COPPER.

THE YERINGTON COPPER DISTRICT, NEVADA.

By FREDERICK LESLIE RANSOME.

INTRODUCTION.

The town of Yerington is in Lyon County, in that part of western Nevada which lies between Tahoe and Walker lakes. (See fig. 6.) The nearest railway station is Wabuska, 12 miles to the north, on the Hazen-Mina branch of the Southern Pacific. The town lies in the middle of Mason Valley, through which Walker River flows northward for some 25 miles before turning east, near Wabuska, around the north end of the Walker Range on its way to Walker Lake. A small part only of its water reaches the lake, however, most of it being used for irrigating Mason Valley, which is under extensive cultivation and yields bountiful crops of alfalfa. The verdant plain, with its winding river and rows of poplars, has its beauty much enhanced by vivid contrast with the adjacent sterile ranges on the east and west, within which are the copper deposits presently to be described. Near Yerington the valley is from 3 to 4 miles wide, but it expands northward to a broad plain, in one place fully 12 miles across and irrigable only in part with the present supply of water.

The principal mines are in the mountain ridge west of town, of which the Indian name is said to be Singatse,[a] but which J. E. Spurr[b] has called the Smith Valley Range. This ridge has an average width of about 4 miles, and the general line of its crest is from 1,600 to 2,600 feet above the valley at Yerington, or from 6,000 to 7,000 feet above sea. West of Singatse Ridge is the arid northern half of Smiths Valley, sloping southward to West Walker River and containing at its upper end the Ludwig mine and the prospecting camp of Buckskin.

[a] Smith, D. T., Geology of the upper region of the main Walker River, Nevada: Bull. Dept. Geol. Univ. California, vol. 4, 1904, pp. 1–32. The name is printed Sing-ats-e in this paper.

[b] Geology of Nevada south of the fortieth parallel: Bull. U. S. Geol. Survey No. 208, 1903, p. 117.

East of Yerington a belt of foothills, about 10 miles wide, intervenes between the valley floor and the bold Walker Range, whose steep eastern slope, probably a fault scarp, overlooks Walker Lake.

The geology of the region adjacent to Yerington received little attention from the earlier explorers. The only publication according

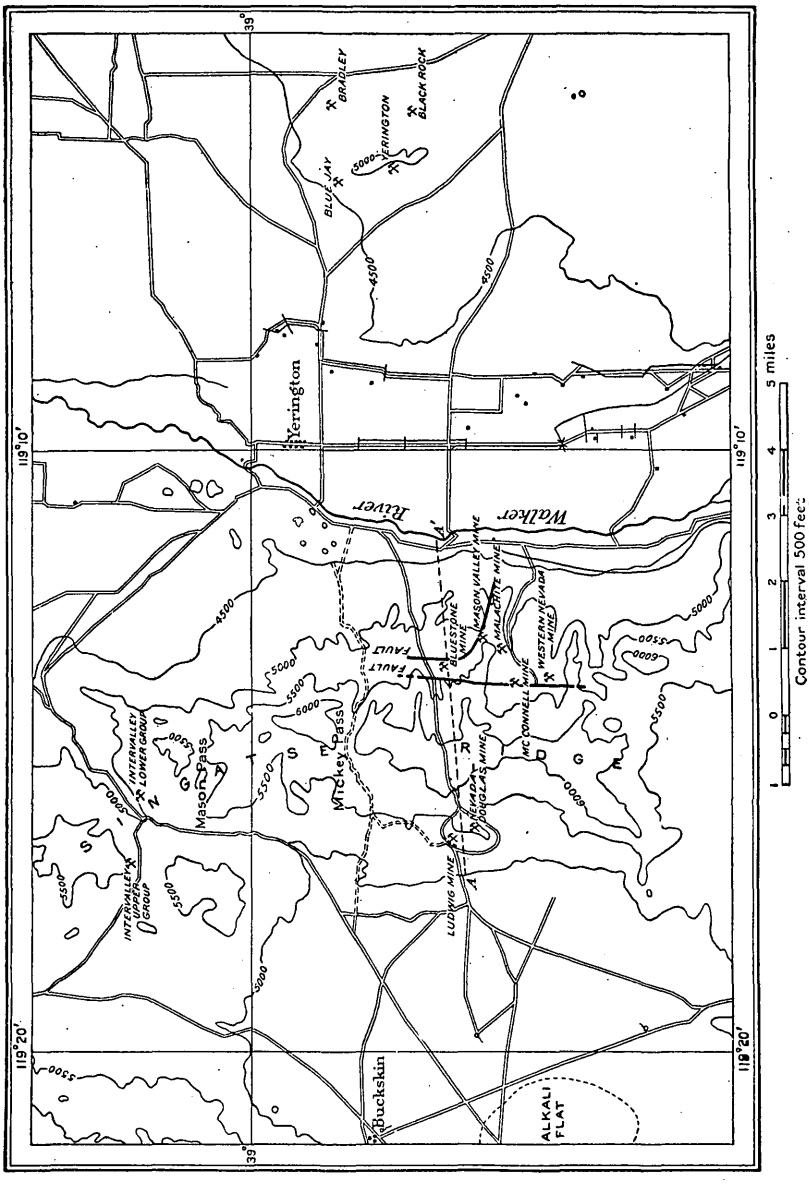

FIGURE 6.—Map of Yerington, Nev., and vicinity. *A—A'*, Line of section (fig. 7).

it more than incidental reference is the paper by Smith, already mentioned, which is accompanied by a geologic map based on the topography of parts of the Wabuska and Wellington atlas sheets of this Survey. Much remains to be learned regarding the distribution and

complex structure of the rocks exposed on both sides of Mason Valley. The facts for this preliminary paper were obtained in the course of a week's visit, during which attention was directed principally to the copper deposits and to the rocks in their immediate neighborhood.

GENERAL GEOLOGY.

PRINCIPAL ROCK GROUPS.

