LEAD AND ZINC.

A NEVADA ZINC DEPOSIT.

By H. Foster Bain.

Introduction.—The production of zinc ores in the Western States has begun to assume great importance. In 1905 the number of producing camps and the total shipments were much larger than in 1904. Colorado, with Leadville as the main shipping district, continued in the lead. The mines of the Magdalena Mountains in New Mexico made heavy shipments. Utah, Idaho, and Montana have become important producers, and smaller shipments have been made from other States and Territories, including Nevada. Important amounts of ore have been brought in from Mexico and some from British Columbia. Old mines are being reopened, new mills are being built, and everywhere through the West the zinc-ore industry is attracting large attention. In the summer of 1905 the writer visited the main zinc-producing districts of the West, and a general report on the western zinc industry is now in preparation as a joint publication of the division of geology and the division of mineral resources. In the course of this investigation the Potosi mine in southern Nevada was visited, and certain of its geologic relations were found to be so interesting that this brief separate discussion has been prepared.

The Potosi mine is located on the western slope of Spring Mountains, about latitude 36° N., longitude 115° 30′ W. It is reached by a 30-mile drive from Good Springs station on the San Pedro, Los Angeles and Salt Lake Railway. The springs from which the station takes its name are about 7 miles west of the railway, at the eastern foot of the mountains, and mark a well-known resting and camping place. The mine proper is near the old Mormon trail from Salt Lake City to Los Angeles and was first worked nearly half a century ago to furnish lead bullets for the pioneers. It had been idle for many years when the coming of the railway and the demand for zinc led to its reopening.

The mountains have been visited by J. R. N. Owen, Gilbert, Weeks, Rowe, and Spurr. The latter has summarized existing knowledge regarding them as follows:[a]

> The Spring Mountain Range is an exceedingly irregular-shaped group of mountains, lying southwest of Las Vegas Range, and separated from the Kingston Range, farther south, by the Pahrump Valley. The general trend of the range is northwest and southeast, and its length in this direction is about 60 miles, and at its northern end, in the neighborhood of Charleston Peak, the total width is as much as 30 miles. This peak constitutes the highest portion of the range, being 10,874 feet above the sea, and is a conspicuous landmark. This range is divided into numerous ridges, which run in many different directions without much visible system. At at least two points at the northern base of the range there occur warm springs, namely, Indian Spring and the spring at White's ranch in Pahrump Valley. This is interesting, since the range contains few igneous rocks.

Geology.—The rocks forming the mountains consist of Cambrian, Carboniferous, and Jurassic sediments, and, near Good Springs proper, a small area of basalt with at least one

[a] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. U. S. Geol. Survey No. 208, 1903, p. 164.

acidic porphyry rock. The Cambrian rocks are found in the northern part of the range and include a blue-gray crystalline limestone, greenish-yellow shales, and thin bands of dark sandstone. A quartzite associated with the limestone is probably also of Cambrian age. The Carboniferous rocks include Mississippian and Pennsylvanian limestones and a considerable thickness of red shale and sandstones. The Mesozoic rocks are represented by conglomerates, sandstones, and shales and carry Jurassic fossils.

Structurally the range is somewhat peculiar, being apparently anticlinal in a north-south section and showing a wrinkled synclinorium in an east-west section. The main mass of the mountains consists of Carboniferous limestones. The Cambrian rocks have been brought up and the Mesozoic let down, with reference to the Carboniferous, by heavy thrust faulting.

No very careful or detailed study of these or any of the surrounding mountains has yet been made and very little is really known of the geology. In the present instance no attempt was made to study the geology of the district, attention being concentrated upon the ore body and the mine.

Ore deposit.—The Potosi mine is located near the mountain marked Olcott Peak on Spurr's map. The limestone here is predominantly fine grained, breaking with a clean conchoidal fracture and being usually dark colored and occasionally very bituminous. Certain of the beds are cherty, but the chert is unequally distributed, much of the limestone being apparently free from it. The beds in which the ore occurs are not cherty. Fossils occur rather abundantly, though none were found immediately in connection with the ore bodies. The forms collected were examined by G. H. Girty and found to be common Carboniferous species, such as especially characterize the "blue limestone" at Leadville. The rocks have been folded sharply and faulted. The ore is found in certain little-disturbed and nearly horizontal beds having a slight dip to the east. The adits by which the mine is opened are in a perpendicular cliff facing west, at the head of a deep arroyo. This cliff seems to mark a fault scarp revealed by erosion. The fault plane, which is apparently vertical and runs approximately north and south, separates the little-disturbed beds on the east from the crumpled and folded limestones which form spurs on either side of the arroyo and stretch off to the west.

