Copper Deposits of Part of Helvetia Mining District, Pima County Arizona

By S. C. CREASEY and GEORGE L. QUICK

A CONTRIBUTION TO ECONOMIC GEOLOGY

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Description and maps of four mines typical of the district

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A CONTRIBUTION TO ECONOMIC GEOLOGY

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By S. C. Creasey and George L. Quick

ABSTRACT

This report presents the economic geology of four mines and the contiguous area in the Helvetia mining district in the Santa Rita Mountains in south-central Arizona. The four mines (Rosemont lease, Leader, Copper World, and Narragansett) were selected for detailed study because they were considered to be representative of the district. Production from the Helvetia district has not been large.

The sedimentary rocks in the Helvetia district range from Cambrian to Cretaceous. The Paleozoic rocks are chiefly limestone, dolomitic limestone, and quartzite; the Mesozoic rocks (Cretaceous) comprise shale, sandstone, and impure limestone. Although the structure largely controlled the mineralization, most of the ore is found in Pennsylvanian and Permian limestones.

The igneous rocks consist of coarse-grained granitic rock ranging in composition from granite to quartz monzonite and monzonite, and a quartz monzonite porphyry. The granitic rock is believed to be post-Paleozoic and pre-Comanche in age, whereas the prophyry clearly intrudes the Cretaceous rocks.

The Helvetia district has been intensely deformed, and complex structures resulted from high-angle normal faults, folds, and thrusts. Apparently thrust faults were active over a considerable period, for the quartz monzonite porphyry is both older and younger than thrust faulting. The ore deposits in the four mines appeared to be adjacent to or near both normal and thrust faults.

The ore deposits are chiefly of the pyrometasomatic or contact metamorphic type, although some of them are not at the contact of intrusive rocks. In the Copper World, Narragansett, and Leader mines, the mineralized zones in part are in lime-silicate rocks developed in limestone along fault zones by silicating solutions. The ore minerals are younger than the lime-silicate minerals, and the ore is in shoots largely within the silicated zones but not strictly coextensive with them. In addition to the contact metamorphic deposits, there is a brecciated area in the porphyry sporadically stained with copper oxide minerals.

INTRODUCTION

LOCATION

The Helvetia mining district is in the northern Santa Rita Mountains, Pima County, 28 miles southeast of Tucson, Ariz. (See fig. 48.)

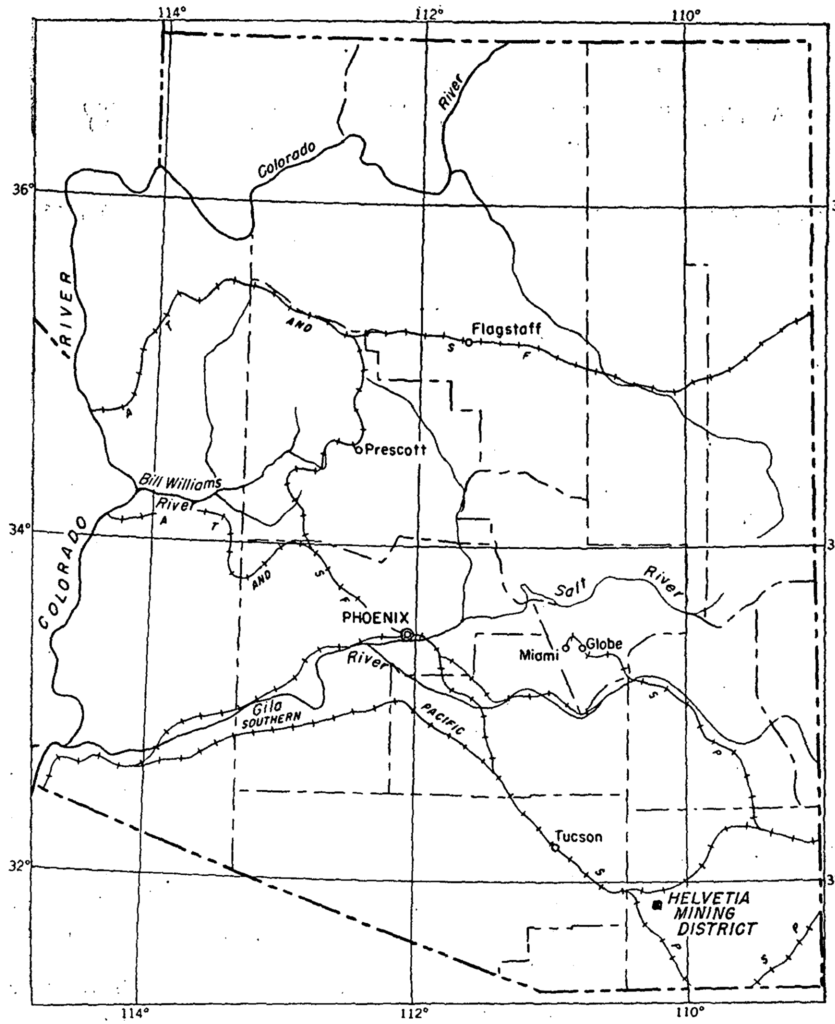

FIGURE 48.—Index map showing location of the Helvetia mining district, Pima County, Ariz.

It is accessible from Tucson by way of Sahuarita on 18 miles of paved road and 14 miles of unimproved dirt road. The area studied is in secs. 23 and 24, T. 18 S., R. 15 E., Gila and Salt River meridian, in the north-central part of the Patagonia quadrangle. The district is bounded on the north and west by the foothills of the Santa Rita Mountains and on the east and south by the Empire Mountains and the upper reaches of the Santa Rita Mountains.

The small area covered in this report lies near the center of the district. The altitude ranges from about 4,600 feet to 6,000 feet; some of the peaks in the Helvetia district are a few hundred feet higher. The topography is generally rough, the vegetation sparse, and the rock exposures good.

From February to May, 1943, the U. S. Geological Survey studied a small area in the central part of the Helvetia mining district due east of the old mining town of Helvetia. In this area many old mines and prospects have been worked at various times, and one mine was opened in 1941. The subsurface openings of most of the properties, especially the smaller prospects and mines, are inaccessible, and in the few mines that can be entered, only a part of the workings are open. For the greater part of the information on the inaccessible parts of the mines examined, on the early history and production of the district, and for part of the description of the regional geologic setting, the writers are indebted to the excellent report on the district by F. C. Schrader (1915).