The rocks in the Yerington district are readily divisible into two groups markedly different in age and structure. The older group consists of schists and limestone with intrusive masses of granodiorite, or quartz monzonite, and related porphyries. This assemblage of rocks was called by Smith the "bed-rock complex," a name which it is not desirable to perpetuate and which will doubtless be replaced when detailed geologic work is undertaken. The granodioritic or monzonitic rocks were by him designated "granite," "granite porphyry," and "porphyrite," although his own petrographic descriptions appear hardly to suggest these names. The younger group, called by Smith the "superjacent series," is of volcanic origin and rests with obvious unconformity upon the older complex. It may in turn be divided into two parts, namely, (1) a series of rhyolitic flows and tuffs, bedded volcanic grits, andesitic tuff, and andesitic breccia, and (2) an unconformably overlying flow of basalt.

PRE-TERTIARY ROCKS.

The schists were examined mainly on the east side of Singatse Ridge, where they are well exposed in the canyon followed by the road to the McConnell mine. (See fig. 6.) Although the schist exhibits some textural and mineralogical variations, the prevailing kind is a hard, tough dark-gray rock of dense texture. The minerals recognizable with the naked eye are triclinic feldspar, hornblende, and epidote, these being rather sparingly distributed through the finely crystalline groundmass. The microscope shows that the schist is a metamorphosed igneous rock, probably an altered andesite. The original porphyritic texture is still recognizable and some of the feldspar phenocrysts are only partly recrystallized. The femic minerals (probably augite for the most part) have been completely changed into green hornblende, epidote, quartz, and pyrite, and a fine-grained aggregate of the same secondary minerals forms the present groundmass.

The schist, which is the prevailing rock in the canyon heading near the McConnell mine, is cut by many irregular dikes of granodiorite or granodiorite porphyry and is in places stained by salts of copper. The same rock is exposed along the lower eastern slope of the ridge

for a mile or two south of the McConnell and Western Nevada mines but is cut off ultimately by granodiorite which forms the lower part of the projecting spur on the southern border of the area mapped (fig. 6). The western slope of Singatse Ridge south of Mickey Pass is composed largely of schist similar to that described, and schist is mapped also by Smith[a] in the foothills of the Walker Range, 9 miles northeast of Yerington, but this locality was not visited.

On both slopes of Singatse Ridge masses of limestone are intricately infolded with the schist. Some of these masses are small and isolated. There is, however, one irregular but fairly continuous band of limestone that stretches north and south about halfway up the eastern slope and contains the Western Nevada, McConnell, Mason Valley, and Bluestone mines. This belt is about 1,000 feet wide at the McConnell mine and ends a few hundred yards north of the Bluestone. A similar band near the west base of the ridge contains the Ludwig and Nevada-Douglas mines.

Some of the limestone is a pure gray crystalline variety which is not noticeably metamorphosed and in which the bedding is distinct. Other parts of the formation, however, are intensely metamorphosed, containing abundant garnet, pyroxene, amphibole, epidote, and pyrite. The distribution of this metamorphism is irregular, and the gradation from masses of nearly pure garnet rock to gray limestone may be complete within a distance of a few feet. In some places the limestone has been changed to crystalline schistose aggregates, which are difficult of distinction from some of the schists not clearly derived from calcareous beds. In fact, the relation between the limestone and the andesitic schists previously described is so intimate as to leave little doubt that a series consisting originally of andesitic rocks, limestones, and perhaps some tuffs and shaly sediments has been folded, squeezed, and mineralogically changed at the same period and by the same set of metamorphic processes. The cause of the metamorphism was the intrusion of the granodiorite and closely related porphyries.

From Mickey Pass (see fig. 6) southward to the latitude of the Western Nevada mine the granodiorite occupies in general that part of the ridge which lies between the summit and the eastern belt of limestone. Along the summit the contact of the intrusive rock with the schist and limestone to the west of it is irregular, and as a whole is indefinite, as the granodiorite sends dikes into the rocks invaded by it, and includes also many masses of them. On the east, however, the line of contact between the granodiorite and the limestone of the Bluestone and Western Nevada belt is fairly straight and runs nearly north and south. It corresponds, at least in part, to a fault

[a] Op. cit., Pl. I.

which has dropped the limestone against the intrusive rock. South of the Western Nevada mine the granodiorite appears to make up a larger part of the ridge, and at the south edge of the area included on the map (fig. 6) this rock extends practically to the river.

The granodiorite of Singatse Ridge is a rock of general granitic appearance and for the most part of evenly granular texture. The coarsest variety noted occurs southeast of the McConnell mine, the average size of the grains being here about 5 millimeters. The constituent minerals are feldspar, quartz, biotite, and hornblende, with subordinate titanite, apatite, magnetite, and zircon, and with secondary epidote. The feldspar is of at least three kinds—plagioclase, orthoclase, and microcline. The plagioclase, which in the specimens examined is near andesine in composition, appears to be generally a little more abundant than the potassium feldspars, and the rock is provisionally called granodiorite. It is quite possible, however, that thorough chemical and petrographic study would show the rock as a whole to be nearer quartz monzonite than granodiorite, the distinction between the two being often a fine one, as must happen when classificatory limits are substituted for the gradations of nature.

The low hills north of Mason Pass and along the road from the pass to Yerington are composed mainly of granodiorite porphyry, which is generally more or less altered. This rock is stained with copper salts in many places, particularly about 1½ miles west of the town, where an attempt was made some years ago to mine and smelt the copper-stained porphyry.

The prevailing rock of the hills which contain the Blue Jay, Yerington, and other mines southeast of Yerington (see fig. 6) is granodiorite, or quartz monzonite, similar in texture to that of Singatse Ridge, but generally fresher and darker. Microscopically this difference is associated with more abundant and fresher biotite than in the granodiorite west of the river, and with the presence of a nearly colorless augite intergrown with the hornblende. A rock apparently identical with the one just described forms a considerable part of the main Walker Range east of Yerington, and is the general country rock in the vicinity of the new mining districts—Mountain View, about 15 miles east of Yerington, on the west slope of the range near its crest, and Granite, about 1½ miles farther east, on the versant toward Walker Lake.