The adits, of which there are two, are about 800 feet above the plain, or at an altitude of approximately 6,500 feet. Above these the hill rises first abruptly and then more gently at least 300 feet. The main ore-bearing bed is flat lying, is about 5 feet thick, and lies immediately above a body of thin-bedded shaly limestone about 20 feet thick. This shaly limestone is dark colored, fine grained, and hard. It is made up of individual beds about 2 inches thick separated by clay partings one-fourth to one-half inch thick.

At right angles to the cliff—that is, running east—the limestone is cut by a series of narrow crevices, in the main pitching south. These show no faulting and are better developed in the limestone above the shaly bed than in it or below. A prospect drift, however, run in a hundred feet or so at the base of the shaly limestone follows one of these crevices. Similar crevices showing some mineralization are said to be traceable as much as 1,000 feet along their strike, though offsetting cross faults occur. There was not time to verify these statements.

The ore consists mainly of carbonate of zinc. Carbonate of lead, some sulphate, and galena also occur. There are occasional copper stains. No pyrites was seen, but iron oxide stains are common. The mine is dry and oxidation has gone far. The galena is only slightly argentiferous. A random sample examined in the Survey laboratory by George Steiger showed practically no silver present. It is said that some ore shipments have run as high as 12 ounces in silver to the ton, but ordinarily neither gold nor silver is determined. The main shipments are zinc carbonate running 40 to 45 per cent of zinc. A mixed grade running 35 per cent of zinc and 20 per cent of lead is also occasionally sold. There is no known gold value.

In general appearance and in mode of occurrence the ore bodies are curiously like some which have been worked in the upper Mississippi Valley region. The long-pitching crevices which show no faulting are similar to the well-known "pitches" of that district, while the concentration or "making" of the ore along the top of the shaly limestone is equally like the relations of the Wisconsin ore to the "oil rock." In Nevada the long period of desert conditions has caused the minerals, which in Wisconsin are generally sulphides, to be largely altered to carbonates and oxides. Similar ores are found in Wisconsin, but generally at levels considerably above the "oil rock," both stratigraphically and topographically. In both cases the ore constitutes a run as defined by Prof. W. P. Jenney[a] along the intersection of a crevice and a favorable horizon; here it is rather just above an unfavorable or impervious stratum. The ore bodies are exceedingly irregular in detail, following the minor fractures and ramifying watercourses through the limestone. In the Potosi mine small druses an inch or so in diameter were noted, which were lined with zinc carbonate, though apparently not connected with any regular crack. Chimneys of ore run up irregularly along the crevices, but so far no ore shoots running down through the shale have been found.

Origin.—The mode of occurrence favors the notion of a simple downward circulation of ore-bearing waters arrested by a nearly impervious bed and depositing their load of mineral along its top. If the original deposition was in the form of sulphides, as is quite probable, the organic matter of the shaly beds was probably important. The subsequent period of oxidation has, however, been so long as to obscure the records of any early stages in this ore body. If we look back to an earlier period, when rainfall was more abundant in this area, we can readily conceive of the formation of these ore bodies under present structural and topographic conditions without any demand on additional agencies. Indeed, it is even possible that in the winter and rainy months the ore is now being concentrated by a simple downward circulation of meteoric waters.

Whether such a simple hypothesis be in fact the correct one in this case can not be determined without more detailed study. For the present it is sufficient to show that it is a perfectly possible explanation of the known facts. Near the mine, as has been noted, is an important fault plane which presumably might have afforded openings for a deep circulation, though the course of the ore body is well developed at right angles to this plane. Warm springs, as noted by Spurr,[b] occur in the mountains but not near the ore bodies, nor are ores known to occur near the springs. One spring, a cold one, is found not far from the mine. No igneous rocks are known nearer than a dozen miles or more from the mine; though in the part of the mountains in which they are found there are certain lead and copper deposits not visited. Prof. E. M. Jenney[c] describes the lead deposits as similar in character and form to those of Missouri, and sees in this similarity an additional reason for referring the Missouri deposits to deep-seated waters connected genetically with some unknown igneous rocks. To the writer it would seem that the analogy might quite as well be the other way and that the relation to igneous rocks in the Spring Mountains was accidental rather than causal.