Four mines, the Rosemont lease, Leader, Copper World, and Narragansett, were examined and mapped as completely as possible. About 4½ square miles, encompassing all the mines examined, was mapped on aerial photographs on a scale of approximately 1 inch to 2,500 feet. These mines and the surrounding areas were selected as representative of that part of the Helvetia district most likely to contain commercial deposits of copper.

Information on the area outside this report, and maps showing the locations of other mines and the extent of the underground workings of the larger mines in the district can be found in the report by Schrader (1915).

HISTORY AND PRODUCTION

Ore was probably discovered in the Helvetia district before the Civil War, but no records are available on the earliest discoveries. The Old Frijole mine, reported to be the oldest in the district, was opened in 1880 and operated for several years. In the early eighties the ore from the district was treated at the Columbia smelter, located on the west side of the Santa Rita Mountains near the Old Tiptop campsite. This smelter was succeeded in 1884 or 1885 by the Mohawk smelter, owned and operated by the Rosemont Mining and Smelting Co., which mined from workings near the Rosemont camp on the east slope of the Santa Rita Mountains.

In the early nineties the Helvetia Copper Co. of New Jersey acquired holdings near the town of Helvetia and operated until 1901. They are reported (Schrader, 1915, p. 96) to have spent $800,000 on development work that included 5 or 6 miles of aerial tramway and a new smelter, and also to have produced about $400,000 worth of copper from ore that averaged 8 to 10 percent copper and contained a small amount of silver and gold.

In 1903, the Helvetia Copper Co. of Arizona began operations that continued until 1911. Its principal holdings were the Black Horse, Copper World, Heavy Weight, Isle Royal, Leader, and Old Dick mines. This company built and operated a smelter in 1905 which was closed in 1907, and thereafter the ore was shipped to the Old Dominion smelter in Globe, Ariz. The total production is not known, but the following partial production figures are given by Schrader (1915, p. 97). In 1907, about $40,000 in ore was shipped, and in 1908, 11,000 tons, valued at $157,000. In 1909, 1,434 tons of copper ore averaging about 5.5 percent copper was shipped to the Old Dominion smelter, and in 1910, the output was valued at $109,000. The company discontinued operations in 1911.

The yearly production of the Helvetia district from 1908 to 1950 is given in table 1. Unfortunately, the individual production of all the mines of the district was never recorded. Since 1940, however, the bulk of the ore produced from the Helvetia district has come from the Rosemont lease, Copper World, Mohawk, and probably the Narragansett mines.

TABLE 1.—*Gold, silver, copper, lead, and zinc produced in the Helvetia district, Pima County, Ariz., 1908–50*

[Data for years 1908–33 after Elsing, M. J. and Heineman, R. E. S. (1936), and for 1934–50 after U. S. Bureau of Mines, Minerals Yearbook. Asterisk indicates conversion from ounces to dollar value]

Year	Number of producing lode and placer mines	Ore (tons)	Gold (value)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
1908	3	892	$61	949	91,164	374		$12,611
1909	2	11,187	597	11,698	1,156,604			157,038
1910	3	124						
1911	2							
1912	4	467						6,353
1913	6	739	64	1,170	62,805	10,392	236,117	24,185
1914	2							
1915	6	2,506	248	3,300	349,945			63,161
1916	11	14,609	289	19,300	1,958,825	71,903		499,820
1917	10	18,499	269	24,525	2,615,613	19,171		736,496
1918	8	16,302	56	17,828	2,156,486	12,406	489,163	595,931
1919	7	3,357	300	5,479	414,370	58,432		86,607
1920	6	2,516	8	6,295	401,244	3,618		80,988
1922	1							
1923	8	683	163	5,024	69,633	40,590		17,360
1924	4	202	31	1,459	33,585	9,018		6,130
1925	8	319	80	2,500	41,972	6,000		8,300
1926	5	73	100	150	9,272	3,000		1,765
1927	4	116	136	73	15,332	2,761		2,359
1928	4	150	140	70	18,750	2,700		3,042
1929	6	756	34	852	84,823	2,774		15,592
1930	3	2,258	185	1,282	145,882	80		19,648
1931	1	40						
1934	3	32	*3,495	102	3,475			379
1935	1							
1937–38	11	1,403	*3,535	14,874	43,099			20,255
1939	5	69	*105	439	8,875	213		1,336
1940	2	1,115	*280	1,409	163,080			19,710
1941	8	440	*445	1,966	58,300	8,300		9,205
1942	3	4,465	*385	3,631	449,000	3,000		57,497
1943	11	3,639	*945	5,549	309,600	26,200	41,000	51,532
1944	10	20,240	*1,785	11,025	1,070,800	67,100	134,000	174,827
1945	7	29,188	*560	10,239	1,516,600	29,500	78,000	224,089
1946	6	44,577	*13,370	12,714	1,904,000		20,000	334,531
1947	9	29,891	*4,340	9,936	1,264,400	3,000	41,800	284,346
1948	9	11,695	*490	5,466	606,400	27,300	27,600	145,584
1949	4	3,170		2,464	266,700	18,200	30,300	61,403
1950	4	1,514	*105					105
Total		227,333	$32,601	181,768	17,290,634	426,032	1,097,980	$3,722,185

GENERAL GEOLOGY

The Santa Rita and Patagonia Mountains form a nearly continuous range of mountains extending from Mexico northward for 45 miles where they are joined by the Empire Mountains, a small outlying group to the east. The southern two-thirds of this chain is composed largely of igneous rocks—chiefly Mesozoic intrusive rocks and related dikes ranging in composition from granite to quartz diorite—and Tertiary volcanic rocks ranging from rhyolite to andesite and including some tuff and agglomerate near Nogales on the Mexican border. Except for a belt in the Canelo Hills, in the east-central part of the chain, the Helvetia district and the adjoining Empire Mountains contain the only large exposures of Paleozoic sedimentary rock in the Santa Rita and Patagonia Mountains. In the Helvetia district the Paleozoic strata crop out in a north-northwest-trending belt about 7 miles long that ranges from half a mile to 2 miles in width. Here the Paleozoic era is represented by rocks ranging from Cambrian to Permian in age, but Ordovician and Silurian rocks are missing. In general, the sedimentary rocks are progressively younger toward the east; Cretaceous strata cover the eastern half of the Helvetia district and most of the Empire Mountains. Appreciable amounts of granite of probable Mesozoic age, several small bodies of intrusive porphyry of Mesozoic age, and one large patch of rhyolite of Tertiary age crop out in the Helvetia district.

