THE DARWIN SILVER-LEAD MINING DISTRICT, CALIFORNIA.

By ADOLPH KNOPF.

INTRODUCTION.

Most of the lead ore produced in California has come from the Cerro Gordo, Darwin, and Modoc districts, all in Inyo County, in the eastern part of the State. The Cerro Gordo district has been by far the most productive, having yielded during its most prosperous years $7,000,000 in argentiferous lead. The Darwin district has probably yielded between $2,000,000 and $3,000,000.

The geologic features of the Cerro Gordo district have recently been described by the writer,[1] and it is the purpose of the present report to describe those of the Darwin district. The data on which this report is based were obtained during the period from May 11 to May 19, 1913.

Some notes on the district have been given by W. A. Goodyear [2] and brief reference has been made to it by H. W. Fairbanks.[3]

GEOGRAPHY.

Darwin is situated in Inyo County, Cal., 24 miles southeast of Keeler, the southern terminus of the Nevada & California Railroad. It is a small settlement which in 1913 contained but a score or two of inhabitants. It lies at an altitude of 4,750 feet on the west slope of a low desert range, sometimes known as the Darwin Hills. It is within this range that the mines here described are situated, and the Darwin district, as the term is used in this report, is coextensive with the Darwin Hills. The legally constituted mining district within which it is situated is known as New Coso.

The Darwin Hills trend in a northwesterly direction. They are bordered on the east, south, and west by great gravel washes, but to the north their termination is somewhat indefinite and their identity becomes lost through coalescence with scattered groups of hills. The length of the range is about 6 miles, and the relief is from 500 to 1,000 feet.

[1] Mineral resources of the Inyo and White mountains, Cal.: U. S. Geol. Survey Bull. 540, pp. 81–120, 1914.
[2] Inyo County: California Min. Bureau Eighth Ann. Rept., pp. 224–226, 1888.
[3] The mineral deposits of eastern California: Am. Geologist, vol. 17, pp. 149–150, 1896.

Physiographically the range has been reduced by long-continued erosion to mature rounded slopes. Rejuvenation has, however, affected the range to some extent within comparatively recent time. This is shown most plainly along the east flank of the southern portion

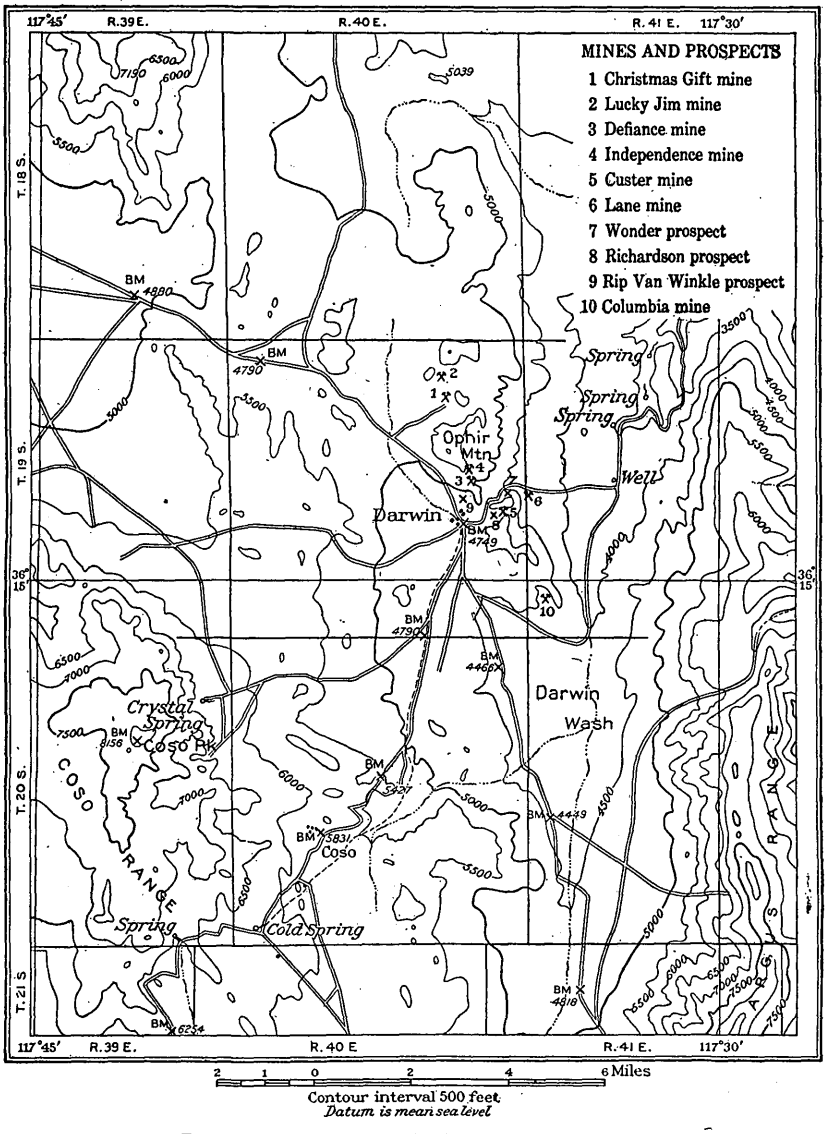

FIGURE 1.—Map of the Darwin district, Cal., and vicinity.

