COPPER.

THE TURQUOISE COPPER-MINING DISTRICT, ARIZONA.

By F. L. Ransome.

INTRODUCTION.

The following notes are the record of a brief visit to the Turquoise district in October, 1911, when a little less than five days was spared from other work for an examination of the complex geologic relations of the copper deposits near Courtland and Gleeson. The results obtainable in so short a time are necessarily incomplete and are presented with the full realization that they are likely to be modified by later detailed study. They would be even more imperfect were it not for the facts that a topographic map by Mr. F. J. Gibbons, engineer of the Great Western Copper Co., was available for the part of the district adjacent to Courtland and that the geologic boundaries had been carefully traced for this area by Mr. W. G. McBride, general superintendent for the same company. The principal changes made in Mr. McBride's work, as presented in figure 17, are the interpretation of some of the boundaries as faults and the inclusion with the Cambrian dolomite and shale of some material originally mapped as quartzite. To both gentlemen I am much indebted for their courteous assistance.

SITUATION OF THE DISTRICT.

The Turquoise mining district is situated on the east flank of the Dragoon Mountains, in Cochise County, Ariz., about 14 miles due east of Tombstone and about 18 miles north-northeast of Bisbee. It lies for the most part in a small group of hills that separate the south end of the main range from the broad expanse of Sulphur Springs Valley. The district is reached from the north by a branch of the Southern Pacific Railroad by way of Pearce and from the south by a branch of the El Paso & Southwestern Railroad from Douglas.

It contains two small settlements—Courtland, shown in figure 17, and the older town of Gleeson, about 1½ miles to the south.

MINING DEVELOPMENT AND PRODUCTION.

During the eighties the Gleeson, Tejon, and a few other mines near Gleeson produced considerable quantities of oxidized ore, carrying gold, silver, lead, and copper, from deposits in a ridge of Carboniferous limestone east of town, but by 1902 these ore bodies had ceased to be profitable. The extension of the railroads into the district a few years ago made possible the utilization of lower-grade ores and at present the Copper Belle mine, near Gleeson, under lease to the Shannon Copper Co., is producing a low-grade pyritic ore.

The turquoise mines, from which the district gets its name, are on the west side of Turquoise Hill, northwest of Courtland (fig. 17). They are said to have been fairly productive, but they are now idle and very little could be learned of their history. Copper mining on an important scale began near Courtland on the Humbot claim about the year 1901, and it is reported that this mine yielded about $100,000 from a body of oxidized ore stoped near the surface. In 1907 and 1908 there was much activity in the vicinity of Courtland and extensive prospecting was carried on at several places by Phelps, Dodge & Co., the Calumet & Arizona Co., and the Great Western Copper Co. The work as a whole was rather disappointing, but the Calumet & Arizona Co. shipped 15,000 to 20,000 tons of 7 per cent oxidized copper ore from the Germania mine, and the Great Western Copper Co. had produced at the time of visit about 30,000 tons of ore from the Mary mine, which is on the same ore body as the Germania. About $250,000 was expended by the Calumet & Arizona Co. on the Leadville claims and some low-grade sulphide ore was found, but work was finally abandoned. Although there is known to be still some good ore in the Germania mine, the only mines in operation in 1911 were the Mary and Mame, both owned by the Great Western Copper Co. At the time of visit this company was shipping from all workings, but mainly from the Mary mine, at the rate of nine 50-ton cars a week.

GENERAL GEOLOGY.

The Dragoon Range, which trends generally north-northwest, with a length of about 25 miles, is composed chiefly of Paleozoic rocks, ranging from the middle Cambrian to the Carboniferous (Pennsylvanian). These are cut by various igneous rocks, especially by a large mass of rather coarse textured granite, which makes up much of the northern part of the range.