The structure in the southern part of the Santa Rita-Patagonia Mountains (Schrader, 1915, pl. 2 and 3) appears to be limited to tilting and broad open folds. In the Helvetia district-Empire Mountains section, however, extensive thrust faulting played an important role in the structural history. Many and extensive thrust faults dipping southwestward at low angles cut the Paleozoic strata and in places, moved Cretaceous strata over Paleozoic. Detailed mapping in the Helvetia district shows that some of the thrusts are folded and strongly suggests that there were at least two periods of thrust faulting.

SEDIMENTARY ROCKS

Both Paleozoic and Mesozoic sedimentary rocks occur within the Helvetia district. The Paleozoic rocks range from Cambrian to Permian in age, whereas the Mesozoic rocks are Cretaceous in age.

The Paleozoic section exposed in the small area mapped consists of quartzite and limestone ranging in age from Cambrian to Permian (pl. 28). Although the Upper Cambrian Abrigo formation and the Devonian Martin limestone have been cut out by faulting in the area mapped, they crop out a short distance to the north. Ordovician and Silurian rocks are not present in this part of Arizona.

The Pennsylvanian and Permian stratigraphic units used in this paper are those of Stoyanow (1936), who subdivided the Naco limestone of Ransome. According to his classification, the beds containing a typical lower Pennsylvania fauna are called Naco (restricted). The Permian strata are divided into those with a Manzano faùna below, comformably overlain by his Snyder Hill formation. In the area covered by this report, the beds containing a Manzano fauna have been further subdivided into a lower and an upper unit, here referred to as lower Manzano equivalent and upper Manzano equivalent.

The thickness of the Paleozoic formations exposed in the Helvetia district is not known. Only three depositional contacts are exposed; all other contacts are either intrusive or fault contacts, and the faulting in the district is so intense that it invalidates even rough estimates of thickness.

CAMBRIAN ROCKS

The Bolsa quartzite of Middle Cambrian age is a thick-bedded recrystallized quartzite containing a few thin conglomeratic beds. It weathers into very large angular blocks and crops out in a discontinuous belt trending north-northwest from the southern boundary of the mapped area to the northwest corner (pl. 28). The Bolsa quartzite is the oldest rock in the area and in every place exposed has either a fault or intrusive contact with adjoining rocks. It is in fault contact with the Naco limestone (restricted), the upper Manzano equivalent, and with the Mesozoic granitic rocks in the northern part of the area. In the central and south-central section of the area it has been intruded by Mesozoic granitic rocks in which it occurs as isolated and partially isolated blocks that are nearly or completely recrystallized. The recrystallized quartzite greatly resembles aplite, having a fine-grained, equigranular allotriomorphic texture. Some rock now thought to be Bolsa quartzite was mapped as alaskite aplite by Schrader (1915, pl. 1). Parts of some of the larger recrystallized masses, however, here and there contain relict textures identifying them as Bolsa quartzite. Other rocks are thought to be quartzite because of mineralogic and textural similarity to altered quartzite and because of their position on outcrop or strike extensions of Bolsa quartzite.

MISSISSIPPIAN ROCKS

The Mississippian system is represented by the Escabrosa limestone, a thick-bedded pure bluish-gray limestone locally recrystallized to a coarse-grained white marble. The Escabrosa limestone crops out in one small patch in the west-central part of the area where it has an overturned depositional contact with the Naco limestone (restricted) on the northeast and is in fault contact with Mesozoic granitic rocks on the other three sides. In other places where it should appear in the area, it has been cut out by faulting.

PENNSYLVANIAN ROCKS

In the Helvetia district the Pennsylvanian system is represented by the Naco limestone (restricted), consisting of a massive gray impure limestone locally dolomitic and containing some shale and cross-bedded feldspathic quartzite. The impure zones locally have been metamorphosed into irregular masses and lenses of lime-silicate hornfels of variable size.

The Naco limestone (restricted) is well distributed throughout the mapped area; the most extensive exposures are in the north-central section, but it underlies areas as much as 500 feet in width and more than 2,000 feet in length in the south-central part of the area and smaller areas in the east-central, north-central, and northwest sections. It is largely in fault contact with adjacent formations of the area; locally, however, it is in normal contact with the Escabrosa limestone and lower Manzano equivalent.

PERMIAN ROCKS

The Permian rocks are represented by beds containing a Manzano fauna and by the Snyder Hill formation of Stoyanow (1936). In the Helvetia district, the beds containing a Manzano fauna have been mapped as upper and lower Manzano equivalents.

The lower Manzano equivalent consists of limestone, soft marl, and discontinuous gypsiferous beds. It crops out in a belt more than 1,000 feet wide and 2,000 feet long in the north-central section, in a window in the Cretaceous sedimentary rocks in the southeast, and in a narrow band northwest of the Narragansett mine. It is in normal contact with the Naco limestone (restricted) in the north-central mass; and in the northeast section a small mass, left as the result of faulting, is in depositional contact with the overlying upper Manzano equivalent. All other contacts are fault contacts.

The upper Manzano equivalent, composed of interbedded quartzite and limestone, is divided into two units (pl. 28). The lower is predominantly feldspathic quartzite but contains beds of impure, dolomitic limestone. The quartzite is even grained, gray to pink, and crossbedded; it weathers into small angular blocks. These characteristics distinguish it from the Bolsa quartzite. The upper unit is chiefly limestone but contains a few quartzite beds. It is light gray, locally dolomitic, and less evenly bedded than the overlying Snyder Hill formation of Stoyanow.