of the range, where recent faulting is strongly indicated. That the east flank of the range is thus determined by a fault scarp is attested by the rugged character of its topography, which contrasts sharply with the smooth rounded slopes on the west side of the range, and

this evidence is corroborated by the triangular faceting of the spurs. Toward the north, however, the fault dies out, as is shown by the fact that a series of basalt flows lying across the trace of the fault seems not to have suffered noteworthy displacement. Of interest in this connection is the fault scarp shown by the Argus Range, just east of the Darwin Hills. The face of this range is determined by a series of step faults, exhibited diagrammatically in a displaced series of basalt flows, whose faulted segments form, as it were, the treads of a stairway of four steps ascending from the valley floor to the summit of the range.

MINING CONDITIONS.

The district lies in the desert region of southeastern California and is therefore arid. The average annual rainfall at Keeler, which is the nearest locality for which records are available, is 3.15 inches, and it is unlikely that the precipitation at Darwin exceeds this, although Darwin is 1,100 feet higher than Keeler. Water is piped by gravity from the Coso Mountains, a distance of 8 miles, and was in 1913 sold at half a cent a gallon for mining purposes and 1 cent a gallon for domestic purposes. An ample supply is said to be available at the well at the lower end of the Darwin Wash, but for most of the mines in the district the utilization of this supply would require a lift of 2,000 to 2,500 feet.

Ore is hauled from the mines to the railroad at Keeler at $6 to $8 a ton, either by team or auto truck. Freight brought out to the district costs $1 a ton more. Miners' wages are $3.50 to $4 a day.

HISTORICAL NOTE.

The name Darwin is said to come from Dr. Darwin French, who in May, 1860, led a party of 15 men in search of the Gunsight lode. This lode was a mythical silver deposit believed to have been found by the emigrant party that was lost in Death Valley in 1850.[1] In the early part of the decade between 1870 and 1880 argentiferous lead ores were discovered in the vicinity of Darwin. A town soon sprang up here and is said to have had at one time a population of several thousand inhabitants. The pipe line which brings water from a spring in the Coso Mountains 8 miles distant and which still supplies all water used for mining and domestic purposes in the district was completed in July, 1875.

Between 1875 and 1877 three smelters were built near the town of Darwin. The largest of these, stated to have had a capacity of 100 tons a day, was erected by the New Coso Mining Co., which owned the Christmas Gift and Lucky Jim mines. This smelter commenced operations in 1875, the lead well being started with lead obtained

[1] California Min. Bureau Third Ann. Rept., p. 33, 1883.

from Cerro Gordo, and a heavy production was maintained during 1876. The Defiance furnace is said to have had a capacity of 60 tons a day and the Cuervo a capacity of 20 tons.

These furnaces, after the activities of the first few years, were operated in a desultory way. Expenses were high, because prior to the completion of the railroad to Keeler in 1883, all freight had to be brought across the desert by teams from Los Angeles, a distance of 275 miles. The richer and more easily mined ore bodies were early exhausted, and as the policy of mining in those days did not consider the wisdom of keeping reserves in advance of extraction, the district soon lapsed into stagnation, occasionally interrupted by periods of moderate activity. The smelters have long been dismantled and destroyed, and the ores now produced are shipped to reduction works at Selby or Salt Lake.

In the early part of 1913 there was considerable activity in the district, especially at the Christmas Gift, Lucky Jim, and Custer mines, and it is hoped that the introduction of modern machinery and the inception of systematic exploration work in some of the old properties may result in a permanent revival of the mining industry. A telephone line connecting Darwin with Keeler was completed in May, 1913.

GENERAL GEOLOGY.

SEDIMENTARY ROCKS.

CARBONIFEROUS SYSTEM.

General character.—The Darwin district is prevailingly underlain by a series of stratified lime-silicate rocks including some interbedded limestone. The lime-silicate rocks are generally of light color—white or light greenish—and are fine grained, ranging from microcrystalline to aphanitic. On account of the dense texture, the constituent minerals are not recognizable to the unaided eye, but under the microscope the rocks are found to be composed either of wollastonite, of diopside, of grossularite garnet, or of diverse mixtures of these three minerals. Because the rocks made up of these different lime-silicate minerals can not be distinguished from one another except by microscopic examination, they are as a rule referred to in this report under the general term "lime-silicate rocks."

The strata are considerably folded and somewhat faulted, and because of this structural complexity no attempt was made to estimate their thickness.

The limestone beds interstratified with the lime-silicate rocks, although not numerous, generally carry fossils which serve to determine the age of the formation. Such fossiliferous strata were found at a number of widely separated localities and show that the sedi-

mentary rocks throughout the district are all of essentially the same age—late Carboniferous (Pennsylvanian). Some fossils found near the Columbia mine were submitted to George H. Girty, who has identified the following forms: *Girtyina ventricosa?*, Lophophyllum? sp., Fistulipora sp.