The hills of the Turquoise district rise 1,000 to 1,500 feet above the adjacent Sulphur Springs Valley, the highest line of summits being composed of hard quartzite which is probably the equivalent of the middle Cambrian Bolsa quartzite of the Bisbee district. The original base of this quartzite was not seen in this reconnaissance, although

E. T. Dumble[1] has reported the occurrence of mica schist, presumably pre-Cambrian, in South Pass, 7 or 8 miles northwest of Courtland. In the vicinity of Courtland the quartzite rests upon a rather fine grained, very much decomposed granitic rock which apparently occupies much of the relatively low ground between the Turquoise Hills and the main Dragoon Range and forms some of the low hills into which that range subsides toward the south. This rock is too much decomposed for complete identification, but apparently it is a quartzose granite in which the feldspar has been wholly altered to sericite. The microscope shows that most of the quartz grains are minutely fissured, the fissures being filled with sericite. The contacts of this rock with the sedimentary rocks are generally covered by loose detritus, but some exposures in the saddle about half a mile southwest of Courtland (see fig. 17) show that the granite rock is intrusive into the quartzite, which has been rendered schistose at the contact. Farther south, between Courtland and Gleeson, it probably is intrusive into the Carboniferous limestone also, although no exposures of this contact were seen.

The quartzite, which forms the steep hills along the western edge of the area mapped in figure 17, strikes on the whole nearly north and south and dips generally eastward at angles ranging from 40° to 80°. It is overlain to the east by a formation of thin-bedded dolomite or dolomitic limestone and shale within which are the Leadville, Mame, and Humbot mines. These rocks, which are probably the stratigraphic equivalent of what was named the Abrigo limestone at Bisbee,[2] have been strongly metamorphosed through the formation of garnet and other silicates with sulphides, chiefly pyrite. Such resemblance as the rocks may once have had to the Abrigo as developed near Bisbee has been obscured by this metamorphism and still more by the oxidation of the pyrite and by the action on the rock of the sulphuric acid thus formed.

Northeast of the Cambrian dolomite and shale is a belt of gray limestone forming Monarch, Casey, and Reservoir hills. This limestone is sparingly fossiliferous and is undoubtedly of Carboniferous age, probably Mississippian. No Devonian rocks were recognized near Courtland, although Dumble[3] has noted the presence of rocks of this age elsewhere in the Dragoon Mountains. The Carboniferous limestone near Courtland has been irregularly invaded by monzonite porphyry and no longer has its original stratigraphic position with reference to the Cambrian beds. In some places it is faulted against these beds and in others it is separated from them by intrusive masses of porphyry.

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[1] Notes on the geology of southeastern Arizona: Trans. Am. Inst. Min. Eng., vol. 31, 1902, p. 713.

[2] Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: Prof. Paper U. S. Geol. Survey No. 21, 1904.

[3] Op. cit., p. 711.

