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TUNGSTEN DEPOSITS OF THE ATOLIA DISTRICT SAN BERNARDINO AND KERN COUNTIES CALIFORNIA

BY

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CONTENTS

ILLUSTRATIONS

TUNGSTEN DEPOSITS OF THE ATOLIA DISTRICT, SAN BERNARDINO AND KERN COUNTIES, CALIFORNIA

By Dwight M. Lemmon and John V. N. Dorr 2d

ABSTRACT

High-grade scheelite ore, with a quartz-carbonate gangue, has been mined in the Atolia mining district from steeply dipping fissure veins of Miocene age. A minor quantity of scheelite has been taken from placers. The country rock is quartz monzonite probably of late Jurassic age.

Approximately 821,000 units of tungsten trioxide (WO_3), equivalent to 13,683 tons of concentrates containing 60 percent of WO_3, has been produced from the district. Of this total, 94 percent came from veins and 6 percent from placers. About 54 percent of the total production has come from the Union mine, which has been developed to a depth of 1,021 feet. Only a few thousand tons of 2-percent ore is in sight in the veins, but future development may lead to the discovery of new ore bodies. Mill tailings contain an appreciable reserve, and they are now being re-treated. The placer deposits contain possibly 28,000,000 cubic yards estimated to average more than a quarter of a pound of scheelite per cubic yard, or a total of at least 280,000 units of WO_3. Certain parts of the placers contain sufficient scheelite to be workable at normal prices, and discovery of methods by which the gold content could be recovered might permit production of scheelite as a byproduct from the submarginal placers.

With favorable prices, it is believed that an annual production of 300 to 400 tons of 60-percent WO_3 concentrates may be maintained over a short period of years.

INTRODUCTION

Location

The Atolia mining district lies near the northern edge of the Mojave Desert, in San Bernardino and Kern Counties, Calif. (see fig. 36). A surfaced highway, U. S. 395, connects Atolia with Johannesburg and Randsburg, which lie 4 miles to the north, and with Kramer Junction, 23 miles to the south. No railroad

enters the district, as the Randsburg branch of the Atchison, Topeka & Santa Fe Railway has been abandoned. The Owenyo branch of the Southern Pacific Railroad lies 9 miles to the north and the main line of the Atchison, Topeka & Santa Fe Railway is 23 miles to the south, at Kramer Junction.

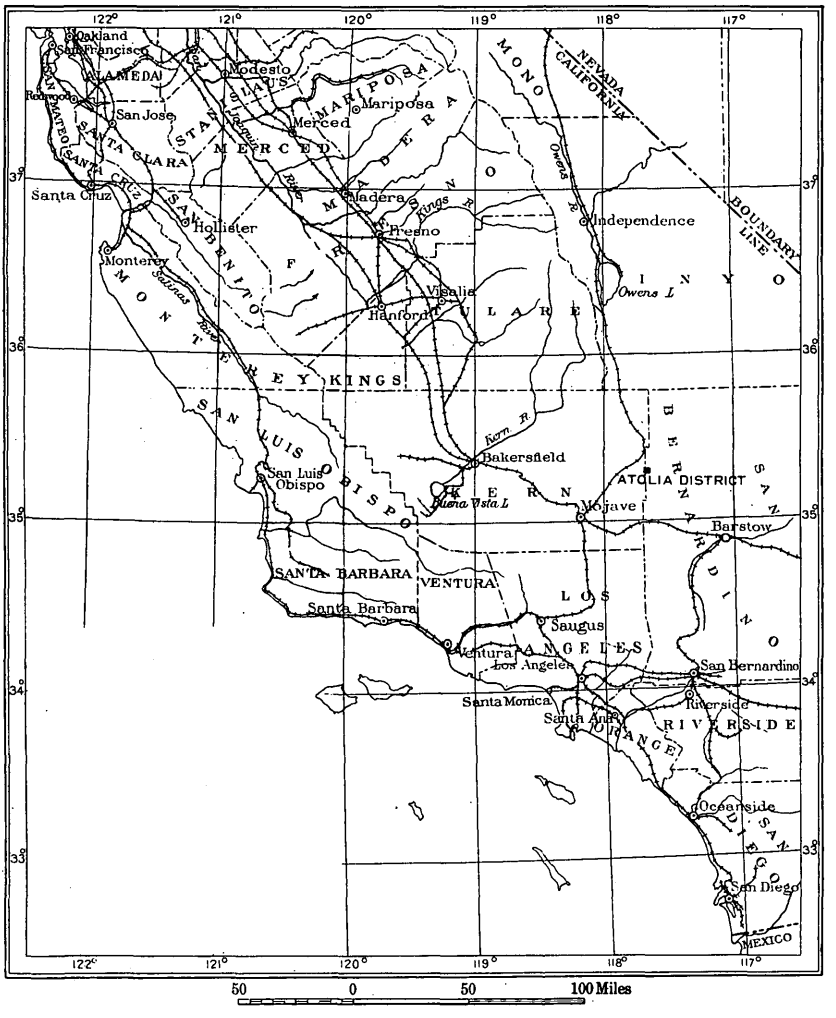

Figure 36.--Index map of southern California showing location of the Atolia mining district.