That not all of the granodiorite and granodiorite porphyry was intruded simultaneously is clearly shown in the hills southeast of Yerington, where the main mass of granodiorite is cut by porphyry dikes of similar chemical and mineralogical character. It is very likely that detailed work on Singatse Ridge would also show two or more periods of intrusion by magmas differing slightly in composition.

The age of the schist and limestone near Yerington is not definitely known. The nearest limestone shown on Spurr's reconnaissance map[a] is in the Pine Mountain Range, 15 miles northwest of Yerington, and has yielded Triassic fossils.[b] D. T. Smith[c] found in one of the Tertiary beds a pebble which contained a fossil, probably *Daonella*, according to Prof. J. P. Smith, who, in communicating this determination to Mr. Smith, mentions having somewhere seen other Triassic fossils collected near Wabuska. The probabilities are, therefore, that the pre-Tertiary rocks near Yerington are Triassic. The intrusion of granodiorite which effected their metamorphism is supposed to have taken place in late Jurassic or early Cretaceous time. A long interval of erosion separated this event from the outbreak of Tertiary volcanism recorded by the rocks next to be described.

TERTIARY ROCKS.

The Tertiary lavas and associated sediments are younger than the ores, and no special study was made of them in the short time available for reconnaissance. East of the Bluestone mine and north of the Mason Valley mine there is a cove or depression in the east face of Singatse Ridge characterized, as may be seen from figure 6, by a rather irregular, finely cut topography, which contrasts with the bolder and steeper spurs of the main ridge. This depression is occupied by Tertiary rocks that evidently have been faulted down into the older series. The course of this fault, which is curved, is partly shown in figure 6. It was not examined north of the Bluestone mine, but the down-faulted block of volcanic rocks appeared to narrow rapidly in that direction. The fault plane is exposed in the main tunnel of the Bluestone mine, about 190 feet from its mouth, where it dips 65° E. The foot wall is limestone. Near the Mason Valley mine the fault curves eastward and can readily be traced over the surface, the ends of the various Tertiary formations abutting sharply against the older schist and limestone.

The Tertiary beds and flows in the down-faulted block strike nearly north and south. They dip to the west—that is, toward the fault at the Bluestone mine—at an angle of 45°. The base of the series may be seen on the edge of the valley near the mouth of the ravine that heads at the Mason Valley mine. At this locality a thin flow of rhyolitic glass rests on the schist with a dip of about 15° W. It is overlain by a thick flow, or series of flows, of yellowish rusty rhyolite. Near the Bluestone mine what appears to be the same

[a] Geology of Nevada south of the fortieth parallel: Bull. U. S. Geol. Survey No. 208, 1903, Pl. I.

[b] Spurr, J. E., op. cit., pp. 122–123.

[c] Op. cit., p. 9.

rhyolite is overlain by rhyolitic tuff containing many fragments of andesite. This in turn is overlain by a very coarse andesite breccia, which is succeeded by well-bedded volcanic grits. Overlying the grits is a soft andesitic tuff.

The general relation of these Tertiary formations to the older rocks and to the structure of the ridge as a whole is illustrated in figure 7, which is partly diagrammatic and makes no pretense of refined accuracy. No measurements were made, but the total thickness of the Tertiary formations in the fault block described is estimated at over 1,500 feet.

Rhyolite, probably equivalent to that of the section just described, makes up a large part of Singatse Ridge north of Mickey Pass and, as indicated by Mr. Smith's map, is well distributed over a region considerably larger than the area here considered.

South of the McConnell mine several of the spurs and summits of Singatse Ridge are capped by olivine basalt. These remnants occur at various elevations, ranging from 4,500 to 6,500 feet. They rest generally on the granodiorite, schist, or limestone, and this fact suggests that the older Tertiary rocks were deformed and much eroded before the basaltic eruptions began. Although the basalt has probably been faulted and in places may have been gently tilted, it nowhere shows dips as high as those of the rhyolitic and andesitic rocks.

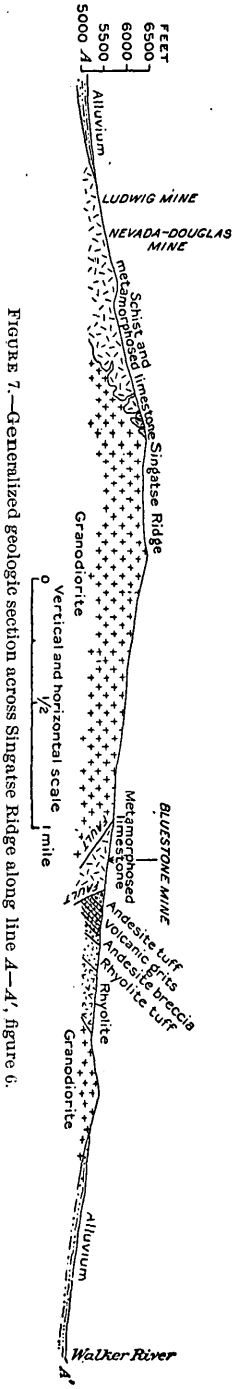

FIGURE 7.—Generalized geologic section across Singatse Ridge along line A—A', figure 6.

DISTRIBUTION OF THE MINES.

The general distribution of the important mines and prospects near Yerington may be seen from figure 6. One group, the members of which are similar in the character and geologic relations of their ore bodies, lies on the east slope of Singatse Ridge southwest of Yerington, about halfway from valley to crest. Together they constitute a chain 2 miles in length, the mines from north to south being the Bluestone, Mason Valley, Malachite, McConnell, and Western Nevada. Most of these mines have shipped some oxidized copper ore, but operations at present are confined to development in the sulphide zone or, at the Mason Valley mine, in a zone of mixed oxidized and sulphide ore.

These mines are from 4 to 8 miles from Yerington by wagon road. The history of all goes back thirty years or more, but none has produced abundantly or continuously. At the western foot of Singatse Ridge are the Nevada-Douglas and Ludwig mines, now under one ownership, the Nevada-Douglas Company having bought the Ludwig in 1907 for about $500,000. By the direct but steep road over the ridge past the Bluestone mine the distance from Yerington to these mines is about 7 miles. The Mason Pass road from town to the Ludwig mine is about twice as long, but is much used because of its better gradient. Both the Nevada-Douglas and Ludwig are old mines and have intermittently produced considerable ore; how much is not known. The Ludwig ore has of late been hauled by a traction engine to Wabuska.