Metamorphism.—The widespread and thorough metamorphism of the Carboniferous rocks is the salient feature of the geology of the Darwin district. By this process many square miles of calcareous and magnesian strata have been converted to wollastonite, diopside, and garnet rocks. Despite this complete metamorphism they retain their sedimentary appearance; in fact Goodyear, and also Fairbanks, following him, termed them "calciferous quartzites." The rocks preserve their banding and stratification, and careful search failed to reveal anywhere any trace of slumpage or collapse of the beds as a result of the metamorphism they have undergone. The conversion of the carbonates of the original rocks into silicates was attended by the expulsion of large amounts of carbon dioxide, and the preservation of the bedded structure therefore seems to indicate that an enormous quantity of material, principally silica, has been added during metamorphism.

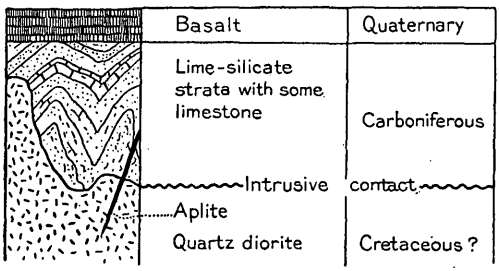

FIGURE 2.—Generalized columnar section for the Darwin district, Cal.

The intensity of these processes is doubtless due to the facts that the Darwin district lies on the margin of the great granite mass that makes up the larger part of the Coso Mountains and that it is underlain at slight depths by granitic rocks, as shown by the multiplicity of dikes and small bosses of quartz diorite and allied plutonic rocks.

Persistent dikes of aplite—pure quartz and feldspar rocks—in places cut the lime-silicate rocks. Some of these dikes, although but a few inches in thickness, show no evidence of chilling of their margins, except where minute apophyses a fraction of an inch thick penetrate the adjacent wall rock. From these facts it may be confidently inferred that the dikes of aplite were injected after the lime-silicate rocks had been formed and before they had greatly cooled.

IGNEOUS ROCKS.

QUARTZ DIORITE.

Granular igneous rocks, as already mentioned, are of common occurrence in this district. The largest mass forms a relatively narrow belt extending for many thousand feet parallel to the general strike

of the strata. It lies near the middle of the range and is well exposed near the Defiance mine.

These rocks are generally of medium or fine texture, and owing to the inconspicuousness of the quartz they contain, they are of dioritic appearance. Microscopic study proves that they are of somewhat greater mineralogic diversity than would be suspected from examination by the unaided eye and shows that they range from quartz monzonites carrying hornblende and biotite to quartz-augite diorites. Some, in fact, as those near the Christmas Gift mine, should be termed augite diorite porphyry. The generalized term quartz diorite employed in figure 2 is meant to include all these different rocks.

In places the quartz diorite carries numerous irregularly shaped nodules composed largely of tourmaline, which undoubtedly represent segregations formed during the crystallization of the magma.

The age of these intrusions is post-Pennsylvanian, and from analogy to the occurrences near by in the Inyo Mountains they may be regarded as probably Cretaceous.

GRANITE PORPHYRY.

A mass of granite porphyry about 200 feet in diameter is intrusive into the lime-silicate rocks a mile south of the Christmas Gift mine, on the trail between that mine and Darwin. A dike of the same kind cuts the quartz diorite and shows chilled edges. The granite porphyry is characterized by prominent phenocrysts of orthoclase, plagioclase, and corroded quartz embedded in a light-pinkish groundmass of aphanitic texture. From its general character the granite porphyry is probably to be regarded as one of the latest manifestations of the epoch of quartz diorite intrusions.

BASALT.

Sheets of basalt cap some sloping mesas in the northeastern part of the district. They have neither direct nor indirect relations to the ore deposits and are therefore of no economic concern. The basalt is a fine-grained bluish-gray variety carrying sporadic small particles of olivine. The eruption of these basalt flows is believed to have taken place in early Quaternary time.

ORE DEPOSITS.

GENERAL FEATURES.

The ore deposits are principally bodies of argentiferous lead. They are generally inclosed in lime-silicate rocks, although a few are in limestone and small isolated masses of ore are found in the quartz diorite.

The metalliferous minerals are galena and its oxidation products, cerusite and anglesite; the gangue minerals are calcite and fluorite, both as a rule very coarsely crystalline. Another material common in the gangue, especially in association with the more highly oxidized ores, is an "iron jasper," which is essentially a silica-iron hydrate compound, probably one of the so-called colloid minerals. Pyrite, locally in considerable quantities, and sphalerite to a minor extent occur in the primary ores.

Oxidation has extended irregularly down to the greatest depths attained in the mines—a few hundred feet. No water has yet been encountered.

GENETIC CLASSIFICATION AND CHARACTER.

The preceding paragraphs embrace all the generalizations concerning the ore deposits that can be made in describing them collectively. Nearly all the more important ore deposits have strikingly individual features and must therefore be described individually.

Genetically classified, the ore deposits range from the contact-metamorphic type to fissure fillings of hydrothermal origin at moderate temperatures.