The upper Manzano equivalent crops out in a north-trending band, over 3,500 feet long and ranging from 500 to 1,400 feet in width. On the west, it is in fault contact with the Bolsa quartzite, Naco limestone (restricted), lower Manzano equivalent, and Stoyanow's Snyder Hill formation; on the southwest, it was intruded by the quartz monzonite porphyry plug; on the east, it is in fault (thrust) contact with Stoyanow's Snyder Hill formation; but on the southeast, it is in depositional contact for a short distance with the overlying Snyder Hill formation of Stoyanow.

The Snyder Hill formation of Stoyanow is the youngest formation of Paleozoic age in the Helvetia district and in the Paleozoic section of southeastern Arizona. In the Helvetia district, it is composed of an evenly bedded pure limestone, dark blue where unaltered and light gray to white where recrystallized.

The Snyder Hill of Stoyanow crops out only in the eastern half of the mapped area. Here it is exposed in a discontinuous north-trending band, broken by the quartz monzonite porphyry plug, and in small exposures west of the upper Manzano equivalent because of faulting. Three small patches in fault contact with the lower Manzano equivalent are exposed in the window in the Cretaceous sedimentary rocks east of the Narragansett mine. Except for the quartz monzonite porphyry, the Snyder Hill of Stoyanow is in fault contact with all adjacent formations.

CRETACEOUS ROCKS

The Cretaceous rocks exposed in the mapped area belong to the Comanche series. They cover a large area in the northeastern part of the Helvetia district and much of the Empire Mountains lying to the east. They are exposed in the southeastern part of the mapped area and consist of interbedded shale, arkosic sandstone, and impure limestone. No attempt was made to subdivide the Cretaceous sedimentary rocks, although by careful mapping several members might be distinguished.

The Comanche strata have been thrust over the Paleozoic strata southeast of Sycamore Ridge and are in fault contact with the Paleozoic formations in the vicinity of the Narragansett mine. However, the contact with the quartz monzonite porphyry is chiefly intrusive, although along the south side of the plug the contact is locally brecciated indicating some movement, probably a minor amount. The sedimentary rocks next to the porphyry have been dragged up and locally metamorphosed in varying degrees, the arenaceous and argillaceous beds are slightly baked and indurated, and the impure limestone beds are partly or completely altered to lime-silicate minerals.

INTRUSIVE ROCKS

The two kinds of igneous rocks occurring in the Helvetia district are representative of only part of the intrusive history of the Santa Rita and Patagonia Mountains. Schrader (1915, p. 57–70) recognized five intrusive rocks of Mesozoic age; listed in chronological order they are granite, quartz monzonite, quartz diorite, quartz monzonite, and granite porphyry. Schrader thought that part of the granite was pre-Cambrian in age, although positive proof was lacking and he made no distinction in mapping.

The igneous rocks in the mapped area consist of a coarse-grained granitic rock, ranging in composition from granite to quartz monzonite and monzonite, and a quartz monzonite porphyry. These two rock types correspond to Schrader's granite and granite porphyry.

The granitic rock occurs in the western half of the area; west of the Narragansett mine it intrudes the Bolsa quartzite, but elsewhere it has fault contacts with all other adjacent formations. At no place did Schrader (1915, p. 57) find the granitic rock cutting the Cretaceous sedimentary formations, but in several districts he found it intruding Paleozoic limestones, hence it is believed to be post-Paleozoic and pre-Comanche in age.

The quartz monzonite porphyry occurs as an irregular stock or plug in the central part of the mapped area. The rock is porphyritic, containing phenocrysts of orthoclase, plagioclase, and quartz in a light-colored aphanitic groundmass. It clearly intrudes the Cretaceous sedimentary rocks and has both intrusive and fault contacts with the Paleozoic limestones. The limestones around the margins of the porphyry have been locally contact metamorphosed to lime-silicate hornfels, principally tactite.

Two elongate masses of siliceous granular rock occur in the granite south of the Leader mine and west of the mineral monument. By hand-lens examination it is impossible to determine whether these bodies are aplite dikes or recrystallized pendants of Bolsa quartzite. Schrader (1915, pl. 1) mapped them as alaskite aplite.

STRUCTURE

The structural history of the Helvetia district includes folding, faulting, and intrusion; but faulting—thrust faulting in particular—is the dominant structural feature. The structure is complex, possibly more complex here than in any other area of comparable size in the Santa Rita and Patagonia Mountains. Undoubtedly the structural picture is not complete as only a small part of the district was mapped; nevertheless, some general conclusions can be made.

In spite of structural complexities due to imbricate thrust faulting, the regional structure is roughly homoclinal with the older formations generally in the western part of the area and the younger formations in the eastern part. The regional strike is northwest.

The mass of granitic rock exposed in the western third of the area is apparently part of a batholith and is one of the important structural features of the area (pl. 28). Its contact with Bolsa quartzite is clearly intrusive; however, the contact between the granite and the limestone of Carboniferous age is faulted wherever the nature of the contact can be determined with certainty. In the vicinity of the Leader and Copper World mines, a wedge of similar granite is thrust over Paleozoic formations.

South of Lopez Pass an irregular plug of quartz monzonite porphyry has intruded the Cretaceous sedimentary rocks and, locally, the Paleozoic formations with which it also has fault contacts. Some of the faults probably are thrust faults. In a general way this mass breaks the continuity of the thrust faults and marks a decided change in the dips of the faults. The difference in dips of the faults north and south of the plug is unexplained; perhaps more extensive mapping in the zone of thrust faulting would indicate more clearly the relation of the plug to the faulting.

The structure has been further complicated by folding of the thrust faults, clearly shown where the window in the Cretaceous strata exposes a dome-shaped area of Permian limestones in fault contact with the overlying sedimentary formations. The folding may have been intense enough to produce overturned folds.