It has been customary in discussions of Western ore deposits to assign to igneous rocks an important genetic rôle. This has been done for deposits essentially valuable for the lead, zinc, or copper content, as well as for those in which gold and silver formed the main element of value. The general validity of the reasoning as applied to the precious-metal deposits is not here questioned, but it seems to the writer that a question may well be raised with regard to those deposits which are mainly valuable for lead and zinc or in which the gold and silver values are small. It is well known that in the Mississippi Valley there are important deposits of lead and zinc ores found in limestone and dolomites and considered by most investigators to have no direct genetic relations to igneous rocks. These ore bodies are characterized by a very simple association of minerals. They are free from arsenic, antimony, and the rarer complex sulphides, and are low in silver where not wholly nonargentiferous. Their origin can not be assigned to igneous rocks, since there are no such rocks to which to relate them and adequate alternative hypotheses are available.

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[a] Jenney, W. P.. Lead and zinc deposits of the Mississippi Valley: Trans. Am. Inst. Min. Eng., vol. 22, p. 189.
[b] Op. cit., p. 165.
[c] Personal communication.

In the West there are considerable bodies of similar lead and zinc ores also found in limestones, and low in silver or free from it. If the explanation advanced for the Mississippi Valley ores be adequate it may well be asked why a more complex origin need be assumed for these ore bodies in the West. In a majority of cases in the West it is true that gold, silver, arsenic, antimony, and other metals characteristic of the ore bodies held to originate in part, at least, through igneous agencies, occur with the lead and zinc, as at Leadville, Park City, Aspen, and elsewhere. It may still be asked why it can not be believed that disseminated lead and zinc in the limestone contributed in an important degree to the ore bodies. Emmons, after an elaborate investigation of the country rocks at Leadville, reached the cautious conclusion that, "although the above facts are not sufficiently conclusive to afford absolute proof that the metallic contents of the deposits were entirely derived from the eruptive rocks, they certainly show the possibility and even probability that this source furnished a part at least of the vein metals."[a] It has been common in subsequent discussions to consider the porphyry rather than the sedimentary rocks as the original home of the metallic minerals, and to follow Emmons[b] in his conclusion that the association of the ores with the limestone is due to the chemical and physical characteristics of the rock—characters which are believed to have given it a selective affinity for ore solutions penetrating the formations as a whole.

At Aspen there are similar limestones and dolomites associated with igneous rocks, but Spurr[c] suggested only the igneous rocks as the original source of the metals. To the writer it would seem more probable that both igneous and sedimentary rocks have contributed their quota to the ore bodies.

The "blue limestone" of Leadville is a well-known metalliferous horizon through several Western States. As noted in the description above, it is in this limestone that the Potosi ores occur. The zinc ores of the Magdalena Mountains in New Mexico apparently come from the same horizon, and in fact the formation is quite as closely associated with lead and zinc in the West as are the Cambro-Silurian rocks of the Mississippi Valley and Appalachian regions. Emmons, in his investigations of the Leadville deposits, considered the hypothesis that the association was primary, but concluded that the exceptions were too numerous to warrant its adoption. He cited in particular the fact that in the adjacent Ten Mile district the ores were in the upper rather than the lower Carboniferous. As noted, he appealed to the physical and chemical nature of the limestone to account for the localization of the ores. It is true, however, that limestones and dolomites of widely differing characteristics serve as country rock to deposits, but that all or nearly all of them are indicative of base-level conditions on the land at the time of their formation—conditions under which chemical denudation and transportation are disproportionately important. Under such conditions the leaching of preexisting rocks is a most important process, and ore minerals, as well as others, may easily be carried to the sea in relative abundance. It would seem that conditions in the sea, if limestones be formed or forming, should be as favorable to the deposition of the ore minerals as at any later period in which similar solutions may be brought into contact with the limestone. The very chemical and physical characteristics appealed to may well be supposed to be operative in the early as well as the later period, and so the limestones as laid down should be storehouses of disseminated ore minerals. These general and theoretical considerations, coupled with the present distribution of the ores, warrant, it is believed, the suggestion that in the Rocky Mountain and Great Basin regions, as in the Mississippi Valley, paleogeography was not without its influence in localizing the ore districts. It is not intended to suggest that this is a complete explanation of the ore bodies of these districts, but merely to urge its consideration as one factor in a very complex process.

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[a] Geology and mining industry of Leadville: Mon. U. S. Geol. Survey, vol. 12, 1886, p. 582.
[b] Op. cit., pp. 540 et seq.
[c] Geology of the Aspen mining district, Colorado: Mon. U. S. Geol. Survey, vol. 31, 1898, p. 235.

SURVEY PUBLICATIONS ON LEAD AND ZINC.