The contact-metamorphic type is represented most clearly by the ore body at the Independence mine. The primary lead ore here consists of galena associated with andradite, and the deposit is situated at the contact of quartz diorite and lime-silicate rocks. Some dark-gray limestone appears a few hundred feet from the deposit, and it is probable that the ore body is a replacement of a limestone bed that escaped alteration to lime-silicate rock. It is noteworthy that the garnet associated with ore deposits is the lime-iron variety andradite, whereas that in the lime-silicate rocks produced by the general metamorphism that affected the district is the lime-aluminum variety grossularite.

The ore body at the Custer mine is probably also of contact-metamorphic origin. The deposit occurs in the broken arch of an anticline, along which the brecciated strata have been recemented by calcite and garnet. The extraordinary coarsely crystalline development of the calcite, cleavage individuals ranging from 12 to 18 inches in diameter being not uncommon, makes this deposit unique in the district. Fluorite is abundantly associated with the galena. Microscopic examination of some veinlets traversing lime-silicate rock, which occurs as an inclusion in the calc-spar on the 300-foot level, shows that they consist of wollastonite, andradite, calcite, and sphalerite.

A transitional type of ore deposit, intermediate between the kind commonly termed contact-metamorphic and fissure veins, is represented at the Defiance mine. The ore occurs as a replacement of

a limestone bed underlain by quartz-augite diorite, as illustrated in figure 3 (p. 13). The primary ore as seen in hand specimens consists of galena, pyrite, and sphalerite embedded in a gangue apparently composed wholly of calcite and fluorite. The microscope reveals in addition considerable orthoclase, commonly in euhedral forms. Apatite in characteristic hexagonal cross sections and in stout prisms is inclosed in the feldspar and more rarely in the calcite, where it may even develop in relatively large irregular aggregates. As orthoclase is an uncommon constituent of ores of this kind, its presence was corroborated chemically. Its optical properties show that it is not the adularia variety.

The quartz diorite forming the footwall of the deposit has obviously been pyritized, and examination under the microscope shows further that the augite has been uralitized and the feldspar partly sericitized. It follows, then, that the solutions which brought in the ore minerals caused the formation of orthoclase in the limestone and sericite in the adjacent igneous rock.

Fissure veins constitute the most numerous type of ore deposit in the district. They differ very considerably from those in most lead-producing districts in that the country rock traversed by the fissures is lime-silicate rock. They differ notably, for example, from those of the Cerro Gordo district, near by, where the galena generally occurs as a replacement of a pure calcitic marble. The walls of the fissures are clean-cut, and the filling along barren stretches consists of large masses or breccias of lime-silicate rock. The ore consists of practically solid masses of galena and its oxidation products; the gangue as a rule contains only small quantities of fluorite.

In addition to the various kinds of mineralization described in the foregoing paragraphs, one other was noted, which, although it produced no deposit of commercial importance, is briefly described for the sake of completeness. On the trail half a mile north of the Defiance mine there is a broad zone of fracturing and brecciation in the quartz diorite. Along this zone the quartz diorite has been much tourmalinized, so that the rock is largely replaced by aggregates composed of small radial groups of tourmaline. In places it has also been impregnated with pyrite crystals, now largely converted to limonite.

ORIGIN.

The genetic mode of presentation adopted in the description of the ore deposits has necessarily anticipated in part some of the matter properly belonging to a discussion of their origin.

The mineralogic character of the ore at the Independence mine, as shown by the association of galena with an andradite gangue, is typical of contact-metamorphic origin, and in conformity with current

theories it is believed that the deposit was formed from solutions given off by deep-seated magmatic sources. Mineralogically similar deposits are described by Goldschmidt [1] as of common occurrence in the Kristiania region, and he adduces strong evidence that they are of pneumatolytic origin.

The intermediate character of the Defiance ore deposit has already been pointed out. The important diagnostic mineral here appears to be apatite. This mineral, as is recognized by many observers, is not uncommonly developed during contact metamorphism. It occurs, moreover, in tin-bearing veins and is present in gold veins formed at high temperature, both as a constituent of the gangue [2] and as a replacement of the wall rock.[3] It is consequently, when formed as a product of replacement, indicative of origin at high temperature. Its presence in the ore of the Defiance mine as a replacement of limestone, and especially as prisms inclosed in orthoclase replacing limestone, points to the transitional character of the deposit, which therefore forms, according to this interpretation, a link between the contact-metamorphic deposits, as represented by the Independence ore body, and the fissure veins of the district.

The affiliation of the fissure veins with the high-temperature deposits of the district is indicated by the mineralogic gradation that can be shown to exist between them. If this relation, which is so obvious, did not exist, the genetic position of the veins would perforce remain doubtful, as the component minerals are all of the kind termed by Lindgren "persistent" and consequently are of no diagnostic value. The fissure veins, it is apparent from the foregoing statements, are regarded as representing the low-temperature end of a genetically related series of deposits, formed at progressively decreasing temperatures.

