of limonite, in which there is some unaltered galena, is exposed in several prospect holes which have been abandoned and are so much caved in that the nature of the occurrence can not be determined. In sec. 13, one-fourth mile southeast of this locality, the bed rock exposed in a steep hillside shows considerable disturbance and an overturned close fold, but no definite fissures or fractures were observed. Nearly all the rocks here are iron stained and in some places contain galena disseminated in small masses. A tunnel about 40 feet long was driven several years ago, when, it is reported, considerable galena ore could have been obtained, some of which was rich enough for shipping. No definite vein or ledge, however, was found. In the NW. ¼ sec. 11, about three-fourths of a mile northwest of the prospects described, a 3 or 4 foot bed of quartzite containing disseminated siderite, together with galena, sphalerite, pyrite, and chalcopyrite, is exposed in a tunnel 30 feet long. This mineralized bed is overlain by a fissile shaly bed which is not mineralized. It lies nearly horizontal and its outcrop can be traced for some distance along the hillside. No definite indication of a mineralized fracture or fissure has been found here, though near the end of the tunnel there is a zone 4 or 5 feet wide in which the rock is broken by many parallel joints which strike N. 20° W. and are nearly vertical.

About 1½ miles west of these prospects there are a number of locations on the headwaters of the West Fork of Slate Creek and near the southwest corner of sec. 9. In one prospect hole examined mineralized quartzite containing galena and sphalerite similar to that already described was found. No definite indications of any mineralized fracture or fissure were seen here by the writer, but from the testimony presented at the hearing it is evident that a heavy "iron cap" consisting mainly of vein quartz and botryoidal hematite has been discovered and partially developed. This material when assayed showed

[a] Ransome, F. L., op. cit., pp. 293–298.

small values in silver and gold, though it contains no unaltered galena. Small amounts of galena were also found in several other prospect holes in this vicinity, in which the relations are similar to those already described and which need not therefore be mentioned in detail.

In T. 45 N., R. 6 E., about 10 miles in a direct line S. 60° E. from the prospects just described, a similar occurrence of galena in quartzite was examined. Here a gray quartzite containing siderite and galena lies nearly horizontal, but is cut by a number of parallel joints which strike N. 70° W. Considerable prospecting was done several years ago in sec. 3, T. 45 N., R. 4 E., and two of the old tunnels are still open. The rocks here are broken by a system of vertical joints which strike N. 70° E. There is no evidence of displacement along these joints, but several of them contain quartz veins, the largest of which, about 6 inches wide, thins down to nothing in a distance of 40 feet. The quartz is honeycombed with iron-stained cavities and contains some weathered pyrite. Prospectors report that the unweathered ore contained galena, and that there was also a large ledge or "blow-out" of galena ore exposed in the creek bed at a point now covered with gravel. Galena-bearing rocks were reported by many witnesses from other localities, and though most of these were not examined by the writer it may reasonably be believed from the evidence presented that such minerals are widely distributed. As far as observed the rocks in which these ores occur belong in the Cœur d'Alene series, and probably for the most part in the Wallace formation. The prevailing strikes, both of the bedding planes and of the most definite systems of jointing and cleavage, are approximately N. 70° W. Samples of such ores taken from seven different localities were assayed for lead and silver, and though none of them were found to carry values sufficient to make them commercial ores under present conditions, all showed the presence of more than traces of these metals in the average proportion of one-third of an ounce of silver to 1 per cent of lead. In the Cœur d'Alene district this proportion is about one-half an ounce of silver to 1 per cent of lead, and it is evident, therefore, that these ores are somewhat lower in silver than those of the Cœur d'Alene district. The only sample collected by the writer which was tested for gold was found to carry 0.02 ounce of gold to 1 per cent of lead. From the testimony of a number of other witnesses who have had analyses made of ores from this region it seems to be true that generally these ores are richer in gold than the lead-silver ores of the Cœur d'Alene district.