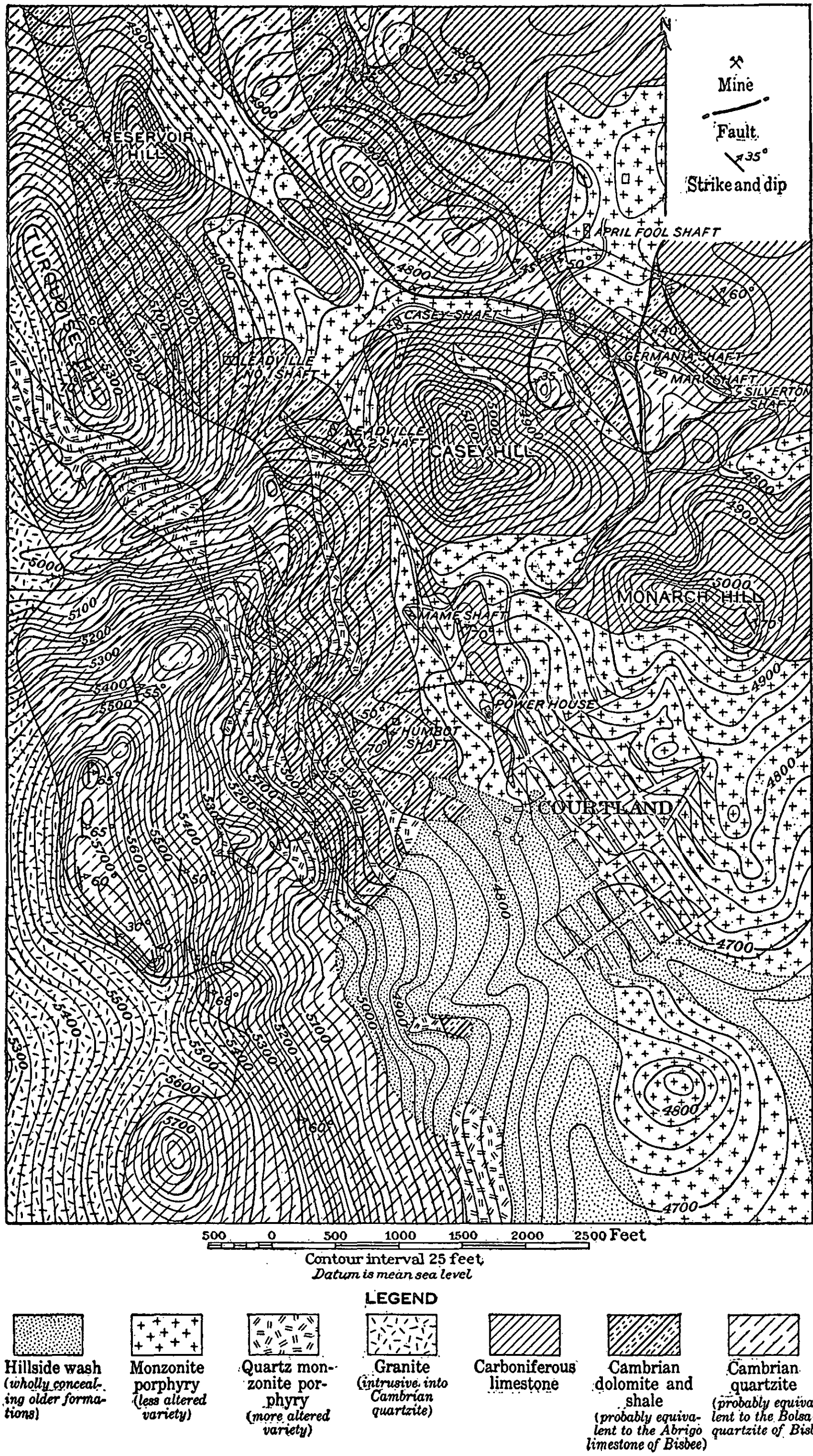

FIGURE 17.—Geologic reconnaissance map of a part of the Turquoise mining district, Arizona. Topography by F. J. Gibbons, engineer, and geologic boundaries by W. G. McBride, general superintendent, of the Great Western Copper Co.; with slight changes by F. L. Ransome.

Northeast of the limestone hills just mentioned lies another area of Cambrian rocks in which are the Mary and Germania mines. These rocks, as is clearly shown by the mine workings, rest on Carboniferous limestone and undoubtedly owe their present position to overthrust faulting. There are many puzzling features, however, in the structural relations of this part of the district and explanation of the overthrust in all its details would require much more than a hasty reconnaissance visit. A careful study of the workings connected with the Mary, Germania, Silverton, April Fool, and Casey shafts would probably clear up many obscurities; but unfortunately the Mary mine and a very small part of the Germania mine were the only openings that were readily accessible in 1911. The quartzite of this area is all much fractured, especially northeast of Casey Hill, and along the railroad north of that hill the principal fractures dip steeply to the northwest, suggesting that the mass may have been thrust from that direction. At the Mary shaft the shattered overthrust quartzite is 115 feet thick and caps the ore body.

The under surface of the overthrust mass is apparently irregular. It is probable that after the overthrust was accomplished the rocks were further dislocated by normal faulting and were deformed by the intrusion of the porphyry. These, however, are merely suggestions and considerable detailed work will be necessary to ascertain definitely the relations of the overthrust to other faulting and to the epoch of intrusion. Southeast of the Mary shaft the layer of brecciated material produced by the overthrust is steeply upturned and outcrops southwest of the Silverton shaft as masses of ferruginous gossan associated with brecciated quartzite and some oxidized copper ore. How far this local steepness of the thrust plane may be original and how far it may be due to later deformation are questions as yet unanswered.

Two varieties of porphyry are recognized near Courtland. One, which is possibly the older, is intrusive, in the form of irregular dikes, into the Cambrian beds in the western part of the area mapped in figure 17. This rock is everywhere much altered and decomposed so that its original character is not closely determinable. It is for the most part nearly white, although in surface exposures it may be stained with rust, and in many places it is not readily distinguishable from some of the altered Cambrian beds. Little can be seen of its original texture, and the microscope shows that the rock is largely a secondary aggregate of quartz and sericite with finely disseminated pyrite. Most specimens show faint outlines of feldspar phenocrysts and a few small corroded crystals of primary quartz. Provisionally the rock will be referred to as quartz monzonite porphyry. One large dike of this rock is represented in figure 17 as extending into the granite west of Turquoise Hill, but no close examination was made of the relations of the two rocks, which here weather much alike and are deeply decomposed.