The Darwin district is somewhat noteworthy, then, as containing within its small area a complete gradation from contact-metamorphic lead ores to fissure-vein deposits showing the ordinary characteristics of hydrothermal origin. In its genetic features it bears some analogy to the Cœur d'Alene district, where a similar sequence has been traced by Ransome.[4] It differs notably from that district, however, in that at Darwin the end members, presumably formed at cooler temperatures, were deposited in lime-silicate rocks, whereas in the Cœur d'Alene district the principal deposits are inclosed in sericitic quartzites which were not affected by the metamorphic in-

[1] Goldschmidt, V. M., Die Kontaktmetamorphose im Kristianiagebiet, p. 218, 1911.

[2] Beck, Richard, Die Lehre von den Erzlagerstätten, 3d ed., vol. 1, p. 433, 1909. Lindgren, Waldemar, Mineral deposits, p. 639, 1913.

[3] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pp. 37, 39, 1912. Von Groddeck, A., Neues Jahrb., Beil. Band 2, pp. 87, 102, 1883.

[4] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Cœur d'Alene district, Idaho: U. S. Geol. Survey Prof. Paper 62, pp. 135–139, 1908.

fluence of the intrusive monzonite. At Darwin the fissure veins were deposited as near their magmatic source as were the contact-metamorphic deposits, at least in so far as present surface exposures of igneous rocks throw light on this problem; at Cœur d'Alene the character of the mineralization changed progressively with increasing distance from the intrusive monzonite. The most probable interpretation to be placed upon this difference is that whereas the genetic sequence in the Cœur d'Alene district represents a sequence in space, the genetic sequence in the Darwin district represents a sequence in time.

SUMMARY.

The ore bodies, ranging from contact-metamorphic deposits to fissure veins, are inclosed in lime-silicate strata of late Carboniferous age. The metamorphism of originally calcareous and magnesian beds to wollastonite, diopside, and grossularite rocks is a result of the invasion of the region by quartz diorite, probably in Cretaceous time. Somewhat later than this general metamorphism came the introduction of the ore, and the evidence seems strong that the metallic constituents were given off from deep-seated portions of the same magma from which the quartz diorite now seen at the surface crystallized. The inclosure of the ore bodies in lime-silicate strata is the distinguishing feature of the Darwin district.

The ores consist of argentiferous galena, with minor pyrite and sphalerite, and are associated in most of the deposits with a gangue of calcite and fluorite. As a rule the galena is largely oxidized to lead carbonate and sulphate. There is, however, no evidence of important migration and secondary concentration of silver, lead, or zinc through the action of oxidizing solutions; indeed, such concentration appears unlikely, from the prevalence of calcite in the deposits.

MINES AND PROSPECTS.

CHRISTMAS GIFT MINE.

The Christmas Gift, situated 2 miles north of Darwin, is one of the oldest mines of the district and has been one of its largest producers. According to Mr. L. D. Skinner, one of the present operators, the total production is estimated to be $550,000; this amount was taken from the surface down to a depth not exceeding 230 feet and from a length of 300 feet along the vein. The mine, originally owned by the New Coso Mining Co., was energetically exploited in early days but soon fell into decline and has since been worked in only a small way by occasional lessees. In 1912, however, the property was taken over under a lease and bond, 10 per cent royalty on the ore taken out to apply on the purchase price, and a systematic develop-

ment of the mine was undertaken in order to determine its possibilities.

The equipment includes a 15-horsepower distillate-engine hoist (sufficient to sink to a depth of 500 feet) and a 40-horsepower distillate engine operating a compressor. The mine is opened by an inclined shaft on the vein, 230 feet long, and by several hundred feet of drifts extending in both directions from the shaft. Exploration from both ends of the lowermost drift was in active progress at the time of visit.

The country rock in the vicinity of the Christmas Gift consists of white lime-silicate rocks pierced by small intrusions of augite diorite porphyry. The lime-silicate rocks are distinctly stratified and, as measured west of the mine, strike N. 30° W. and dip 25° W. Eastward from the mine the rocks are progressively less metamorphic, and a considerable number of beds of Fusulina-bearing limestone, weathering dark blue, are interbedded with the lime-silicate strata. Dikes and small masses of porphyry penetrate the lime-silicate strata in the surrounding area, especially west and southwest of the mine. An intrusion, whose outcrop is 100 feet in diameter, appears one-fourth mile south of the mine. It is a rather dark gray rock displaying a somewhat porphyritic structure on weathered surfaces. Under the microscope this rock, which is ideally fresh, is seen to be composed dominantly of plagioclase and augite. Biotite is a rare constituent. The plagioclase occurs in two generations; orthoclase is present interstitially and incloses the plagioclase of the second generation. Quartz is rare, and apatite and magnetite occur as accessory minerals. The rock may accordingly be designated a diorite porphyry, although closely approaching a diorite in character. Some of the open cuts on the southwest extension of the vein show diorite porphyry which has obviously been altered by garnetization. This is confirmed by microscopic examination, which shows the augite and plagioclase of the igneous rock invaded by a new growth of andradite, epidote, calcite, and titanite.