COPPER DEPOSITS.

Copper ores, some of which are in valuable deposits, are well distributed over the whole district. These probably occur in several of the Cœur d'Alene formations, and although they are all connected with definite fractures or lines of faulting they present some variety in their occurrence. The most important series of prospects is found in a belt about 6 miles wide extending for about 16 miles southeast from Stevens Peak along the Montana-Idaho boundary. A great deal of development work has been done in this belt, since it is easily accessible from points on the Northern Pacific Railway. The ore bodies here are deposited in fault fissures which strike approximately east and west. Although the intrusive masses of diabase already mentioned are common in this vicinity, none of the copper-bearing ledges have been definitely connected with them. These ledges are for the most part contained in rocks which probably belong to the Wallace formation and the displacements along the fissures are probably not very great. Croppings of the veins are usually indicated by heavy "iron caps," which sometimes project above the surface, forming what are locally called "blow-outs." The gossan usually consists of breccia derived from the wall rocks cemented by hematite and limonite. It usually contains the copper carbonates, malachite and azurite. At greater depths the ore is still mixed with broken country rock, but the vein matter consists of calcite, siderite, and some quartz, with more or less sulphides of copper and iron. In one instance galena and chalcopyrite are present in nearly equal amounts, but usually galena is not present. Nearly all these ores carry considerable gold.

The Bald Mountain ledge, situated near the north line of T. 46 N., R. 7 E., may be taken as a typical example of the copper-bearing veins in this belt. This ledge is developed by a tunnel for nearly 1,000 feet. It strikes approximately east and west, but does not extend in an exactly straight line, and dips to the north at an angle of about 60°. The ledge matter varies in width from 1 to 8 or 9 feet and consists of brecciated quartzite similar to the walls, cemented with vein matter consisting of quartz, calcite, and siderite, in which sulphides of copper and iron are contained. At one point there is a definite ore shoot several feet thick, extending for 100 or 200 feet along the tunnel. The ore in this shoot consists of nearly pure siderite containing chalcopyrite scattered through it. When assayed a specimen of this ore was found to contain 1.5 per cent of copper, 0.02 ounce of gold, and 1 ounce of silver per ton. At the face of the tunnel the ledge consists of brecciated country rock cemented together by quartz, with some calcite and siderite. A specimen of the most promising ore in the face was assayed, showing a trace of gold and 1.42 per cent of copper. The croppings of this ledge are said to be easily traceable on account of a heavy "iron cap." Some distance beyond the end of the tunnel an ore shoot which promises to be considerably richer than that described has been found and toward this the tunnel is being extended.

The Monitor mine, also in T. 46 N., R. 7 E., and about 2½ miles southeast from the Bald Mountain, is the only one which has actually produced ores on a commercial scale. It is connected with the railroad at Saltese, Mont., by a wagon road 5½ miles long. The developments have not yet progressed far enough to tell definitely either the dimensions of the ledge or the direction of its strike, but it is evident from the developments already made that it is of the same type as the Bald Mountain ledge already described. The strike is said to be nearly east and west and it dips about 80° N. The ore consists of a great deal of brecciated material cemented by vein matter and is evidently deposited along a fault. That the movement has continued since the deposition commenced is shown by slickensiding of some of the ore. The mine is developed by a shaft to a depth of 300 feet, and by short tunnels on the 100, 200, and 300 foot levels. Above the 100-foot level nearly all of the ore is oxidized and consists of hematite and limonite mixed with the carbonates of copper. Below a depth of 125 feet, however, there are no carbonate ores, and the principal copper-bearing mineral is chalcopyrite associated with pyrrhotite. Evidently the main shaft of the mine has been sunk directly on a rich ore shoot which cropped at the surface. The ore body is probably at least 10 feet wide, though the walls are not yet well defined and its extent has not been determined. Ores from this mine carry considerable gold as well as copper. In the oxidized upper portion the gold value is often as high as $12 per ton, but below the 60-foot level it ranges from $3.60 to $8 or $9 per ton. The copper ore shipped ranges from 10 to 30 or 40 per cent. This mine was discovered in 1897 and the first shipment of ore was made in 1900. In all, about 500 tons of ore have been sent to the smelter. The ore is first hauled by wagon 5½ miles to Saltese, Mont., whence it is shipped by rail to Tacoma, Wash.; the total cost of shipping and smelting amounts to nearly $8 per ton. Three hundred tons of the ore netted the owners of the mine $34.85 per ton after the freight and smelting charges were deducted.