About a mile north of Mason Pass (see fig. 6) and 9 miles northwest of Yerington by road, are the upper and lower workings of the Intervalley mine. These are shallow prospects which were never productive and are now idle. Buckskin, about 4½ miles west-northwest of the Ludwig mine, is a prospecting camp, in the vicinity of which some shallow exploration is in progress.

Another group of prospects lies in the low hills from 4 to 5 miles southeast of Yerington. Among these the Blue Jay, with a 450-foot shaft, and the Yerington, 412 feet deep, are the most important. The latter only was in operation in 1908. A mile east of the Blue Jay is the Bradley, about 100 feet deep, and a mile south of this mine is the Black Rock, with still less development. No work was in progress at either place at the time of visit.

DESCRIPTIONS OF MINES AND PROSPECTS.

BLUESTONE MINE.

The Bluestone mine is situated 4 miles southwest of Yerington, halfway up the east slope of Singatse Ridge, at an elevation of about 5,300 feet. It was worked about thirty years ago, and for a time supplied natural bluestone (chalcanthite) to the amalgamating mills at Virginia City. A small smelter was built at the mine and ran for a few years on partly oxidized ore stoped above the 100-foot level; but no great production was attained and operations of late have been restricted to systematic exploration and to experiments in ore treatment.

The mine is opened on three levels, approximately 100, 200, and 275 feet below the surface. There is also a sublevel 25 feet below the 275-foot level. The principal drifts and crosscuts are within the ore body, which is of generally elliptical plan with a length between 300 and 400 feet and a width between 200 and 300 feet. No regular structures are followed by the drifts, which are devious and have been

so laid out as to leave no large blocks of the ore-bearing ground unexplored. The 100-foot and 300-foot levels connect with the surface through adits. The lower or main adit runs westward and cuts the ore body at 780 feet from the portal. It then turns toward the northwest and continues for nearly 400 feet through the ore and into the country rock on the other side. The total development work is from 6,000 to 8,000 linear feet.

The ore lies in limestone near the contact of this rock with granodiorite, which is widely exposed just west of the mine. The contact, as mentioned on page 102, is due to faulting; the fissure at this place strikes a few degrees east of north and dips 35° E. Both granodiorite and limestone are crushed and sheared in its vicinity. The ore is wholly in the limestone, being from 50 to 100 feet or more east of the fault zone, which shows no mineralization. The belt of limestone containing the ore is here about 700 feet wide and is bounded on the east by the down-faulted block of Tertiary volcanic rocks already described. This fault, crossed by the main adit 190 feet from the portal, is a clean-cut unmineralized fissure with an easterly dip of 65°. It has no connection whatever with the deposition of the ore.

The plan of the ore body, as already stated, is roughly elliptical, the longer axis trending about 25° west of north. The northwest end of the mass is thus nearer the granodiorite than the southeast end. The dip is variable, but the mass as a whole dips to the east at an angle of about 45°, so that the ore is nearer the granodiorite on the 275-foot than on the 100-foot level. There is no sharp separation between ore and limestone, although on the foot-wall side of the ore body there is a persistent seam or fissure which in places serves practically as a wall. The ore, however, does not everywhere extend as far west as the seam, and the limestone beyond this fissure, which shows no evidence of important movement, contains the same minerals as the ore. A similar but less persistent fissure serves in some places as a hanging wall for the ore body, which at its ends passes gradually into mineralized but unprofitable limestone. Similar gradations from ore to limestone may be observed at many places within the mass of the ore body. The ore maintains its general character down to the 275-foot level, but the 300-foot sublevel at the time of visit showed only mineralized country rock. Mr. C. A. Weck, superintendent of the mine, has estimated on the basis of careful sampling that the quantity of ore blocked out is between 2,000,000 and 3,000,000 tons, with an average tenor of 3 per cent of copper.

The ore consists essentially of chalcopyrite disseminated as grains and small irregular masses through limestone that has been altered to an aggregate consisting chiefly of a yellowish-gray epidote with subordinate calcite and quartz. A little garnet has been noted by

Mr. Weck, and a careful microscopical study of various specimens of the metamorphosed limestone in the vicinity of the ore body would probably reveal other silicates also. The mass of the ore, however, has the simple mineralogical composition given above. The ore proper is almost free from pyrite, but the chalcopyrite gives place to this sulphide as the ore grades into country rock. The microscope shows a little apatite with the epidote in some thin sections.

Oxidation is not extensive and scarcely penetrates to the 100-foot level, while chalcopyrite is present in the croppings. The products of oxidation are malachite (with possibly some brochantite and libethenite), azurite, cuprite, and chalcanthite. These are generally associated with sulphides, and there are no large masses of thoroughly oxidized ore. A little chalcocite occurs above the 100-foot level, but there has been no important enrichment through the secondary formation of this mineral. It is evident that the ore body as a whole is too solid to have been penetrable to any considerable depth by oxidizing solutions, and that erosion has kept pace with the process of weathering.

At the time of visit experiments were in progress to determine the best method of concentrating the ore. The scheme devised is to crush the ore and pass it through a 10-mesh screen. The material is then given a slight roasting, which renders the chalcopyrite magnetic, and is passed through Wetherill magnetic separators. The experimental extraction ranges from 92 to 95 per cent, but the concentrates still contain considerable epidote.

The Bluestone ore body is a partial replacement of limestone by chalcopyrite, this replacement being accompanied by metamorphism of the limestone to epidote and other silicates, and by the metasomatic formation of disseminated pyrite. The process of ore deposition appears to have been completed before the limestone was faulted down into its present relation with the granodiorite and, of course, before the faulting which affected the Tertiary volcanic rocks. Ore deposition bears no genetic relation to any discoverable zone of major fissuring. The original cupriferous solutions probably penetrated the limestone at high temperature and under great pressure through small or microscopic fractures. The mineralogical character of the deposits suggests that the deposition of the ore was closely connected with the intrusion of the granodiorite, and that the ore body should be classified with those of contact-metamorphic origin.