Many papers relating to silver-lead deposits will be found included in the list on pages 9 to 13 of this bulletin. The principal other papers on lead and zinc, published by the United States Geological Survey, or by members of its staff, are the following:

ADAMS, G. I. Zinc and lead deposits of northern Arkansas. In Bulletin No. 213, pp. 187-196. 1903.

ADAMS, G. I., and others. Zinc and lead deposits of northern Arkansas. Professional Paper No. 24, 118 pp. 1904.

BAIN, H. F. Lead and zinc deposits of Illinois. In Bulletin No. 225, pp. 202-207. 1904.

——— Lead and zinc resources of the United States. In Bulletin No. 260, pp. 251-273. 1905.

BAIN, H. F., VAN HISE, C. R., and ADAMS, G. I. Preliminary report on the lead and zinc deposits of the Ozark region (Mo.-Ark.). In Twenty-second Ann. Rept., pt. 2, pp. 23-228. 1902.

CLERC, F. L. The mining and metallurgy of lead and zinc in the United States. In Mineral Resources U. S. for 1882, pp. 358-386. 1883.

ELLIS, E. E. Zinc and lead mines near Dodgeville, Wis. In Bulletin No. 260, pp. 311-315. 1905.

GRANT, U. S. Zinc and lead deposits of southwestern Wisconsin. In Bulletin No. 260, pp. 304-310. 1905.

HOFFMAN, H. O Recent improvements in desilverizing lead in the United States. In Mineral Resources U. S. for 1883-84, pp. 462-473. 1885.

ILES, M. W. Lead slags. In Mineral Resources U. S. for 1883-84, pp. 440-462. 1885.

KEITH, A. Recent zinc mining in East Tennessee. In Bulletin No. 225, pp. 208-213. 1904.

RANSOME, F. L Ore deposits of the Cœur d'Alene district, Idaho. In Bulletin No. 260, pp. 274-303. 1905.

SMITH, W. S. T. Lead and zinc deposits of the Joplin district, Missouri-Kansas. In Bulletin No. 213, pp. 197-204. 1903.

ULRICH, E. O., and SMITH, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. In Bulletin No. 213, pp. 205-213. 1903. Professional Paper No. 36, 218 pp. 1905.

VAN HISE, C. R. Some principles controlling deposition of ores. The association of lead, zinc, and iron compounds. Trans. Am. Inst. Min. Eng., vol. 30, pp. 102-109, 141-150.

VAN HISE, C. R., and BAIN, H. F. Lead and zinc deposits of the Mississippi Valley, U. S. A. Trans. Inst. Min. Eng. (England), vol. 23, pp. 376-434.

WINSLOW, A. The disseminated lead ores of southeastern Missouri. Bulletin No. 132, 31 pp. 1896.

WOLFF, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin No. 213, pp. 214-217. 1903.

ALUMINUM.

The known bauxite districts of the United States were examined and reported on in detail some years ago by Dr. C. W. Hayes, and so far no large extension of the industry has taken place outside the area covered by his work. That such an extension is possible, however, is evidenced by discoveries which have been made during the past two years. Bauxite deposits of more or less promise have been uncovered in the vicinity of Fort Payne, Ala., as well as in Tennessee, Virginia, and Pennsylvania. In all these cases the bauxite is associated with Cambrian or Cambro-Ordovician rocks—the Knox or Shenandoah limestone of the valley regions—so that the newly found ore bodies correspond clearly to the type described by Hayes from Alabama and Georgia.

SURVEY PUBLICATIONS ON ALUMINUM ORES—BAUXITE, CRYOLITE, ETC.

The following reports published by the Survey contain data on the occurrence of aluminum ores and on the metallurgy and uses of aluminum:

CANBY, H. S. The cryolite of Greenland. Nineteenth Ann. Rept., pt. 6, pp. 615-617. 1898.

HAYES, C. W. Bauxite. In Mineral Resources U. S. for 1893, pp. 159-167. 1894.

——— The geological relations of the southern Appalachian bauxite deposits. Trans. Am. Inst. Min. Eng., vol. 24, pp. 243-254. 1895.

——— Bauxite. Sixteenth Ann. Rept., pt. 3, pp. 547-597. 1895.

——— The Arkansas bauxite deposits. Twenty-first Ann. Rept., pt. 3, pp. 435-472. 1901.

SCHNATTERBECK, C. C. Aluminum and bauxite (in 1904). In Mineral Resources U. S. for 1904, pp. 285-294. 1905.

STRUTHERS, J. Aluminum and bauxite (in 1903). In Mineral Resources U. S. for 1903, pp. 265-280. 1904.