In the immediate vicinity of the Monitor mine, both west and south for 6 or 7 miles, copper-bearing ledges have been located which are reported to be of the same general type. One of these, known as the Buffalo, crosses the Montana-Idaho boundary and was examined by the writer. This mine or prospect is about 8 miles southeast of the Monitor, and is being developed on the Montana side, where it is reported to carry good prospects in copper. Where it crosses the divide the vein is exposed in an open cut. It is here several feet wide and the ore consists for the most part of spathic iron containing very little, if any, copper or gold.

Other locations in this belt where development is in progress and in which the general relations are believed to be similar to those described are known as the Park, Springfield, Champion, Wonderful, Eagle, Bullion, North Star, Alpino, Richmond, Leroy, Wampum, and Kootenai Giant claims or groups of claims. Outside of this belt, which lies along the

Montana boundary, the copper prospects are scattered and undeveloped. Several copper-bearing ledges along St. Joe River below the crossing of the De Borgia trail are reported by prospectors, but these have not been examined by the writer, though specimens of copper ore consisting of chalcopyrite and quartz were found in the gravels in St. Joe River near the point where the De Borgia trail crosses. A rather promising copper prospect in which the ore consists for the most part of carbonates is reported from T. 42 N., R. 8. E., near the southern boundary of this district.

In T. 45 N., R. 3 E., there is a group of copper prospects, some of which have been partially developed. They occur for the most part in a white quartzite, which may be identical with the Revett formation, and near some masses of intrusive granite. The best known of these, called the Black Prince, is situated at the mouth of Black Prince Creek, in section 10, and is developed by two short tunnels, but it has been abandoned for several years. The ore body consists of brecciated quartzite, having the interstices filled with vein quartz which contains a considerable amount of bornite, chalcopyrite, and pyrite. Some well-defined joints, one of which seems to mark the wall of the ore body, strike N. 65° W. On the dumps of this tunnel there are several tons of rather promising ore, but the face of the tunnel shows only narrow stringers of ore, surrounding the fragments of quartzite. Two samples, one taken from the face of the tunnel and the other from the surface croppings, were assayed, showing the presence of copper and gold, but no trace of silver. Copper-stained débris has been found for several miles northwest from the Black Prince, and near Big Creek, which joins St. Joe River in section 5, there are several partially developed prospects, some of which promise to yield copper ores, while others may lead to deposits of lead and silver or gold. The prospects examined show a large deposit of gossan, in which neither galena nor stains of copper were recognized. Assays of samples taken at random showed small amounts of gold and silver, but no trace of copper. Prospectors interested in the development of these claims report that the assays which have been made range from 80 cents to $10.75 in gold. The development has not progressed far enough to show the course of the veins. Near them, however, there are outcrops of breccia indicating a fault which strikes N. 70° W., and it is probable that the course of the heavily mineralized deposits just described will be found to be parallel with it. To the north of this place, for several miles along Big Creek, in T. 56 N., R. 3 E., there are reported to be prospects showing carbonates of copper, but these were not examined by the writer.