Some of the complexities of the faulting are worth noting, although the explanations are only tentative and would certainly be modified in part by additional work. The westernmost fault separating the granitic rock from the Paleozoic rocks in the northwest and central part of the area and the Bolsa quartzite from the Naco limestone (restricted) in the south-central part dips about 50° W. at its northern end. West of the Leader mine however, it dips from 50° to 60° E. and from here southeastward along the strike the dip increases until it reaches the vertical at the sharp bend in the fault southwest of the mineral monument. From this point south the fault dips westward at a high angle. South of the quartz monzonite porphyry plug and west of the Narragansett mine, all the faults dip westward in contrast to the eastward dip of the faults north of the plug. The dip of the fault contact between Cretaceous strata and Paleozoic formations in the eastern part of the window in the Cretaceous strata southeast of the plug is congruent with the eastward dips of the faults farther north. Despite the reversal of dips north and south of the plug, the same general succession of Paleozoic formations occurs in both places. The thrust-fault contact between the Cretaceous and Paleozoic rocks has the same reversal of dip, changing direction of dip between Lopez Pass and the

Narragansett mine, and the Cretaceous sedimentary rocks are exposed continuously between the two points. It seems almost certain that continuity of the formations existed prior to the intrusion of the plug. The most logical explanation that can be advanced for the reversal of dip of the faults is folding, very possibly contemporaneous with the intrusion of the quartz monzonite porphyry plug.

Thrust faulting may have been rather active over a considerable length of time, and, in a general way, can be divided into two periods separated by the intrusion and solidification of the quartz monzonite porphyry plug. In the area of the Rosemont lease, the quartz monzonite porphyry locally intrudes the Paleozoic limestone formations; the thrust fault, which farther north separates the upper Manzano equivalent and the Snyder Hill formation of Stoyanow, appears to have been intruded by the porphyry. The ore bodies of the Rosemont lease are located along the fault in a zone of lime silicates. In contrast, however, the high-angle westernmost fault, which is a thrust fault, at least in part, appears to cut the plug; if this is true, the plug is an allochthonous mass terminating at depth against a thrust fault.

Wherever detailed maps were made, small high-angle faults were found to offset both the thrust faults and the igneous contacts.

Folding in the limestone is widespread throughout the mapped area, but is not evenly distributed. The limestone in some of the thrust plates is contorted into tight, nearly isoclinal folds, whereas in other plates the folds are open or the beds overturned. In contrast, the beds of the more competent upper Manzano equivalent appear to be largely homoclinal.

ORE DEPOSITS

The ore deposits are of the pyrometasomatic or contact-metamorphic type, although some of them are not at the contact of instrusive rocks. In the Copper World, Narragansett, and Leader mines the mineralized zones, in part, are in lime-silicate rocks developed in limestone along fault zones by silicating solutions. The ore minerals were formed later than the lime-silicate minerals, and the ore is in shoots largely within the silicated zones but not strictly coextensive with them.

The age of the ore minerals is not precisely known. The close association of the lime-silicate zones and mineralized zones lying within them with faults in the Copper World, Leader, and Narragansett mines strongly suggests some control by the faults. In all three mines, however, there has been movement on the faults after the formation of the ore, but movement may have been small. The quartz monzonite porphyry plug is mineralized locally, as is the lime-silicate zone in the Rosemont lease, which is attributed to contact-metamorphic action of the quartz monzonite porphyry. The plug intrudes the Cretaceous

Comanche series, making the ore in the Rosemont lease post-Comanche or possibly post-Cretaceous in age. No evidence of more than one general period of mineralization was observed. Because of the similarity between the ores of the Rosemont lease and those of the Copper World, Leader and Narragansett mines, the mineralized zones in all four mines are thought to be genetically related and to be of the same general age, Late Cretaceous or post-Cretaceous.

The ore bodies are irregular lenticular zones lying largely within and generally parallel to the lime-silicate zones. The contact between ore and lime-silicate gangue is sharp in places and gradational in places. The general attitude and shape of the ore bodies appears to be controlled by the configuration and attitude of the silicate zones in which they are localized. Fracture zones, cross fractures, changes in attitude of fracture zones, and possibly folding are thought to have influenced the location of ore minerals in the silicated zone.

The depth of oxidation in the district is highly varied. In the Copper World, Leader, and Narragansett mines, oxidation extends below the lowest accessible level, which is about 200 feet below the surface in the Copper World mine. In the Rosemont lease the sulfide minerals are partly oxidized on the haulage level, but in the lowest underhand stope, which is about 60 feet lower, the sulfide minerals are unoxidized. Writing of the entire Helvetia district, Schrader (1915, p. 98) says,

> The lower limit of the oxidation zone is irregular and ranges from 100 to 300 feet below the surface . . . what is regarded as ground-water level was struck a little below the 300-foot level in the Isle Royal mine.

The Isle Royal mine is within 1,000 feet of the Copper World and Leader mines (pl. 30).

The ore minerals, identified megascopically, are predominantly chalcopyrite and oxidized copper minerals including azurite, malachite, cuprite, and chalcanthite. Minor amounts of scheelite, sphalerite, and molybdenite are also present, and a little chalcocite occurs in the Narragansett and Copper World mines. The gangue materials are mostly silicated limestone, limestone, limonite, and pyrite. Limonitic and pyritic gangue is especially abundant in the Leader and Copper World mines. The constituents of the silicated limestone are largely garnet, quartz, diopside(?), tremolite, actinolite, and wollastonite, as well as other undetermined minerals of contact-metamorphic origin.

MINES

ROSEMONT LEASE

The Rosemont lease consists of six patented claims, the King, Exile, Amole, Bonnie Blue, Malachite, and Cuprite, which in 1943 were held by lease and bond by M. N. Wolcott of Bisbee, Ariz. Mr. Wolcott acquired the claims in 1941 from the Lewisohn Estates of New York City.

In the area of the Rosemont lease between the quartz monzonite porphyry and the limestone of Paleozoic age is a zone of silicated limestone, usually garnet bearing, resulting from the contact-metamorphic action of the quartz monzonite porphyry (pl. 29). A contact-metamorphic zone is not continuous around the periphery of the plug, but a zone is exposed continuously for more than 650 feet on the northwest contact of the plug. This continuous zone appears to have been formed where the porphyry was intruded along a thrust fault, the same thrust that separates the upper Manzano equivalent from the Snyder Hill formation of Stoyanow to the north. The three largest workings of the Rosemont lease are within this contact-metamorphic belt; here the ore appears to be localized, in part at least, in northeast-striking fractures generally parallel in strike to the belt of silicated limestone. The largest sulfide zone lies next to a cross fault that may have controlled in part the localization of the sulfide minerals.