The vein strikes approximately N. 40° E. and dips 75° SE.; it therefore cuts across the stratification of the inclosing rocks at an angle of 70°. In width it ranges from 2 to 8 feet, averaging 4 feet. The walls are exceedingly well defined and, as seen on the 150-foot and 230-foot levels, show horizontal corrugations. In open cuts northeast of the shaft a dike about 3 feet thick cuts across the vein. The dike is considerably pyritized, indicating that it had been injected prior to the period of deposition of ore in the vein, and although the walls of the vein show strong horizontal scorings, the dike nevertheless is not displaced. This may indicate either that the dike was injected during the interval between the act of fissuring and the period of

mineralization, or that the fissuring was produced by oscillatory movement along the fracture zone without essential resultant displacement. Some fissures trending obliquely to the vein exhibit strong vertical corrugations, but no ore has been found in these fissures; the significance of this is not wholly clear.

The lime-silicate rocks of the inclosing strata are generally of microcrystalline texture, but aphanitic varieties occur. The filling of the vein along barren stretches consists of a breccia of lime-silicate rock. Some of this material taken within the vein on the 300-foot level, 100 feet west of the shaft, proved under the microscope to be practically solid wollastonite rock. A specimen from the footwall on the 200-foot level was found to be composed entirely of closely packed grains of diopside. These diverse rocks are indistinguishable to the eye, and similar variation is likely to occur from place to place along the vein, on account of the fact that it crosscuts the stratification of the lime-silicate rocks.

The ore forms irregular masses in the vein. Lead carbonate and sulphate associated with "iron jasper" form a common vein-filling material. The unoxidized ore consists of galena, massive as a rule and containing less than 1 per cent of pyrite. No sphalerite was noted to occur with the sulphides, but the zinc silicate calamine, crystallized in radial groups, was found in the oxidized ore in small quantities; presumably, therefore, zinc blende is a minor constituent of the primary ore. Fluorite, abundant elsewhere in the district, is exceedingly rare as a gangue mineral. The extent to which the ore is oxidized is not closely dependent on depth but was probably determined by the perviousness of individual ore masses. Heavy galena ore appears at a depth of 50 feet west of the shaft, but in other places oxidized ore occurs down to the lowest level.

The production at the time of visit was at the rate of 100 tons a month. The shipments during May averaged 60 ounces to the ton in silver, 45 per cent of lead, and $2 to the ton in gold.

LUCKY JIM MINE.

The Lucky Jim mine, situated a short distance north of the Christmas Gift, was located December 12, 1874. Goodyear[1] wrote in 1888 concerning the Lucky Jim that "Mr. J. A. McKenzie [the owner] thinks [that] this mine has turned out an aggregate of between $1,250,000 and $1,500,000, but that on the whole more money was expended here than was ever taken out, which seems not improbable."

The equipment consists of a gasoline hoist and compressor, and the mine is opened by a vertical shaft 300 feet deep and by an incline extending 180 feet below the bottom level. These figures coincide

[1] California Min. Bureau Eighth Ann. Rept., p. 225, 1888.

with those given by Goodyear, so it is evident that no exploration in depth has been attempted since 1888. The mine was operated during the early part of 1913 but was closed in May.

The geologic features are similar to those at the Christmas Gift mine. The country rock consists of lime-silicate strata cut by a few small bodies of diorite or diorite porphyry, the largest of which in the vicinity of the mine is that near the boarding house. The mineralization also appears to be essentially similar to that at the Christmas Gift, although some barytic ore was noted on the east end of the vein.

DEFIANCE MINE.

The Defiance group consists of four patented and three unpatented claims, situated a mile north of Darwin. The most work has been done on the Defiance mine, and this part of the property has been the largest producer. The last work was done in 1900.

The equipment consists of a steam hoist, the water for which must be pumped from Darwin, overcoming a lift of approximately 400 feet. At the place of maximum mineralization an incline averaging 35° was sunk on the deposit for a distance of 380 feet. From the level at the bottom of this incline, which is known as the fifth, a winze has been sunk to an additional depth of about 100 feet, and some drifting and stoping have also been done here.

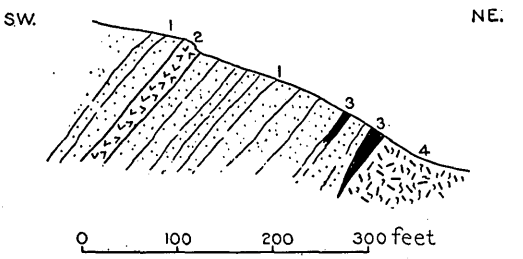

FIGURE 3.—Diagrammatic section across the Defiance ore bodies, Darwin, Cal. 1, Lime-silicate strata; 2, aplitic granite; 3, ore bodies; 4, quartz diorite.

The main ore body lies at the contact of diorite and lime-silicate rocks, as is shown in figure 3. The diorite is a medium or fine grained gray granitoid rock, which, as shown in numerous sections under the microscope, ranges from quartz diorite to quartz monzonite. The quartz is present in moderate quantity, and this fact, together with its interstitial distribution, accounts for its inconspicuousness to the unaided eye. The country rock above the hanging wall of the ore body consists predominantly of brilliant white-weathering lime-silicate strata, striking N. 45° W. and dipping 45° SW. These strata are generally of dense texture, but some beds show small macroscopic garnets, probably grossularite. One of the close-grained varieties examined microscopically consisted of wollastonite with subordinate diopside.