In T. 43 N., R. 4 E., considerable prospecting has been done on a vein carrying pyrite, chalcopyrite, and bornite in white quartz. From the testimony of other witnesses this seems to be a well-defined vein traceable for 400 or 500 feet in a northeast-southwest direction, and contained between walls of schistose quartzite, which is probably equivalent to the Revett quartzite of the Cœur d'Alene district. The vein is reported to be about 10 feet wide and is developed by several open cuts and a tunnel 36 feet long. An average sample of the ore taken across the ledge is said to have yielded $2.48 in gold, silver, copper, and lead. A picked sample which was assayed for the writer was found to contain a trace of gold, 0.8 ounce silver, and 2.1 per cent of copper. Copper ores have been reported by prospectors from many other parts of this region, but except in the localities described there have been no attempts at development and the prospects were not examined.

PLACER-GOLD DEPOSITS.

This region has been prospected more or less for placer gold for the past forty years, and although there are placer-mining districts a short distance away on nearly all sides, attempts to locate valuable deposits of this kind have here been unsuccessful. In the surrounding regions placer gold is mined at Murray[a] in the Cœur d'Alene district, at Tyson, about 10 miles west of the southwest corner of this district; near Dent and Orofino,[b]

[a] Ransome, F. L., op. cit., pp. 299–300. [b] Lindgren, Waldemar, op. cit., pp. 84–85.

on North Fork of Clearwater River, from 10 to 20 miles south; at Moose Creek,[a] Cedar Creek, and St. Joe basin, near the southeast corner of this district; and at Deer Creek, near the northeast boundary.

On the headwaters of St. Joe River a small placer district, locally called the St. Joe basin, is partly within the area covered by the map, Pl. IV, though the protest regarding that part of the classification has been dismissed. Owing to the short time available for field work and the fact that it is outside the area involved in this hearing it was not examined by the writer. Gold was discovered as early as 1870, and a few men have mined here continuously for the past ten years, but no large amounts of gold have been obtained. The district is said to be 25 miles distant from Iron Mountain, Montana, from which place a wagon road leads up Cedar Creek to within a few miles. Cedar Creek in Montana, a tributary of Missoula River, and Moose Creek in Idaho, a tributary of Clearwater River, are placer-bearing streams in the same vicinity. St. Joe basin, so called, is described as a gravel-covered flat several miles long, containing about 320 acres, at the head of Middle Fork of St. Joe River. The auriferous gravels here are deep and owing to a reef of bed rock near the lower end of the deposit it has been impracticable to drain them, so that except around its rims the basin deposit has not yet been worked. Medicine, Wisdom, Sherlock, and Rocker creeks are small placer-bearing streams tributary to the basin, and probably contributed much of the gold in the larger deposit. The bed rock along these streams is reported to be quartzite cut by "seams of quartz and talc," containing free gold. Coarse colors of gold are found in the gravels of St. Joe River as far down as the crossing of the De Borgia trail, but attempts to locate valuable deposits below the basin have not been successful. The gravels along St. Joe River through its whole length contain large quantities of garnets and of black sand consisting of magnetite and ilmenite.

Near the western boundary of this district, in T. 45 N., Rs. 2 and 3 E., there are deposits of auriferous gravel along Mica Creek, from which it is possible that miners could make wages by sluicing. Attempts at placer mining have been made at several other places, but none of these have been at all successful.

GOLD-QUARTZ VEINS.

It has been shown that some of the ledges described as copper deposits also carry considerable amounts of gold. Near Wards Peak, however, in the eastern part of the district, and from that point southward for several miles, the rocks are cut by distinctly gold-bearing quartz veins, some of which are undoubtedly of economic value. Two such veins southeast of Wards Peak are partially developed and were examined. The country rock here consists of a sericitic slate or quartzite, which is probably equivalent to the Prichard slate of the Cœur d'Alene district. It is cut by quartz veins, which extend more nearly north and south than east and west. One of these, called the Gold Mountain vein, has a width of about 15 feet; it strikes N. 20° W. and stands nearly vertical. It has been traced northwestward about one-fourth of a mile and is there exposed in the face of a steep cliff. Two large stringers parallel with the bedding of the slate lead off to the west from the main vein. The ore of the Gold Mountain lode consists for the most part of white quartz, but near one of the walls it is heavily mineralized with pyrite in large tubes. Where developed by the shaft this pyrite is altered to hematite or limonite, in which the free gold can often be seen by the naked eye. Picked samples of this ore when assayed showed values exceeding $60 in gold to the ton, while average samples carefully taken across the whole width of the ledge are reported to yield about $10 in gold per ton.