MASON VALLEY MINE.

The Mason Valley mine is three-quarters of a mile southeast of the Bluestone and at nearly the same elevation. The ore body outcrops at about 5,500 feet above sea level, and has been cut by tunnels running southwestward into the ridge at elevations of 5,385, 5,325, and

5,200 feet. A new tunnel, known as No. 4, is being driven at 5,080 feet, and is expected to enter the ore at about 1,100 feet from the portal. There are also some abandoned workings, which attained a depth of nearly 200 feet, and which, like the Bluestone mine, supplied copper sulphate to the mills on the Comstock lode. The recent work is of an exploratory character, and is mainly on the No. 3 level.

The country rock of the ore is limestone, which shows much local alteration. This rock is cut off just north of the mine by the fault previously mentioned, which has dropped the Tertiary volcanic rocks against it. Whether the limestone is entirely continuous along the west side of this fault with that of the Bluestone mine, or whether some exposures of schist intervene, was not ascertained. The limestone area continues to the south over the spur between the Mason Valley and Malachite mines, both of these being on the same irregular zone of mineralization. Some schist, however, separates this belt from the limestone of the McConnell mine. (See fig. 6.) The Mason Valley mine is at least half a mile east of the fault contact of the limestone with the granodiorite.

As exposed at the surface the copper-bearing zone in the limestone trends nearly north and south, but is curved and irregular. Its greatest width is about 150 feet. Its total length, without measurement of sinuosities, is nearly 2,000 feet. Probably beneath a small part only of the copper-stained croppings is ore present in commercial quantity. The workings of the Mason Valley mine show that the ore bodies are irregular and indefinitely bounded masses which, as a rule, grade into garnetized limestone, although in some places, particularly on the west side, there is a close fissure or joint separating ore from country rock. The development at present is insufficient to reveal the sizes or shapes of the ore shoots, but apparently they do not extend continuously from the surface down. The No. 2 tunnel, for example, is in barren ground, with ore above and below it.

The sulphide ore is composed essentially of pyrite and chalcopyrite, with garnet, pyroxene, and a little calcite. Epidote is possibly present in some varieties, but does not appear in the thin sections examined. The most abundant and characteristic gangue mineral is a pale-brown or amber-tinted garnet, which in crystals is almost transparent, and where massive is not unlike the epidote rock of the Bluestone mine in general appearance. No chemical analysis has been made of this garnet. Although its color suggests the calcic aluminous variety grossularite, the work of Lindgren [a] and of Kemp and Gunther [b] has shown that much of the brown garnet in contact-

[a] Copper deposits of the Clifton-Morenci district, Arizona: Prof. Paper U. S. Geol. Survey No. 43, 1905, p. 134.

[b] White Knob copper deposits, Mackay, Idaho: Trans. Am. Inst. Min. Eng., vol. 38, 1908, pp. 286–287.

metamorphic deposits is the calcic-ferric variety andradite, or is a kind containing at least a considerable proportion of the andradite molecule. Under the microscope some of the garnet from the Mason Valley mine shows the optical anomaly frequently seen in this mineral, namely, sharp division into birefringent sectors.

The pyroxene is light green and in thin section is nearly colorless. It is without crystal planes and either occurs in xenomorphic aggregation with garnet and sulphides or forms dull-green radiating lamellar masses of diallagic habit. The lack of luster and transparency of these masses suggests partial decomposition, and microscopical examination shows this to be the case; all the coarse lamellar aggregates examined are mixtures of original pyroxene with secondary serpentine, calcite, fibrous amphibole, and in some specimens epidote. The pyroxene is presumably diopside or an augite near diopside in composition.

The primary ore of the Mason Valley mine contains more pyrite with the chalcopyrite than that of the Bluestone mine, and appears to be generally of lower grade. Oxidation, however, has penetrated deeper and has effected some local concentration down to the No. 3 tunnel, although some sulphides occur at the surface. On the No. 3 level there is a considerable body of rich ore, consisting of impure earthy cuprite with much disseminated native copper. The shape and extent of this body, which contains up to 20 per cent of copper, have not been fully ascertained. Chalcocite in a soft sooty condition occurs sparingly, but there has been no important enrichment through the formation of this sulphide. The minerals noted in the oxidized zone are malachite, azurite, cuprite, native copper, limonite, gypsum, and chalcanthite.

As in the Bluestone mine, the original ore of the Mason Valley mine forms irregular metasomatic masses in limestone and is without definite boundaries. Its character suggests contact-metamorphic action, although the ore is not at present close to the granodiorite.

MALACHITE MINE.

The Malachite mine is from a third to half a mile south of the Mason Valley mine and is on the same general zone of mineralization. The workings comprise some old adits from which was taken partly oxidized ore similar to that of the Mason Valley mine. At the time of visit a shaft was being put down in the limestone below the old tunnels, but this shaft was not yet in ore and was not examined.

McCONNELL MINE.

The McConnell mine is about a mile southwest of the Mason Valley mine and 7 miles from Yerington by road. The limestone, which is the mineralized rock, here constitutes a north-south belt from 300 to

400 yards wide, bounded on the east by schist and on the west by granodiorite. Whether this western contact is the result of intrusion or of faulting is not quite clear, but it is thought to correspond to a fault. The ore bodies are at the western edge of the belt near the granodiorite. The limestone which incloses them is a fine-grained gray variety which is not on the whole much altered, although here and there it contains irregular masses of silicates and sulphides. Between this gray limestone and the granodiorite intervenes locally a small mass of intensely metamorphosed rocks that are cut by dikes and tongues of granodiorite. These altered beds, probably once calcareous shales, are now crystalline schists rich in garnet and epidote.

The older workings of the McConnell mine comprise open cuts and short tunnels in the oxidized ore and an adit several hundred feet in length with considerable drifting in the sulphide zone. At the time of visit work was confined to sinking by a shaft near the portal of the main adit. This shaft was then 400 feet deep in dark limestone carrying a little pyrite and epidote.