The second variety of porphyry, which occupies considerable areas east and north of Courtland, is intrusive mainly into the Carboniferous limestone but is in igneous contact with the Cambrian beds also. Although nowhere fresh, this porphyry as a rule is darker in color and much less altered than the other variety. Where comparatively fresh this rock shows abundant phenocrysts of reddish feldspar which are mostly plagioclase, although some of the larger crystals are orthoclase. There are visible also a few small irregular grains of quartz and fairly abundant chloritic pseudomorphs after biotite. The microscope shows that this rock also is a quartz monzonite porphyry, although apparently it is less silicic than the variety first described. Even the freshest specimens are more decomposed than mere inspection of hand specimens suggests and the rock of the low rounded hill just south of Courtland, supposed from its texture to belong to the second variety, is altered and bleached to a product closely resembling the porphyry west of the Mame shaft.

It appears that the two varieties of porphyry here described belong to the same rock type—quartz monzonite porphyry—and it is possible that they represent contemporaneous intrusions of the same magma; but their general appearance is sufficiently different to justify their provisional distinction in a preliminary examination of the field.

The cause of the metamorphism of the dolomitic Cambrian beds is not entirely clear. The alteration is probably connected with the intrusion of the porphyries, but as the visible portions of these igneous masses have themselves undergone metamorphic changes it appears that the transformation must be due principally to some underlying body of eruptive rock.

West of the Copper Belle mine, near Gleeson, there is a decomposed rock with contorted flow banding and a dark color due to very abundant dendritic films of manganese oxide. This is apparently a rhyolite. The only other igneous rock noted in the district is a gray tuff-breccia that was cut in the workings of the Casey shaft. This rock is altered and contains finely disseminated pyrite but is clearly of andesitic or latitic character and perhaps records volcanic activity at the time of the porphyry intrusions. Its geologic relations could not be ascertained in 1911, but as it is abundant on the dump of the shaft it possibly has considerable extent underneath the overthrust mass of Cambrian quartzite.

COPPER DEPOSITS.

The copper deposits of the Turquoise district may be grouped as follows: (1) Oxidized blanket deposits connected with thrust faulting, exemplified by the ore bodies of the Germania and Mary mines.

(2) Pyritic deposits with some associated bodies of oxidized ore in the Cambrian dolomitic limestone and shale, exemplified by the Mame and Leadville mines. (3) Pyritic deposits with associated bodies of oxidized or enriched ore in Carboniferous limestone, exemplified by the Copper Belle and other mines near Gleeson.

The general plan of the Mary-Germania ore body is shown in figure 18, the outline for the portion of the body within the Mary claim corresponding approximately to what is known of the extent of the ore, while the boundaries of that portion within the Germania claim are surmised from an inspection of the map of the