The Revenge lode, which lies about half a mile west of the Gold Mountain, strikes a little east of north. It has a width of about 5 feet and its ore, like that of the Gold Mountain ledge, consists of weathered pyrite contained in white quartz. This pyrite, however, is much more evenly distributed through the quartz than is the case in the Gold Mountain

[a] Lindgren, Waldemar, op. cit., p. 108.

ledge. Picked samples of this ore yielded when assayed about $40 in gold to the ton. It is reported that average samples indicate that the ore will run not far from $10 per ton.

Both these veins appear to be widest where they cut a diabase dike 100 feet wide, which extends N. 80° E. The effect of the dike seems to be purely mechanical, since away from it the veins show a tendency to divide up into stringers.

A vein called the Mother lode, situated on a spur of Wards Peak about half a mile north of the boundary, consists at the surface of two veins, each about a foot thick, which come together in the face of the tunnel 25 feet in from the surface. Both these veins are cut by a horizontal fault having a throw of about 1 foot.

Similar ores occur about 2 miles north of the boundary around Eagle Peak, and about 5 miles north of the boundary, in a mine owned and formerly operated by the Deer Creek Mining Company. This mine is equipped with a small stamp mill, which was idle during the past season. The company also controls some placer deposits along Deer Creek, on which development work was in progress in September, 1905. The gold in the quartz ledges of this neighborhood is free as far as the ledges have been developed. It seems probable, however, that in depth it will be found refractory and will require concentrating and smelting.

Fragments of quartz similar to or resembling that at Wards Peak were found strewn on the surface along the De Borgia trail to the southern limit of the area examined. In this distance one large quartz vein 10 feet or more in width and several smaller veins were seen. A sample from the large vein was found to contain traces of gold and half an ounce of silver to the ton. Only one of the smaller veins was sampled and assayed, but this was found to contain no traces of gold. In the altered quartzites and schists found in the southwestern part of the district a few small quartz veins were noted. One of these, which cropped out along the trail near Slide Rock Peak, in T. 44 N., R. 3 E., is about 1 foot thick and lies between the bedding of the country rock, which here probably belongs to the Prichard formation, though it is altered practically to a mica-schist. A sample taken from this vein when assayed yielded a trace of gold and no silver.

Very little prospecting has been done in the southern part of this district, and no prospect holes were seen by the writer. It is remote from settlements and difficult of access. The obvious occurrence here, however, of small quartz veins carrying traces of gold seems to warrant the belief that there may be some gold-bearing veins of economic value.

RÉSUMÉ AND CONCLUSION.

This region is practically unexplored and undeveloped, though its geologic and topographic conditions are quite similar to those of the Cœur d'Alene mining district, to which it is adjacent. Prospects, more or less promising, of lead-silver, copper-gold, and gold ores have been found at many widely distributed localities, most of which are along the trails or adjacent to the larger streams. Commercially, valuable ores have been produced at only one of these localities.

Most of the lead-silver prospects are in the northwestern part, and the ore consists of galena, either distributed through the country rocks or contained in masses of limonite or iron caps, whose relation to the country rock has not yet been determined. These ores average one-third ounce of silver to 1 per cent of lead.