The dike—or perhaps more properly sill, as it lies parallel to the stratification—which is situated some 200 feet stratigraphically above

the ore body, is of granitic or aplitic character. It consists dominantly of orthoclase, with quartz and plagioclase, and has been subjected to pyritization, accompanied by the formation of sericite and calcite.

The ore body, which rests on the diorite as a footwall, is from 200 to 300 feet long. At the mouth of the main incline it is 40 feet or more thick and consists of highly oxidized siliceous, gossany fluoritic material, although in this thickness of 40 feet there are included large masses of pure limestone. Evidently the bulk of the oxidized material did not constitute ore, for only a small fraction of it was removed. In places some heavy lead carbonate ore mixed with fluorite, chrysocolla, and other minerals can still be found. A small quantity of galena embedded in fluorite occurs in the outcrop; pyrite is represented by casts and by limonite pseudomorphs. Locally the pyrite casts are coated with minute green crystals of sulphur, as is easily verified by their ready combustibility.

Primary ore seen on the dump (probably in the main low-grade "reject") consists of abundant euhedral pyrite, with galena and resinous sphalerite, in a gangue of fluorite and coarse calcite. The fluorite is white, purple, or green. Chalcopyrite, which is the probable source of the copper in the chrysocolla, is of rare occurrence. Similar material found in place in a drift below the fifth level shows abundant pyrite in well-formed pyritohedral and cubical crystals averaging a quarter of an inch in diameter, together with minor galena and sphalerite, inclosed in calcite and purple fluorite. Under the microscope this material showed in addition considerable orthoclase and some apatite.

The ore of the Defiance mine is reported to have had a value, as sorted and shipped, of $100 a ton in lead, silver, and gold, the gold being present, however, to the extent of $4 a ton.

Above the main ore body of the mine is a short, narrow tabular mass of ore that lies parallel to the strike of the inclosing rock and has been exploited by open cuts.

INDEPENDENCE MINE.

The Independence mine, which is part of the Defiance group, lies north of the Defiance mine at an elevation of 850 feet above Darwin. It is opened by an adit and a network of drifts.

The ore body is situated at the contact of lime-silicate rocks with diorite, which is the northward extension of the belt forming the footwall of the Defiance ore deposit. The showing on the surface is surprisingly small in view of the large amount of mineralized rock revealed in the drifts. Much of this, however, is iron oxide material with some gypsum and sulphur, but one drift shows a good body of lead carbonate ore, though this is said to be low in silver.

Geologically, the most interesting feature of the Independence ore body is the fact that the galena and its alteration products are inclosed in a gangue of garnet of the variety andradite. This gangue is, in general, not easily distinguishable from the lead carbonate, but in places it is well crystallized in green dodecahedrons.

CUSTER MINE.

The Custer mine, which is a short distance east of Darwin, was being worked by a small crew of men during 1913. It is equipped with a 10-horsepower gasoline hoist and is opened by an incline to a vertical depth of 240 feet. Below the lowest level, called the 300, a winze was being sunk at the time of visit.

The property has recently changed hands. The production under the former owners is said to have been $200,000, and under the new management $30,000 was taken out.

The country rock in the vicinity of the mine consists of highly garnetized sedimentary beds, which still preserve their sedimentary banding and stratification. A specimen taken from near the outcrop of the ore body is a remarkably heavy and dense rock of almost chertlike texture; rarely it shows short, narrow calcitic laminæ inclosing small well-crystallized garnets. Such rock proves under the microscope to consist essentially of a dense aggregate of garnet, which has been determined to be the iron-bearing variety andradite. A small intrusion of fine-grained quartz monzonite appears in the tunnel.

Behind the engine house the strata strike N. 25° W. and dip 55° W., but a short distance to the east, near the blacksmith shop, they dip 45° E. The rocks have thus been folded into a sharp anticline, and the arch of this anticline has been broken and the strata brecciated. The breaking of the arch probably took place prior to the garnetization, inasmuch as the breccia is recemented by coarse spar intergrown with garnet.

The ore-bearing zone extends along the broken arch of the anticline. The surface showings give a very inadequate idea of the geologic features of the ore deposit, and especially of the immense spar bodies revealed by the underground exploration. The outcrop appears to represent the apex of a great body of white calc-spar, whose distinguishing characteristic is its extraordinary coarsely crystalline development. Cleavage masses of calcite 6 inches in diameter are abundant, and individuals ranging from 12 to 18 inches are not uncommon. The white spar is more or less studded with crystals of pyrite; on oxidation these cause a darkening of their inclosing matrix. Blocks of lime-silicate rock are present as sporadic inclusions. The shape of the spar mass has been imperfectly deter-

mined by mining operations, but locally, as below the 300-foot level, an unbroken stratum of the garnet rock on the west flank of the anticline forms a hanging wall, dipping 60° W.