Water is scarce. Domestic supplies are piped from wells northeast of Red Mountain, about 6 miles northeast of Atolia, and are sold at 3/4 cent a gallon. The industrial water supply is pumped from wells near Cuddeback Lake, now dry, 8 miles east of Atolia.

History of mining

Tungsten was first discovered in 1904 in placer operations at the St. Elmo gold mine south of Atolia. In tracing the placer northward, George Gaylord and Pat Burns overlooked the Atolia veins, although they located scheelite lenses in the Stringer district, several miles north of the Union mine. Shortly afterward the Papoose vein was discovered in an outcrop near the present town of Atolia, and within a few months the Union deposits at the west end of the field were discovered. The Atolia Mining Co. was organized in 1905, and most of the productive part of the district came under its control.

Wartime boom prices in 1916 brought thousands of miners into the district to work the placer deposits of the "Spud Patch," so named because the pieces of scheelite resembled potatoes. The richness of the ore led to high-grading and to theft of concentrates, and scheelite "spuds" were an acceptable medium of exchange in the bars and stores of the region.

Tungsten prices collapsed when the armistice was signed in 1918, and the district was inactive from then until 1924, when the Union mine was reopened. Large-scale placer operations were carried on in the Spud Patch area from 1926 to 1931.

In 1934 Atolia Rand Placers, Inc., purchased and leased surface rights in the western part of the Atolia district and drilled about 1,500 test holes to sample the gold-scheelite

placer deposits. The samples were treated in a small pilot mill, and later a large plant was constructed. This plant operated for about 6 months before being shut down because of poor recovery; it was afterward partly dismantled.

From 1936 to 1938 the Pacific Placers Engineering Co., controlled by J. K. Waddley, operated dry-placer machines in the Baltic Gulch area, between the Union mine and the Stringer district. This operation was experimental and was not on a large scale.

For many years much of the mining on the properties of the Atolia Mining Co. has been done by lessees, the company itself operating the mill and only occasionally working a few of the mines. The scale upon which lessees have operated ranges from the common two- or three-man partnership lease to companies that have employed 25 to 50 men, such as the Smoot & Main lease of the Flatiron and Par mines and the Rust & Main lease, which at one time operated the Union mine. In 1937 there were more than 50 leases in the field, upon which about 250 men were employed; but during 1938 and 1939 lower tungsten prices coupled with company policy caused a great decrease in this number, although there were still 27 men leasing on company property in February 1940. At that time about 40 men were working in the district besides the employees of the Atolia Mining Co. Recent company operations have been largely restricted to retreatment of tailings from the old Papoose mill and to a little underground development in the Paradox No. 3 mine.

Production

The quantity of concentrates produced and sold by the Atolia Mining Co. each year to the end of 1939 is listed in the table below and amounts to 795,148 units--more than 95 percent of the total output of the district. Production from other properties in the district, roughly estimated to total 26,000 units,

brings the total for the district to 821,148 units. The second largest production has come from the Spud Patch placer deposits, which were most active in 1916-17. Hess [1] estimated the total production for those 2 years to be not more than 300 tons of concentrate containing 60 percent of WO_3 (18,000 units). The total placer production, including that from the Atolia Mining Co. placer plant, probably has not exceeded 50,000 units, or, roughly, 6 percent of the total production of the district.

Concentrates produced and sold by the Atolia Mining Co.

Year	Units [1]	Price per unit
1906	15,832.00	
1907	24,963.00	
1908	4,891.00	
1909	33,191.00	
1910	30,775.00	
1911	23,677.00	
1912	24,987.00	
1913	32,921.00	$ 7.98
1914	27,996.00	6.50
1915	54,375.00	14.03
1916	108,539.00	33.74
1917	116,307.00	18.54
1918	61,763.00	25.11
1919	4,086.51	16.70
1920	No concentrates shipped.	
1921		
1922		
1923	10,867.73	8.13
1924	8,057.13	8.28
1925	26,549.68	9.45
1926	20,161.02	12.60
1927	17,569.06	10.80
1928	17,598.23	10.53
1929	8,681.57	11.66
1930	5,898.81	11.87
1931	1,938.11	12.10
1932	1,888.92	7.75
1933	8,356.38	9.43
1934	14,058.61	14.47
1935	10,484.05	14.42
1936	12,116.36	15.27
1937	21,592.95	21.57
1938	20,233.62	19.42
1939	24,792.59	14.99
	795,148.33	

[1] A unit is 20 pounds of contained WO_3.

[1] Hess, F. L., Mineral Resources U. S., 1916, part 1, p. 791, and 1917, part 1, p. 933.