The unoxidized ore, as exposed in the lower or main adit, resembles in appearance that of the Mason Valley mine. There is much pyrite with the chalcopyrite, and the material is evidently not of high grade. The principal gangue minerals are pale-brown garnet and a light-green amphibole. It is probable that pyroxene is also present in some parts of the ore body, although it does not appear in the thin sections examined. Coarse lamellar aggregates similar to those in the Mason Valley mine, but more decomposed, were noted in some of the cuts in the partly oxidized ore.

WESTERN NEVADA MINE.

The Western Nevada mine is half a mile south of the McConnell mine and is similarly situated on the same limestone belt. The zone of mineralization is here about a quarter of a mile wide, with irregular isolated bodies of sulphides and silicates distributed erratically through it. Some of these bodies are at or very close to the granodiorite; others are separated from it by masses of gray unaltered limestone. The body of ore now being explored in the Western Nevada mine is about 1,000 feet east of the granodiorite, the intervening rock, which forms a small hill, being comparatively little-altered gray limestone.

The principal adit is 1,000 feet in length and runs northeastward through the limestone to the granodiorite. There are extensive lateral drifts from this adit, and a winze, 90 feet deep at the time of visit, will be sunk to 300 feet. The present workings explore the ore bodies to a total depth of about 300 feet.

The contact between the limestone and granodiorite is due to faulting, the fault plane dipping to the east at 54°. There is a seam

of gouge, and the limestone of the hanging wall is much broken but no mineralization has taken place along the fault. About 100 feet east of the fault fissure is a nearly north-south zone of crushing in the limestone, which is occupied in part by a quartz vein carrying pyrite but no constituents of value. This vein, which has not been much explored, dips 35° E. It is probably younger than the cupriferous ore bodies in the limestone, but its age could not be definitely ascertained.

The croppings of the Western Nevada mine, which are partly capped by younger basalt, show abundant chrysocolla, copper carbonates, and epidote, and considerable bodies of such ore have been opened in cuts and superficial tunnels. The main adit that passes under these older workings has not, however, revealed as much ore as was hoped. It traverses for the most part hard altered limestone with irregular and ill-defined bunches of lean pyritic ore. The change from masses of sulphides and metamorphic silicates to fine granular white or gray limestone is in many places unexpectedly abrupt. The most altered variety is a hard, tough dark-green aggregate of pale-green augite or diopside, garnet, pyrite, and chalcopyrite.

In some places the garnet has decomposed to chlorite and the augite to pale-green amphibole, serpentine, and calcite. Calcite occurs also in some specimens as a constituent belonging, like the garnet and pyroxene, to the period of metamorphism.

The ore bodies of the Western Nevada mine as opened on the main level at a depth of about 200 feet have the general character of unenriched contact-metamorphic deposits. Their profitable exploitation and concentration constitute a difficult problem.

LUDWIG MINE.

The Ludwig mine lies on the west side of Singatse Ridge at the edge of Smiths Valley. It is worked through a vertical shaft 400 feet deep with a steeply inclined winze 200 feet deep, below the 400-foot level. The 400-foot, 500-foot, 550-foot, and 600-foot levels were the only ones examined, the levels above the 400-foot having been stoped out and abandoned. The drifts vary in direction from north to N. 35° E. The most extensive level is about 400 feet long.

Unlike the deposits on the east side of the main ridge, the Ludwig ore body is of lodelike form with a steep dip to the east. The ore zone is from 50 to 60 feet wide on the upper levels, but in the deeper workings the number of crosscuts is too small to show fully the limits of the pay shoots. No walls are known, for example, on the 400-foot level. The general country rock is limestone. That in the foot wall is an ordinary gray massive limestone which for a depth of 50 feet

has been extensively altered to solid alabastine gypsum by acid solutions from the oxidizing sulphides. The hanging-wall limestone is generally thin bedded and contains garnet with other metamorphic silicates. The beds dip to the east at about 65°, but are intruded and disturbed by dikes of granodiorite porphyry, one of which, just north of the shaft, forms the hanging wall of the lode. Within the ground explored the fissuring that permitted the ore deposition appears to have coincided with the plane of bedding between the massive limestone, which is probably over 100 feet thick, and the thinner, more metamorphosed beds now forming the hanging wall.

The ore from the surface to the 500-foot level is mainly oxidized. It consists on the 400-foot level of a large mass of shattered limestone, whose interstices and fissures are filled with coarsely crystalline calcite. This vein matter once contained sulphides, but these have been oxidized, and chrysocolla, earthy oxides, and carbonates have been secondarily concentrated in solution cavities and along zones of crushing in the original vein material. The best oxidized ore thus forms bunches distributed through the lode. There was considerable migration of the copper during oxidation and the chrysocolla and carbonates have been in part deposited by metamorphism in the calcite, the replacement having begun its attack from cracks and cleavage planes. Some unoxidized ore, consisting of pyrite and chalcopyrite in a gangue of calcite, pale-brown garnet, and quartz, remains at the south end of the 400-foot level and shows what must have been the character of at least a part of the mass that has undergone oxidation.

The ore on the 550-foot level consists chiefly of sulphides and carries from 2 to 3 per cent of copper. There is, however, some rich oxidized ore even at this depth, one soft, earthy face exposed at the time of visit affording assays up to 40 per cent of copper. Ore enriched by the deposition of chalcocite on pyrite is also present, but the quantity of such rich sulphides is apparently not great. The 600-foot level showed no ore at the time of visit; the vein filling then exposed consisted of coarsely crystalline white calcite with some quartz and a little pyrite.

A notable feature of the oxidized ore is the occurrence here and there of libethenite, a hydrous phosphate of copper ($Cu_3P_2O_8 \cdot Cu(OH)_2$), in crystalline aggregates resembling malachite. Attention was first called to the occurrence of this mineral in the Yerington district by Smith,[a] who found at the Blue Jay mine, east of town, a few small crystals, which were studied crystallographically in the Survey laboratory by Mr. W. T. Schaller.[b]

[a] Op. cit., p. 31.