The copper-gold ores are more widely distributed. They occur in definite veins developed along fault fissures, and their outcrops are indicated by gossan stained with copper carbonate. In depth the vein matter consists mainly of siderite, calcite, and quartz, with the sulphides of copper and iron. The proportion of gold to copper varies greatly, though it seems to average about 0.02 ounce of gold to 1 per cent of copper. Most of the development of these veins has been done in a belt a few miles wide near the Montana-Idaho State line, where about 500 tons of high-grade ore have been mined and shipped.

Gold placers of economic value are not known to occur within the area involved in this contest, though prospectors report that fine colors of gold can be obtained from the gravels

of many of the streams, and there is a small placer district adjacent to the southeastern part which has produced some gold for the past twenty or thirty years. Gold-bearing quartz veins, some of which are valuable, occur in the eastern and southern parts of the area in controversy. These veins contain free-milling ore at the surface, but will probably become base in depth. No gold ores except those in which copper is associated have been produced on a commercial scale.

Since these lands had already been classified by the United States mineral commission, the burden of proof as to their nonmineral character fell to the railway company. After reviewing the great volume of evidence presented, the officials of the Cœur d'Alene land office have made a report recommending that, with the exception of a few small tracts regarding which there is specific evidence of nonmineral character, the mineral classification be allowed to stand.

COPPER DEPOSITS NEAR LURAY, VA.

By WILLIAM CLIFTON PHALEN.

INTRODUCTION.

In an investigation of the copper deposits of the eastern United States by Mr. W. H. Weed, the writer was detailed to reexamine several properties in the Blue Ridge region near Luray, Va. The special object of this work was to find additional evidence concerning the genesis of the ores, previous examinations by Mr. Weed having resulted in conclusions wholly at variance with the opinions held by the various companies operating in the region. This paper is based on field observations and careful study of thin sections under the microscope.

Location.—The region treated in the following notes lies at or near the summit of the Blue Ridge, between Page and Madison counties, Va., and along the western foothills of the same a few miles south of Luray, also near the crest of the ridge near High Knob, between Greene and Rockingham counties, some distance to the southwest.

THE ROCKS.

In general, the Blue Ridge in this section is made up chiefly of basalt, but along its western flank at various points may be seen the outcrop of an extensive mass of syenite. On the east flank of the ridge, near the head of Robertson River (Robinson River [a]) and a few miles southeast of Fishers Gap (Milams Gap [a]), in Madison County, there is an intrusion of biotite-granite. Of these rocks the basalt has the more interest in this connection from the fact that it carries the copper ore. It is inferred that this rock is the Catoctin schist of Keith,[b] and that it is coextensive with the South Mountain basalts of Pennsylvania described by Bascom [c] and Williams.[d] According to Keith, the rock is Algonkian in age.

The chief mass of the basalt, or melaphyre, or greenstone, as it has been variously termed, is dense and dark green, except where thoroughly epidotized, when it assumes a lighter-green hue. Its original constituents are not determinable without microscopic aid, save perhaps an occasional phenocryst of olivine. From the facts that bosses of syenite are seen in it in the region near Fishers Gap and that it has been subjected to an intense metamorphism along its contact with the syenite on the west slope of the ridge and wherever the two rocks are contiguous, it is inferred that the syenite is the younger of the two rocks. This inference is strengthened by the perfectly fresh, holocrystalline character of the syenite at the immediate contact and by the lack of weathered fragments or bowlders of the syenite in the basalt. This contact metamorphism has resulted in a more or less schistose rock, quite different from that of the main mass, which, in this particular district, is not regionally schistose. The basalt is regarded as more recent than the granite of the east side, from the metamorphism exhibited by the latter along the contact. This has resulted in a gneissoid belt several feet in width. These conclusions regarding the relative ages of the igneous rocks have been deduced from the examination of a limited number of contacts

[a] Names in parentheses are used locally.
[b] Keith, A., Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 296 et seq.
[c] Bascom, F., Bull. U. S. Geol. Survey No. 136, 1896, pp. 68 et seq.
[d] Williams, G. H., Am. Jour. Sci., 3d ser., vol. 44, pp. 490-496.

and are given subject to revision, as the writer is aware of their somewhat doubtful character.