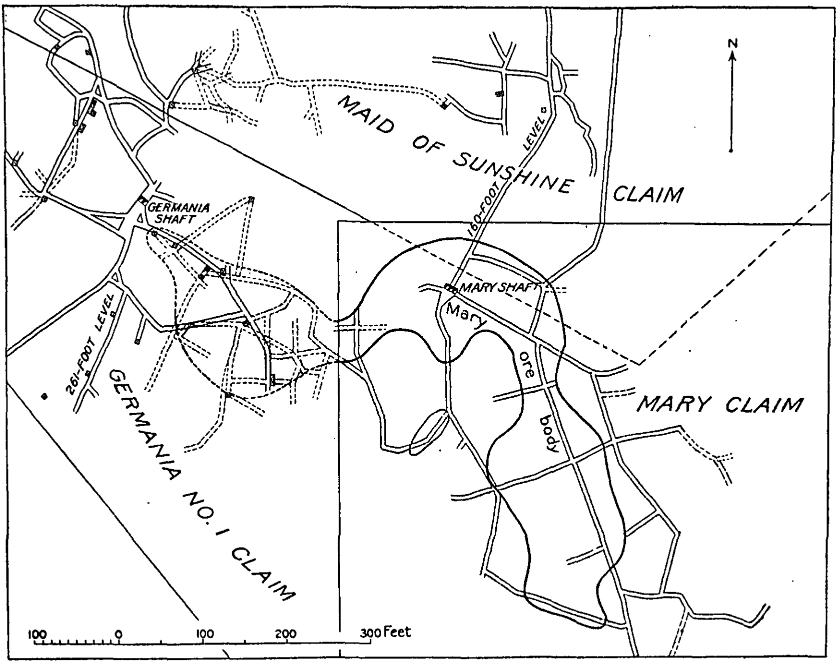

FIGURE 18.—Plan of parts of the 160-foot level of the Mary mine and of the 261-foot level of the Germania mine, Turquoise mining district, Arizona, showing the approximate outline of the main ore body.

underground workings of the Germania mine, the presence of sublevels and ore chutes being taken as indicative of stoping. Whether or not considerable ore occurs north of the Germania shaft was not ascertained. The ore is as irregular in thickness as in plan, the maximum being 50 feet and the average probably about 15 feet. The ore body is accompanied by much soft limonitic and clayey material, the whole closely resembling the oxidized ore and so-called "ledge matter" of some of the Bisbee mines. Definite boundaries are lacking, but the ore body as a whole rests on Carboniferous limestone and is overlain by shattered quartzite, which at the Mary shaft is 115 feet thick. Decomposed porphyry occurs with the quartzite above the ore, with the underlying limestone, and to some extent mingled with the ore, which in the main, however, is a replacement of the limestone.

The ore itself is as a rule a soft mass of earthy oxides of iron and copper, flecked and streaked with malachite and mingled with clay-like decomposition products of varied color and constitution. Here and there are irregular crevices or cavities lined with crusts of chrysocolla, malachite, and azurite. No sulphides have been found either in the ore or in the porphyry and limestone immediately under the ore, and the limestone is not metamorphosed.

The ore-bearing solutions evidently gained access to the broken ground along the thrust plane and replaced the shattered limestone by ore. The ore during deposition apparently was not limited in its downward extent by the zone of brecciation but replaced irregularly part of the underlying limestone, especially in the vicinity of fissures. Whether it was originally deposited as sulphides or was carried down from some overlying formation through the shattered quartzite and deposited directly in oxidized condition in the fault breccia and on top of the limestone is an open question. The view that the ore was deposited as sulphide and has been completely oxidized, essentially in place, by water that has percolated down through the porous quartzite capping is regarded as the more probable.

Northwest of the Mary and Germania mines and north of the Casey shaft there is a ridge of quartzite that apparently is part of the overthrust mass. Although it would be unsafe from a reconnaissance examination to predict the occurrence of ore bodies under this quartzite, it may be pointed out that there is a bare possibility of their existence. The exploratory drifts from the April Fool shaft do not extend far enough west to test this possibility thoroughly. Whether there are any drifts extending north from the Casey shaft and exploring the base of the quartzite in this ridge could not be learned in 1911. The Miami shaft, which is just north of the area covered by figure 17, was sunk by the Calumet & Arizona Co. through the small mass of quartzite that is shown about 2,000 feet northwest of the April Fool shaft, and extensive exploratory work was carried on in the underlying limestone, but without success.

Of the mines in the Cambrian dolomite and shale (Abrigo formation?) the Mame alone was open for examination in 1911. The Mame has reached a depth of 300 feet, but only the 100-foot level was examined in 1911, as time was short and according to Mr. MacBride the conditions on the lower levels are substantially the same as on the first level.

The general country rock of the Mame, Humbot, and Leadville mines is a series of shales and thin-bedded dolomitic limestones cut irregularly by many dikes and sheets of quartz monzonite porphyry. The beds have prevailingly steep dips to the east. The entire belt of these rocks from Courtland northward shows decided metamorphism. The calcareous beds have been transformed to hard fine-grained aggregates consisting largely of garnet, with perhaps other silicates, quartz, calcite, and pyrite. The porphyry has been altered to fine-granular aggregates of quartz, sericite, and pyrite. The pyrite, though widely disseminated through the rocks, is more abundant at some places than at others. The superficial weathering of this formation is accompanied by further changes. The oxidation of the pyrite, with the production of sulphuric acid and sulphates, bleaches portions of the rocks and leads to the accumulation of iron oxides in other portions. In connection with this weathering there has been some concentration of oxidized ore near the surface, especially at the Humbot mine, but such concentration is local and superficial.