[b] Clarke, F. W., and others, Contributions to mineralogy; Bull. U. S. Geol. Survey No. 262, 1905, pp. 140–143.

The Ludwig deposit differs from those on the east side of the ridge in the fact that it fills a fissure. The original filling contains some garnet and quartz, but is predominantly calcite, with enough pyrite and chalcopyrite to make an ore of very low grade.

On the hill slope above the Ludwig mine there are many places where the schist and metamorphosed limestone, particularly the latter, carry small quantities of oxidized copper ore. Most of these deposits are clearly small bunches. Some of them probably represent sulphides that have been oxidized in place; others appear to be due to secondary deposition along minor fissures by cupriferous solutions which have percolated down from inconsiderable masses in rock that has since been removed by erosion.

NEVADA-DOUGLAS MINE.

The old workings of the Nevada-Douglas mine, idle at the time of visit, are, as shown in figure 6, on the crest of a little spur, half a mile southeast of the Ludwig mine and 500 feet above the valley. The country rock is limestone, which is extensively but irregularly altered to garnet rock. At the mine the garnet zone is at least 600 feet wide, strikes north and south, and carries bunches of ore that have no definite walls, although they trend in general with the inclosing rocks. The old workings, which are fairly extensive, consist of various tunnels, shafts, and open cuts that are not all on the same ore body.

Most of the ore taken out and piled on the dumps is oxidized material and consists largely of blue and green chrysocolla. Associated with this mineral is some epidote in coarsely crystalline masses and small quantities of copper carbonates. The oxidized ores are succeeded at moderate depth by fine-grained granular masses of pyrite, chalcopyrite, and garnet. This material has undergone some enrichment by the deposition of a dark copper sulphide, probably chalcocite, on the surfaces and in cracks of the older sulphides.

At the edge of Smiths Valley, west of the old workings and 2,200 feet south of the Ludwig mine, a new tunnel has been begun for the purpose of cutting the Nevada-Douglas ore bodies at greater depth. This tunnel was about 400 feet long at the time of visit and is practically all in garnetized limestone. No work was in progress at this adit in 1908.

INTERVALLEY MINE.

The Intervalley workings lie about a mile north of Mason Pass and are in two groups a mile apart. The openings are shallow and no work was in progress in 1908. The country rock is granodiorite porphyry. The main workings of the upper group, which were the only ones examined, consist of an incline about 100 feet in length

with some short drifts. The deposit is a vein which strikes nearly east and west and at the surface has a width of 3 to 4 feet. The filling is calcite with some malachite and chrysocolla. The dip is to the north and is about 12° at the surface, but increases to 30° or 35° near the bottom of the incline. The vein appears to have little persistency in any direction and at the face of the incline is a mere seam with no ore.

YERINGTON MINE.

The property of the Yerington Copper Company was the only one in the group east of town at which any prospecting was in progress in 1908. The general country rock is granodiorite or quartz monzonite, which is cut by a dike of porphyry about 25 feet wide. The dike strikes N. 55° W. and dips 65° to 70° SE. The shaft, which is 412 feet deep, follows the mineralized foot wall of this dike.

The dike rock is apparently granodioritic or monzonitic, but it is altered and contains much epidote, calcite, chlorite, and sericite. Quartz is less abundant than in the granodiorite which the dike cuts. The dike becomes finer grained near its walls and grades into a banded flinty selvage which, near the surface, is generally stained with carbonate of copper.

The ore, as seen on the 400-foot level, consists essentially of pyrite, which is disseminated through the granodiorite for a distance of a few feet from the dike. No distinctly cupriferous minerals were seen at this depth and the ore is clearly of very low grade. Its average width appeared to be about 4 feet. A little good chalcocite ore was found between this lean ore and the oxidized zone. There is no fissure filling and no evidence of much movement in the rocks since the intrusion of the dike. Mineralization has worked metasomatically outward from the contact between the dike and its inclosing rock, producing a low-grade pyritic deposit which has been superficially enriched by descending solutions.

The dike and its attendant zone of mineralization extend northeastward over the ridge (see fig. 6) for a distance of at least half a mile, and have been superficially prospected at various places.

BLUE JAY MINE.

A mile north of the Yerington mine, on the same side of the ridge, is the Blue Jay mine, in a band of dark rock which is distinctly visible from town and was supposed in the field to be a dike cutting the granodiorite. On fresh fracture and in thin section, however, the difference between the rocks proves to be slight and to be partly due to the greater alteration of the supposed dike. The dark rock, therefore, may be merely a zone of alteration accompanying two or more parallel fissures. The necessarily brief examination given this fea-

ture and the few specimens collected are insufficient to determine the point, and pending further examination the darker rock will be provisionally referred to as a dike.

The dike is from 300 to 400 feet wide at the Blue Jay mine, strikes N. 70° E., and can be followed in that direction for about a mile. It becomes narrower toward the east and finally disappears under alluvium. It is stained with copper salts at many places along its course, and near the Blue Jay mine bunches of oxidized copper ore are distributed through the entire width of the dike. The principal mineralization, however, follows the southern wall, on which a shaft has been sunk for 450 feet. The contact is said to be vertical for about 150 feet and then to dip steeply to the north. The dump of the abandoned shaft shows considerable oxidized ore containing chrysocolla, malachite, cuprite, and libethenite. Careful study might show also some brochantite, a mineral not readily distinguishable from malachite on superficial examination. The oxidized ore passed below into lean pyritic ore with some chalcopyrite. Whether any chalcocite was found is not known.

The material on the dump indicates that the deposit is of metasomatic origin and does not to any considerable extent fill an open fissure.

BRADLEY PROSPECT.

The Bradley prospect is a mile east of the Blue Jay mine, on a fissure in granodiorite. The fissure strikes N. 35° E. and dips 40° SE. The workings comprise an inclined shaft 100 feet deep and some open cuts. Only oxidized ore was seen. It occurs in bunches along the fissure zone, the maximum width observed in the accessible opening being about 4 feet. The ore contains some specularite.