The exploration, most of which is on the King claim, consists of three separate workings and five prospect adits, all rather limited (pl. 29). The largest and most productive workings consist of an adit, about 340 feet of crosscuts, drifts, and stopes. About 200 feet of these workings are in the mineralized zone from which came most or all of the ore mined during 1941–42. Less than 50 feet southwest of these workings, although not connected with them, is a 150-foot drift connected with a 60-foot crosscut that are in the same mineralized zone. Apparently the southwesternmost workings were present in 1909 as Schrader (1915, p. 119) mentions them in his report. From 200 to 400 feet north of these workings are several short prospect adits and one opencut about 100 feet in length ending in an adit and a small stope (pl. 29). Most of the prospect workings were driven in garnet-bearing lime-silicate rock containing a small amount of oxidized copper minerals, chiefly malachite, azurite, and cuprite.

The mineralized zone exposed in the main workings and those immediately to the southwest is 240 feet long and from 15 to 25 feet wide. The maximum known depth of the mineralized zone is 60 feet below the haulage level of the main workings.

Chalcopyrite and pyrite are the most abundant primary minerals; scheelite occurs in traces disseminated throughout the mineralized zone, and a small pocket of molybdenite occurs on the haulage level. About 400 feet north-northwest, a small pocket of garnet lime-silicate rock in limestone, exposed in a small opencut, contains appreciable chalcopyrite and sphalerite. The oxidized part of the mineralized zone contains azurite, malachite, cuprite, and limonite. Other oxidation products from chalcopyrite, pyrite, and possibly sphalerite may be present but were not recognized.

In 1943 the lessees mined all the ore from the underhand stope in the largest workings, and sorted it by hand. The ore was carried by an aerial tramway 400 feet uphill to the ore bin, and then trucked 20 miles to the railroad station of the Southern Pacific Company at Vail, Ariz. During 1941–42, the mine produced several thousand tons of hand-sorted ore averaging approximately 6 percent copper.

The mineralized silicated limestone in the prospect workings to the north is probably not to be considered ore under present conditions, and the tonnage of mineralized rock that could be mined from any one of these workings is small.

COPPER WORLD MINE

The Copper World mine is on the Brunswick, Owasko, Little Dave, and Copper World patented claims, which are owned by Mrs. Lon Blankenship of Tucson, Ariz. The mine is in a general zone of fracturing in the hanging wall of a fault, which brings Naco limestone (restricted) over Bolsa quartzite (pl. 30). This fault dips steeply eastward at the surface and flattens at the depth of the lower mine workings. The Naco has been partly silicated and generally fractured for several hundred feet next to the fault. The sulfide minerals occur along fractures, in irregular replacement bodies, and in disseminated grains within the zone of fracture and silication. The ore minerals are chalcopyrite, subordinate amounts of chalcocite, malachite, azurite, and chalcanthite, and traces of scheelite. The gangue materials are pyrite, iron oxides, limestone, and lime-silicate minerals.

The mine contains four main levels at 125 feet (135-foot level), 215 feet (200-foot level), 305 feet (300-foot level), and 395 feet (400-foot level); and two sublevels at 60 feet (100-foot level), and 160 feet vertically below the collar of shaft no. 1. The four main levels contain respectively 800, 3,140, 1,400, and 200 feet of workings, and the two sublevels contain 800 and 200 feet of workings. A 500-foot double-compartment inclined shaft that originally provided access to all the levels is now burned out. A 200-foot, single-compartment vertical shaft provides entry to the 200-foot level and a small part of the workings on the 100-foot level. Only the accessible workings are shown on plates 30 and 31. On the 200-foot level, 100 feet southeast of the inclined shaft, the 308-foot stope, which pitches steeply to the southeast, connects the south drift of the 200-foot level with 300-foot level. This stope (Schrader, 1915, p. 102) contained one of the principal ore bodies of the mine.

The lower part of this stope is inaccessible, but it is unlikely that more than a few hundred tons of ore remains in it, inasmuch as Schrader (1915) reported that in 1910 this ore shoot was practically exhausted. According to Schrader (1915, p. 104), rich ore occurred on the 135-foot level in the south and north drifts, and, on the old 100-foot level, ore occurred principally in the vicinity of the inclined shaft. In addition to the 308-foot stope, which extends from the 300- to the 200-foot levels, Schrader (1915, p. 103) speaks of ore in several places on the 200-foot level now inaccessible, chiefly south of the inclined shaft. On the 300-foot level the ore lies south of the shaft, according to Schrader (1915, p. 103), and consisted of two shoots in addition to the 308-foot stope shoot.

The accessible workings on the 200-foot level at the time of the author's examination contained no ore bodies of minable size. On the western edge of the old 308-foot stope, there was a small patch of ore, and at other places on the level, irregular patches of disseminated sulfide and smaller veinlike zones of more massive sulfide were visible (pl. 31). These were, however, largely pyritic. The oxide minerals of copper were distributed widely throughout the level, but concentrations sufficient to constitute ore were not observed.

Between 1900 and 1910, the Copper World mine produced 4,250,000 pounds of copper, $1,000 in gold, and $20,000 in silver for a total production value of $705,000, (table 2). According to the best information available concerning the grade, the ore averaged about 5.17 percent copper (Schrader, 1915, p. 100). Recently the vertical shaft was reopened and a small headframe erected. The mine was not being worked in 1943.

TABLE 2.—*Approximate total gold, silver, and copper yielded by seven mines in the Helvetia district*

[Elsing, M. J., and Heineman, R. E. S., 1936, p. 97]

Mine and year	Copper (pounds)	Gold (value)	Silver (value)	Total value
Rosemont & Mohawk, 1899–1929	2,900,000		$20,000	$710,000
Helvetia (Copper World), 1899–1911	4,250,000	$1,000	20,000	705,000
Tip Top (Little Helvetia), 1904–26	1,000,000		4,000	160,000
Narragansett, 1915–20	6,000,000		40,000	1,525,000
Columbia, 1882	500,000			95,000
Omega, 1883	500,000			85,000
Silver Spur, 1880–89			40,000	40,000
Total	15,150,000	$1,000	$124,000	$3,320,000

LEADER MINE

The Leader mine is on the Copper Fend, Copper World, and Owasko patented claims of the Helvetia Copper Co., which are owned by Mrs. Lon Blankenship of Tucson, Ariz. The mine was inactive in 1943 although it was operated for a short period prior to December 1942. A small flotation-concentrating mill with a capacity of 50 to 75 tons is on the Copper Fend claim near the portal of the mine.