The ore is found in bunches or pockets distributed irregularly through this great body of spar. Although occurring thus erratically the different pockets are said to be connected as a rule by indications of ore sufficient to serve as guides in the search for undiscovered bodies. The metalliferous minerals are principally lead carbonate and galena. Fluorite occurs invariably in association with the lead ore or in the vicinity of the ore pockets; its presence may therefore be useful as an indication in the exploration for ore. Several hundred tons of coarsely crystalline purple and rose-colored fluorite have accumulated on the dumps.

The ore recently shipped averages 130 ounces to the ton in silver, 10 per cent of lead, and $4 to the ton in gold; it is therefore much more highly argentiferous than the average ore of the Darwin district.

LANE MINE.

The Lane mine is situated a few miles northeast of Darwin, on the east flank of the Darwin Hills. A single-stack water-jacketed blast furnace was built here, but its operations are said to have been unprofitable. Water for the operation of this plant was pumped from wells in the Darwin Wash. The mine is opened by two shafts, one equipped with a steam hoist and the other with a gasoline hoist.

The vein, striking N. 65° E., cuts across the strike of the strata at a considerable angle. The country rock consists of lime-silicate strata interbedded with dark-blue crinoidal and Fusulina-bearing limestones. The primary ore, in part at least, was galena embedded in fluorite, though the principal ore mined was doubtless lead carbonate. On the dumps there is considerable iron-bearing jasper commonly netted with veinlets of chrysocolla.

The depth attained is reported to have been 640 feet, and at that depth the ore is said to have been faulted off. The last shipment of ore, consisting of 42 sacks, was made in 1909 and is stated to have carried 75 ounces in silver to the ton and 48.6 per cent of lead. The total production of the mine is estimated as between $400,000 and $500,000.

WONDER PROSPECT.

On the trail west of the Lane mine is a prospect which shows in exaggerated form the distinguishing features of many of the ore deposits of the Darwin district. The prospect is opened by a short tunnel, and the walls and in places the roof of this tunnel are lined with extremely coarse calcite, cleavage individuals 6 inches and even a foot across being common. Mingled sporadically with this calcite

is some coarsely crystalline fluorite. Some lumps of heavy galena ore with fluorite gangue have been piled on the dump. Associated secondary minerals are lead carbonate, linarite, caledonite, and iron-bearing jasper. A small amount of chalcopyrite was noted and is probably the source of the copper in the linarite and caledonite.

RICHARDSON PROSPECT.

At the Richardson prospect, just east of Darwin, a copper-bearing vein has been opened by an inclined shaft about 40 feet deep. The ore is highly oxidized, consisting of chrysocolla, malachite, and a dark-red iron-copper oxide. Chalcopyrite appears to have been the primary sulphide. Fluorite, commonly purplish, and calcite constitute the main minerals of the gangue.

RIP VAN WINKLE PROSPECT.

The Rip Van Winkle prospect is situtated on the west slope of the Darwin Hills a short distance north of town. A shaft 8 feet deep had been sunk on the ledge, but by whom and when had long been forgotten, and the ledge was rediscovered near the close of 1912. Sinking was in progress at two points on the ledge at the time of visit. The ledge is from 4 to 6 feet wide; the outcrop is of a sparry character but of rather inconspicuous appearance, even where it is free from surface débris. The strike of the ledge is N. 60° E. and the dip ranges from 70° SE. to vertical. The inclosing country rock consists of lime-silicate strata. A microscopic examination of a specimen from a horse in the ledge shows that it is essentially a garnet rock; the garnet is colorless, and its refractive index is 1.75, indicating that it is a grossularite.

The ore makes in bunches in the ledge, and this is perhaps the reason why the original locators abandoned the prospect, as the test pit was sunk at a barren point. A coarse calc-spar accompanies the ore, and fluorite occurs in minor amounts. The ore is mainly galena and lead carbonate carrying a subordinate quantity of pyrite. It carries approximately 1 ounce of silver to the ton for each per cent of lead.

COLUMBIA MINE.

The Columbia mine, near the south end of the Darwin Hills, is said to have been located as the Dargon in 1872 but was soon afterward abandoned and lay idle for many years until it was relocated as the Columbia. The total production is estimated to be $75,000. The country rock in the vicinity of the mine is limestone and in general is much less highly metamorphic than in other parts of the district. Crinoidal limestones carrying Fusulina and Bryozoa occur just north of the mine. The ore body consists of a vertical vein ranging on an

average from 4 to 6 feet in width, though in places expanding to considerably greater thicknesses. Most of the ore so far extracted has been taken out from a length of about 200 feet, and the extreme depth attained is 225 feet. The ore consists largely of iron-bearing jasper carrying in places lead carbonate and galena. A notable constituent of the gangue is a highly glassy calcite forming an abundant incrustation in the ore. Locally the wall rocks have been recrystallized to a coarse spar. By careful sorting and jigging of the fines a product carrying between 40 and 60 per cent of lead and approximately 1½ ounces in silver to the ton for each per cent of lead is obtained.