At the Mame mine the oxidized ore is wholly inconsiderable and the work in progress during 1911 was directed to the exploration of the metamorphosed beds and the altered porphyry for bodies of pyritic ore. These are generally of lenticular form and lie with their greater dimensions approximately in the planes of bedding. They are said to be most abundant and largest close to the porphyry intrusions, which in their altered condition are difficult to distinguish underground from some of the metamorphosed sedimentary beds. These ore bodies have no sharp boundaries but are merely those portions of the formation where the pyrite is more thickly disseminated than elsewhere or where it has formed in solid masses by metasomatic replacement of the calcareous strata and probably, to some extent, of the porphyry also. Not all of the pyritic material contains enough copper to be classed as ore and numerous assays are necessary to determine the limits of each ore body. The deposition of the ore has no obvious relation to fissuring. The pyrite, together with the small proportion of chalcopyrite that gives the whole its value as a low-grade copper ore, was apparently formed during the general metamorphism of the formation by hot mobile solutions under such pressure that they were capable of moving along bedding planes and of penetrating the mass of the rock through minute openings and by molecular replacement.

At a few places in the Mame mine there has been a little chalcocitic enrichment, but the greater part of the ore has undergone no modification since it was first deposited.

In 1911 there had been shipped from the Mame mine about 1,500 tons of ore from development work, but stoping had not been begun.

The dump of the Leadville No. 1 shaft, about half a mile northwest of the Mame, shows considerable low-grade pyritic ore. The geologic conditions at the two mines are similar and if the Mame develops into a profitable mine this will probably lead to a resumption of work at the Leadville.

The Humbot shaft is situated about 800 feet south of the Mame and belongs to the same company. Although the rocks are identical with those of the Mame and although oxidized ore to the value of $100,000 is said to have been mined from open cuts near the shaft, considerable exploratory work on two levels has failed to show any sulphide ore bodies of workable size.

No special examination was made of the mines in Carboniferous limestone near Gleeson. The Copper Belle is opened by a 300-foot shaft with three levels. The country rock is gray limestone, which dips 30°–50° E. and contains a number of intrusive sheets of altered monzonitic or dioritic porphyry. The ore bodies of the Copper Belle occur along the contacts of this porphyry with two beds or slablike masses of limestone and have a total length from north to south of about 500 feet. The ore is mainly granular pyrite with a little chalcopyrite and scattered bunches of bornite, sphalerite, or galena. It has been deposited by irregular metasomatic replacement of the limestone, which shows no general metamorphism. The porphyry also is full of finely disseminated pyrite and carries small stringers of the same sulphide. The ore is graded into two classes and is shipped to the Clifton district, where its high percentage of sulphur and freedom from gangue make it valuable for smelting with other ores.

TURQUOISE DEPOSITS.

The turquoise occurs in joints and small irregular fractures in a bed of Cambrian quartzite that dips 65° E. and outcrops along the west side of Turquoise Hill a few feet above the contact with the decomposed granitic rock previously referred to. At the opening examined the bed has been stoped to a width of 4 feet and a depth of 75 feet or more, the bottom of the shaft being now filled with water. A short distance north of this opening and near the western boundary of the area mapped other workings, perhaps a little more extensive than those visited, have been opened on the same bed of quartzite.

SURVEY PUBLICATIONS ON COPPER.

The following list includes the principal publications on copper by the United States Geological Survey or by members of its staff. In addition to the publications cited below, certain of the folios of the Geologic Atlas of the United States contain discussions of the copper resources of the districts of which they treat. This list does not include publications on Alaska, a list of which is given in Bulletin 520, the annual report on progress of the Survey's investigations in Alaska for 1911.

The Government publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The publications marked "Exhausted" are not available for distribution but may be seen at the larger libraries of the country.

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LEAD AND ZINC.

SURVEY PUBLICATIONS ON LEAD AND ZINC.

The following list includes the more important papers on lead and zinc published by the United States Geological Survey. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The publications marked "Exhausted" are no longer available for distribution but may be seen at the larger libraries of the country.

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