BLACK ROCK PROSPECT.

The Black Rock prospect is a little more than a mile south of the Bradley and is even less developed. The fissure, along which the granodiorite has been mineralized, strikes N. 70° E. and dips 60° N. The material thrown out from the shallow openings contains considerable vein quartz, showing that the deposit has, in part at least, filled open spaces in the fissure. This quartz carries much specularite with a little chrysocolla and chalcopyrite. The specularite is apparently not due to superficial oxidation, but has crystallized with the quartz.

GENERAL CHARACTERIZATION OF THE COPPER DEPOSITS.

As appears from the preceding descriptions, the copper deposits near Yerington are of three kinds—(1) irregular bodies formed by metasomatic replacement of limestone and genetically associated with

metamorphism of a kind usually attributed to the contact action of intrusive rock, (2) metasomatic vein deposits in altered limestone, and (3) metasomatic vein deposits in granodiorite.

The deposits of the first class are exemplified by those of the Bluestone, Mason Valley, Malachite, McConnell, Western Nevada, and Nevada-Douglas mines. The original sulphides of these ores are pyrite and chalcopyrite in various proportions. The gangue minerals are pyroxene, amphibole, epidote, garnet, and calcite. The proportions of these also vary widely in different deposits. The tenor of these primary ores is generally low; probably no masses of large size average over 3 per cent in copper. The largest and richest body of such ore that has been at all satisfactorily blocked out is that of the Bluestone mine, which is about 300 feet long and of approximately the same width and depth.

The oxidation of these ore bodies has not been extensive and appears to have penetrated deepest in the Mason Valley mine. There has been no important enrichment through the deposition of chalcocite or other secondary sulphides, though some of the oxidized ore is of high grade.

Although these deposits are of a character usually associated with contact metamorphism they are not very closely related to igneous contacts. Those nearest the granodiorite owe their present proximity to that rock to faulting. Consequently they can not be regarded as typical contact-metamorphic deposits, although they are believed to belong in that general class and to be genetically connected with the granodioritic intrusion.

The only important deposit of the second class is the Ludwig ore body, in which the vein is composed mainly of coarsely crystalline calcite carrying some garnet with pyrite and chalcopyrite. Oxidation in this deposit has extended to a depth of about 500 feet and has produced ore of shipping grade. At the base of the oxidized zone there has been some chalcocitic enrichment. The occurrence of garnet in the vein material links this deposit with those of the first group, but the fissuring and veining probably took place after the limestone had been considerably metamorphosed.

The deposits of the third class include those of the Intervalley, Blue Jay, Yerington, Bradley, and Black Rock mines or prospects. They are characterized by the development of pyrite with subordinate chalcopyrite in granodiorite or monzonite along zones of fissuring. In two of them, the Intervalley and Black Rock, there has been some filling of open spaces, but in the others the sulphides have developed within the rock alongside the narrow fissures that served as channels for the depositing solutions. No thorough study of the action of these solutions on the wall rock has been made. The deposits, however, are believed to represent a stage of mineralization

later than those in which the deposits of the first and second classes were formed. The economic importance of the deposits of the third class is as yet unproved.

The total quantity of oxidized ore exposed in the district is small and there is no indication of any extensive sulphide enrichment. The quantity of gold or silver in the ores is practically negligible. The future of the mines depends on the working of low-grade primary deposits. The conditions are in some respects favorable for cheap mining and concentrating; a railroad could be constructed from Wabuska along Walker River with very little difficulty, water is more plentiful than in most other parts of Nevada, and many agricultural products can be grown in Mason Valley. On the other hand, water, tailings, and smelter fumes are subjects concerning which miners and farmers usually find agreement difficult.

MOUNTAIN VIEW AND GRANITE.

Although the settlements of Mountain View and Granite are not in the Yerington district, they were hastily visited in the course of the reconnaissance, and such observations as were made may conveniently be recorded in this place. Mountain View is 15 miles east of Yerington, near the crest of the Walker Range. The general country rock is granodiorite or quartz monzonite, which is overlapped by rhyolite along the west side of the range. Both andesite and rhyolite occur on the crest of the range south of Mountain View, resting on the granodiorite and capped by basalt.

The Mountain View mine is developed by three short tunnels. The lode, which follows a narrow decomposed dioritic dike, strikes N. 75° E., and is about vertical. The mineralization is mainly on the south side of the dike, and much of the vein filling is a soft, light pumice-like quartz that contains a little native sulphur. This material has probably resulted from the oxidation of a pyritic vein. It is said to carry up to $50 a ton in gold and silver. The lower tunnel at the time of visit was just getting into pyrite, the tenor of which was not known. But little vein quartz was visible on this level, the pyrite being disseminated through the dike accompanied by a few small bunches of specularite.

The same dike and attendant fissures continue eastward over the crest of the range, and on the east slope, near the summit, were being worked by lessees on the Big Twenty ground. Here there were three or four shafts up to 100 feet deep. A little oxidized gold ore had been shipped, but the lessees had not received returns at the time of visit and did not know its tenor.

East of these leases and about 1½ miles east of Mountain View is Granite, a new town of 30 or 40 tents and board cabins. This set-

tlement, which is most easily reached from Schurz, on the Hazen-Mina branch of the Southern Pacific Railroad, was not very active at the time of visit and prospecting appeared to be in progress only along the line of the Mountain View and Big Twenty lode and at the Beach copper mine, about 1½ miles south of town and near the crest of the range. At this place there is a prominent vein in granodiorite, which strikes N. 50° E. and dips 60° SE. This vein is from 8 to 25 feet wide at the surface and shows copper carbonates in a gangue of quartz and crushed granodiorite. A tunnel 400 feet in length has been run from 100 to 200 feet below the croppings and shows that the granodiorite is considerably disturbed and that the vein, so large above, has a tendency to split up and become irregular below. No ore had been found on this level at the time of visit, but work was still in progress.

SURVEY PUBLICATIONS ON COPPER.

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The United States 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. Those marked "Exhausted" are not available for distribution, but may be seen at the larger libraries of the country.

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