The property was developed through a 60-foot vertical shaft and an adit. The accessible workings connecting with the main drift or haulage level consist of 700 feet of drift, 415 feet of crosscuts, and four stopes on the haulage level. In addition, five sublevels are 30, 34, 40, 48, and 56 feet below the haulage level. Plate 31 shows all the accessible levels except the 40-foot and 48-foot sublevels, which were omitted for the sake of clarity. In 1909, according to Schrader (1915, p. 106), the mine workings aggregated 2,000 feet or more and contained three levels, the lowest of which was the 140-foot level. This level was under water at the time of visit.

The Leader mine lies on the footwall side of a thrust fault (pl. 30) that has moved granitic rocks over limestone and silicated limestone of the Naco limestone (restricted). In general, the limestone strikes northwestward and dips to the east; it is highly brecciated and locally intensely altered to lime-silicate minerals, principally garnet and epidote. The sulfide minerals are pyrite, chalcopyrite, and molybdenite. Pyrite, some of which is cupriferous, is the most abundant sulfide mineral. Pyrite and chalcopyrite are closely associated, although pyrite is more widespread. The distribution and amount of sulfide minerals in the walls of the old stope west of the haulage level and of the underhand stope to the east suggest that the copper ore was pyritic and that in places the copper content diminished so gradually that the extent of the minable ore was determined by assays.

The principal zone of chalcopyrite-pyrite mineralization in the mine averages 8 feet in thickness and is exposed for 180 feet on the haulage level, starting at a point 380 feet from the portal. This zone contains four stopes, three east and one west of the haulage level, and all are accessible from the haulage level. The ore in the two southernmost stopes appears to have been quite pyritic and the tonnage mined from them was small. The two northern stopes, one east and one west of the haulage level, appear to be in the same ore shoot. Although this shoot parallels in strike and dip the contact of the granitic rock and limestone, it pitches northward. Most of the production that came from the accessible part of the mine was mined from these two stopes; the pillars in the underhand stope contain the only copper ore visible in the mine. At other places, in the vicinity of the portal and the vicinity of the face of the haulage level, the thrust fault zone, and in places the limestone, are mineralized for a foot or two adjacent to the fault. Oxidation has obscured the character of some of the original sulfide minerals, but the amount of pyrite appears to be large.

One zone of molybdenite is separate from the chalcopyrite, and no relationship between the two minerals could be established. The molybdenite occurs in a zone lying beneath the Leader adit and shaft. The zone is accessible by a series of inclines connecting sublevels at 30, 34, 40, 48, and 56 feet below the haulage level. The footage of workings on all the sublevels is small; the workings of the 40-foot sublevel are the most extensive. Small disconnected molybdenite stopes occur on the 40-foot sublevel, and molybdenite occurs on the 34-, 40-, and 48-foot sublevels. The 56-foot sublevel, the lowest level accessible in the mine, contains no molybdenite, although it lies directly downdip from the molybdenite stopes on the 40-foot sublevel.

The molybdenite occurs in the walls as disseminations forming scattered bunches or pockets of molybdenite-bearing rock and as thin seams that commonly swell to small pockets as much as a foot long and several inches wide at intersections with other seams. The molybdenite is in the limestone and silicated limestone on the footwall side of the thrust fault. Silication appears to be more intense here than at other places in the mine, and garnet is the most abundant lime-silicate mineral.

The chalcopyrite-pyrite mineralized zone has a strike length on the haulage level of 180 feet, and it extends 30 feet updip and somewhat more than 70 feet downdip. The lower part of this stope is under water. The zone dips 25° E. and pitches northward. The dip of the thrust fault over the mineralized zone is appreciably less than elsewhere in the mine. This change in dip in the thrust fault forms a roll that may have been important in the localization of the sulfide minerals. Although the molybdenite occurs only in one general zone in the mine, it is concentrated in pockets and small discontinous seams that contain no apparent leads from one to the other or any guides for their location.

The production of the Leader mine is unknown, but Schrader (1915, p. 106) says,

> This mine was among the early discoveries of the camp and is one of its leading producers. It produced a large amount of ore in the early days, much of which is said to have averaged 14 percent in copper. The various chambers and particularly the large stope east of the tunnel, which descends at an angle of about 40 degrees, indicates that a large amount of ore has been removed. The mine still contains and is now producing considerable low-grade copper ore.

The mine was operated for copper in 1942 by Robert Burney, Sahuarita, Ariz., but the production is not known.

A few tons of molybdenum ore were mined in 1934 by Molybdenum, Inc. It is reported that molybdenum was mined during World War I, but this has not been substantiated. Production records, reserves, and most of the information on occurrence and distribution of the molybdenum were obtained from Charles A. Anderson (written communication).

The Leader mine contains several thousand tons of low-grade pyrite-chalcopyrite mineralized rock in a zone about 400 feet north of the portal. This low-grade block may contain some pockets of ore, but the location of such pockets within the block is not predictable. The face in the largest underhand stope gives no clue to the grade of the ore downdip, for it is covered by water.

The exposed reserves of molybdenite-bearing rock are small and largely limited to the 40-foot sublevel where a few scores of tons of ore could be obtained by hand sorting. Although there are no guides to the location of other pockets of molybdenite, additional exploration in the general zone containing the molybdenite probably would result in the discovery of additional pockets and seams of the grade and size of those already exposed.

NARRAGANSETT MINE

The Narrangansett mine is on the Narragensett Bay and Olcutt patented claims owned by Harold Steinfeld and Co. of Tucson, Ariz. Part of the workings extend under the Daylight and York patented claims owned by the Lewisohn Estates of New York City. In 1943 all four claims were held by lease and bond by F. A. Bennett of Tucson, Ariz.