The basalt is comparatively simple and is composed of plagioclase-feldspar, pyroxene, and magnetite, which may be titaniferous, together with olivine and the secondary constituents epidote, chlorite, serpentine-asbestos, quartz, the iron oxides, and leucoxene. The olivine occurs frequently as phenocrysts, sometimes 3 or 4 mm. in diameter, and generally presents a thoroughly corroded periphery surrounding a tolerably fresh nucleus. At times even this has disappeared, leaving a brownish-red mass of iron oxide to mark its former position. The results of the microscopic examination show profound alteration and the original constituents are not readily determined. Of the secondary constituents enumerated above, epidote is by far the most important. Some of this constituent, including part of that seen at the lowest worked levels, has been formed by interreaction between feldspar and pyroxene. The question of its various modes of origin is one of the most interesting chemico-geological problems of the region.

The syenite of the west slope has been referred to the hypersthene-åkerite type of Brögger and is essentially a quartzose augite-syenite. It is a coarse-grained dark rock with the feldspar, pyroxene, and quartz visible to the naked eye. It is made up of the minerals orthoclase, much of which is microperthitic, plagioclase, quartz, hypersthene, diallage, magnetite, apatite, zircon, and microcline, together with the alteration products epidote, chlorite, and sericite. Sometimes this rock is thoroughly epidotized, and then forms that peculiar rock known as unakite.[a]

The granite of the east base of the mountain, near Fishers Gap, is the biotite variety and has not been examined by the writer in thin sections.

THE COPPER ORES.

Developments.—The Blue Ridge in this part of the State is a single ridge composed entirely of igneous rocks. It has been mentioned that of these the basalt carries the copper. The occurrence of copper in this region has long been known. There is a tradition that on the land of the Blue Ridge Copper Company, 1 mile southeast of Fishers Gap, the metal was mined and shipped before the civil war. At the time of the writer's last visit, in May, 1905, an incline 42 feet in depth had been dug by this company about 150 feet above the confluence of the main head forks of Robertson River, and from the foot of the incline a 40-foot drift had been run in a northeasterly direction to intercept a supposed cupriferous zone in the old shaft 100 feet higher on the hill. Before this zone was reached operations were temporarily suspended and drilling had just begun on a third shaft northwest of the old shaft and higher on the hill. It is the company's intention to resume operations at an early date on the drift from the incline, and when the copper-bearing zone is reached to sink the old shaft still lower. A few tons of ore have already been shipped from this property.

The most extensive developments in this part of the State are those of the Virginia Consolidated Copper Company, whose property lies on one of the foothills at the west base of the Blue Ridge about a mile northwest of Ida post-office, 6 miles southeast of Luray. An inclined shaft has been sunk about 300 feet, and at the 80, 120, and 280 foot levels, drifts of varying lengths have been run off. At present (May, 1905) operations are temporarily suspended. It is the intention, however, to continue the shaft at least 200 feet lower. Besides the work of these two companies, more or less prospecting has been done in the vicinity of Stony Man and at the head of Overall Run, 13 miles northeast of Luray. The work seen at the former locality is very old. The most noteworthy instance is the old shaft reported 60 feet deep, but filled with water when visited. Near the head of Overall Run, in Warren County, prospecting on a small scale has been done very recently for Front Royal people on the so-called "Empire vein." Two abandoned shafts lower on the hills than the "vein" indicate that interest in the copper resources of the region was aroused

[a] Phalen, Smithsonian Miscellaneous Collections, vol. 45, 1903, p. 309.

some time ago. Both these shafts, when visited, were filled with water. The more recent, on the R. A. Martin tract, was sunk to a depth of 70 feet by Mr. S. M Boyd, of Philadelphia. It was worked intermittently during 1903 and 1904, work having been suspended at the end of the latter year. The older of the shafts is situated on the F. C. Hartley estate, below and southwest of the Boyd shaft. According to report it was worked over thirty years ago.