The Narragansett mine lies a mile and a half east-southeast of Helvetia on the east slope of the Santa Rita Mountains and about 2,500 feet south of the Rosemont lease on the opposite side of the quartz monzonite porphyry plug. The mine contains 2,600 feet of drifts and crosscuts, 260 feet of inclined winzes, and many stopes. Most of the stopes lie below the haulage level. The mine was developed through an adit from the Narrangansett Bay claim and a 100-foot inclined shaft from the Daylight claim. Plate 32 shows all the known workings, but some of the details on the outline of the stoped zones are lacking.

In 1943 the lessee was driving an adit from the Daylight claim to intersect the ore shoot beneath the level of the old workings and had engaged a mineral surveyor to establish control points by a transit survey for the new adit and to survey the old workings in the mine.

The rocks exposed in the area of the Narragansett mine consist of Paleozoic and Cretaceous sedimentary rocks. The Paleozoic section is represented by Bolsa quartzite, Naco limestone (restricted), lower Manzano equivalent, and Snyder Hill formation of Stoyanow. Each of the formations is in fault contact with adjacent ones. Most of the lower Manzano, and the Abrigo formation, Martin limestone, and upper Manzano have been cut out by faulting, and the Bolsa quartzite and Naco limestone (restricted) have been duplicated. The Paleozoic section overlies the Cretaceous sedimentary rocks on a fault contact. All major faults are vertical or dip westward, in contrast to the prevailing easterly dip of the major faults farther north in the Helvetia district. As discussed in the section on structure, the formations here may have been overturned after a period of major thrusting but before the period of mineralization.

The Paleozoic limestone formations and the Naco limestone in particular have been intensely silicated. In places, the westernmost belt of Naco limestone has been altered almost completely to a garnet lime-silicate rock over large areas. Some of this garnet rock appears to have been mineralized. Smaller bands of garnet lime-silicate rock containing locally small amounts of copper oxide minerals occur in the Snyder Hill formation of Stoyanow southeast of the portal of the Narragansett mine.

The portal and most of the drifts and crosscuts in the Narragansett mine are in the Cretaceous formations, which consist of bedded arkosic sandstones and shales. The Cretaceous strata contain only small amounts of copper. Apparently the Paleozoic limestone formations were more susceptible to mineralization.

The ore shoot lies along the axis of a south-plunging syncline in the folded low-angle thrust fault that brings limestone of Paleozic age over Cretaceous sedimentary rocks. The ore lies in a crushed zone 7 to 8 feet thick, in the altered limestone hanging wall and consists of copper carbonates and minor amount of chalcopyrite and chalcocite in a gangue composed principally of silicated limestone, iron oxides, and some pyrite.

From 1915 to 1920 the Narragansett mine yelded 6 million pounds of copper (table 2). The known reserves of ore are negligible, but Charles Taylor, county assessor, Pima County, Ariz., stated (oral communication) that operations in the Narragansett mine were stopped because the ore passed out of the Narragansett Bay claim into the Daylight claim, part of the Lewisohn holdings. The mine shows no evidence of other ore bodies.

OTHER MINES AND MINERALIZED AREAS

Approximately midway between the Rosemont lease and the Narragansett mine in and along the south side of the quartz monzonite porphyry is a breccia zone, whose outcrops are sporadically stained with oxidized copper minerals. The breccia zone lies chiefly within the Alta Copper and Malachite claims owned by the Lewisohn Estates of New York City. In 1939 the Anaconda Copper Mining Co. explored the mineralized zone with a diamond drill.

TABLE 3.—*Other important mines in the Helvetia district*

Mine	Location	Workings	Ore association and ore minerals	Production (tons of ore)
Black Horse	Adjunct of Copper World mine.	100-ft shaft and 400 ft of drift	Ore bodies in a ledge of silicified limestone. Ore minerals consisted of chalcopyrite and pyrite coated with chalcocite.	Unknown.
Isle Royal	1,000 ft south of Copper World mine.	800-ft shaft and 4,000 ft of workings distributed on seven levels.	Ore bodies on contact between granite and limestone and near a fault. Ore minerals consisted of copper carbonates, cupriferous pyrite, and chalcopyrite.	30,000.
Heavy Weight	½ mile northeast of Copper World and Leader mines.	3,000 ft or more of workings on three levels.	Ore on a sheared contact between limestone and intrusive rock. Ore minerals consisted of copper carbonates and chalcopyrite.	Unknown, but heavy contributor to output of camp from 1889 to 1902.
Old Dick	½ mile east of Helvetia	3,000 ft or more of workings mostly on one level.	Replacement deposits in limestone. Ore minerals consisted of copper carbonates and other oxidized copper minerals.	Unknown, but one of the heaviest of the early producers in the Helvetia camp.
Mohawk	⅓ mile northwest of Helvetia	200-ft shaft and 400 ft or more of drift, largely on the 100-ft level.	Ore occurred in garnetiferous limestone in two bodies on 100-foot levels. Ore mineral was chalcopyrite.	3,000.
Omega	1½ miles east of Helvetia and ¼ mile south of Isle Royal mine.	2,000 ft of workings, including four tunnels, a shaft, a winze, and an opencut.	Ore is in fault zone between granite and limestone. Ore minerals consisted of both iron and copper sulfides and their oxidation products.	2,000 before 1909.
Tiptop	¾ mile north of Helvetia	4,000 ft of workings chiefly on two levels.	Mine is on faulted contact between limestone and granite. Ore minerals consisted of copper sulfides and copper carbonates and averaged about 6½ percent copper.	Over 20,000.

On the surface the mineralized zone is shaped roughly like a trapezoid with sides of 400 and 200 feet and a height of about 150 feet. The long side trends eastward and roughly parallels the contact between the quartz monzonite porphyry and the Comanche series. The rocks in the breccia zone, a mixture of porphyry and Comanche series, are iron stained, and fracture surfaces are partly coated with oxidized copper minerals, chiefly malachite.

From 200 to 600 feet south of the porphyry contact is a 50-foot garnetized limestone bed that contains several prospect pits in which are exposed malachite-stained silicated rock and gossan, presumably derived from pyrite and chalcopyrite.

Other important mines in the Helvetia district, as described by Schrader (1915), are listed in table 3 along with their location, total amount of workings, ore associations, ore minerals, and production.

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