At the mines of the High Top Copper Company, near High Knob, about 7 miles southeast of Elkton, considerable development work has been done. In addition to several prospects scattered about the property a shaft has been sunk to a depth of 90 feet and about 300 feet farther down the hill a level has been run in about 50 feet. It is the intention of the company to sink the shaft and continue work in the level until the two intersect, as well as to sink other shafts and run other levels on them on the company's property to the northwest. At the present time the machinery on the ground aggregates 200 horsepower, with compressors and air drills for facilitating the work. It is the intention of the management to add largely to the equipment in the near future. Unfortunately, at the time of the writer's visit to the region (February, 1906) the shaft was filled with water, hence the copper-bearing rock in it could not be studied.

Occurrence.—The ore deposits seen at all of these points are similar in character. The ore usually occurs along joint planes and in fissures and is most frequently accompanied by quartz. It may accompany shear zones, which are a very conspicuous structural feature in the localities visited. At the mines of the Virginia Consolidated Copper Company near Ida, where development has reached the maximum in the region under discussion, it was noted that these shear zones correspond to a system of joint planes in the country rock varying in direction within the limits S. 4° W. and S. 25° W. A similar though not so close a relationship between the strike of these shear zones and a prominent system of joints was observed at the property of the High Top Mining Company. Usually the alteration of the country rock has reached its maximum in close proximity to these shear zones, or accompanying them. Similar zones of alteration were seen at the Blue Ridge Copper Company's workings near Fishers Gap, but development had not proceeded far enough to systematize them.

Near these shear zones the country rock is decidedly epidotized. Chlorite has also formed as well as quartz and feldspar, an association in the case of the last two minerals indicating the action of ascending thermal agencies. Some chalcopyrite and bornite may be found accompanying the quartz and feldspar. The copper sulphides are not confined to the veins near or in these shear zones, however, but occur in the mass of the basalt as well. The surface indications in the region lead to the conclusion that the ore deposits are irregular in occurrence, that the alteration of the country rock has been rather general, and that, although it may prove to be, as a rule, more marked along the major joint planes and in the shear zones, it also probably occurs along the minor joints and the innumerable cracks in the rock.

Origin.—Besides the alteration, the weathering of the rocks has resulted in the production of quartz and calcite, which occur as fillings along the joint planes, sometimes as mere films, locally swelling into lenticular masses, which may end abruptly or zigzag in the most irregular fashion through the rock. The main masses of copper ore are found generally associated with these secondary minerals which have resulted from weathering. This ore is in the form chiefly of native copper and cuprite, with small amounts of malachite and azurite. From their mode of occurrence these fillings and lenses are believed to be veins. At the Virginia Consolidated Copper Company's mine they appear to be developed on a larger scale comparatively near the surface and to diminish in extent with depth. From the fact that the mines near Ida tend to become dry with depth, it is believed that the moisture in the workings is chiefly of meteoric origin and moreover has been instrumental in producing the main ore deposits. The disseminated sulphides have probably furnished much of the ore, which has been segregated along the fissures and joint planes in the rock

and has perhaps been dissolved and redeposited many times before finding its present position. Although ascending waters may have been instrumental in bringing up a portion of the sulphides, such as the chalcopyrite in the quartz veins associated with the shear zones, there is no evidence that this sulphide will increase in depth or that it occurs in large bodies. If this concentration by descending surface waters be the true origin of the workable bodies, the ore must be sought near the surface and will tend to diminish in depth, a conclusion in accord with field observations at the localities studied.

Finally, it may be mentioned that these occurrences are examples of the "Catoctin" type of copper deposits of the southern United States, which have been described by Weed.[a]

[a] Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 498–504.

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