251029 O—40——2

Previous work

The main geological work in the Atolia district that has led to publications has been done by F. L. Hess and C. D. Hulin. Hess made studies of Atolia properties at various times between 1906 and 1918. Hulin's work, a survey of the entire Randsburg quadrangle, is more recent and more comprehensive. Hulin was prevented by lack of time from making detailed examinations in the tungsten district, and his own observations there are largely supplemented by information from the mining companies.

The following papers containing information about the Atolia district have been published:

Hess, F. L., Gold mining in the Randsburg quadrangle, Calif.: U. S. Geol. Survey Bull. 430, pp. 23-47, 1909.

Hess, F. L., Tungsten minerals and deposits: U. S. Geol. Survey Bull. 652, 85 pp., 1917.

Hess, F. L., Chapters on tungsten in annual volumes of Mineral Resources U. S., 1905-25.

Hulin, D. C., Geology and ore deposits of the Randsburg quadrangle, Calif.: California State Min. Bur. Bull. 95, 152 pp., 1925.

Prommel, H. W. C., Sampling and testing of a gold-scheelite placer deposit in the Mojave Desert, Kern and San Bernardino Counties, Calif.: U. S. Bur. Mines I. C. 6960, 18 pp., 1937.

Vanderburg, W. O., Methods and costs of concentrating tungsten ores at Atolia, San Bernardino County, Calif.: U. S. Bur. Mines I. C. 6532, 12 pp., 1931.

Field work

The writers, assisted by MacKenzie Gordon, Jr., were engaged in field work in the Atolia district from November 26, 1939, to March 3, 1940. Lemmon is largely responsible for underground mapping, Dorr and Gordon for surface work. Geologic level maps on scales of 20 and 30 feet to the inch were

made of all accessible underground workings. A surface map prepared by the Atolia Mining Co. is the nucleus of the topographic sheet (pl. 35), and the company's primary traverse is the base for the extended triangulation system used in completing the map by plane-table and alidade survey. Depth to bedrock was observed where possible and is shown in many places by records of drill holes on properties of Atolia Rand Placers, Inc., and of the Federal mine group. All this information has been utilized in drawing contours of the bedrock surface (see pl. 35).

Acknowledgments

To operators, property owners, and residents of the district we owe thanks for the loan of maps and records, for pertinent information, and for cordial cooperation. This survey would have been impossible without the assistance and collaboration of the staff of the Atolia Mining Co., particularly Livingston Wernecke, president and manager, L. E. Putnam, superintendent, and W. L. Cox, resident engineer and geologist. We are also specifically indebted to J. C. Raynor, C. E. Irwin, J. L. Danziger, P. J. Osdick, F. W. Royer, J. W. Platte, Ed Smoot, Tim O'Connor, and A. A. Turner. We are deeply obligated to Mary Elizabeth Dorr for field aid and office assistance.

GEOLOGY

The Atolia district occupies a pediment partly covered with alluvium on the southeast flank of the northeast-trending Rand Mountains, a tilted fault block. This range consists of pre-Cambrian metamorphic rocks into which several igneous bodies have been intruded. It contains many gold-bearing veins, which were the source of much of the gold in the Atolia placers. The surface of the tungsten district is gently rolling and has in

general a gentle slope southeastward. It drains toward Cudde-back Lake, a playa about 7 miles east of Atolia. The rock that contains the scheelite veins and underlies all of the area mapped on plate 35 is the Atolia quartz monzonite, probably of late Jurassic age. Dikes of diorite, aplite, and granite, probably of Mesozoic age, cut the quartz monzonite, but because these dikes are not present in the principal mines and are covered with overburden on the surface they were not mapped. Two diabase dikes, probably of Miocene age, cut the quartz monzonite and the scheelite veins. Miocene sedimentary rocks known as the Rosamond series occupy a small area in the eastern part of the district. Quaternary alluvium covers most of the surface.

Rocks

Atolia quartz monzonite and allied dikes.--The Atolia quartz monzonite is a light-gray medium-grained, granitic rock, which consists mainly of nearly equal quantities of orthoclase, plagioclase, and quartz and contains minor quantities of hornblende and biotite. Common accessory minerals are sphene, apatite, and magnetite. The orthoclase is mostly interstitial between the plagioclase crystals.

The quartz monzonite in the mapped area is part of a large mass that forms the principal basement rock in the southern and eastern parts of the Randsburg quadrangle, although in Red Mountain and the Lava Mountains, to the northeast of Atolia, it is capped by the Miocene sedimentary rocks and andesite and is elsewhere largely covered by alluvium.

Several diorite dikes 5 to 15 feet thick are visible on the Paymaster claim, which is west of the highway and between Atolia and St. Elmo. Other dikes may be seen on the Paradox claim, southeast of the Paradox No. 1 mine and east of the

highway. The diorite is medium-grained and contains nearly equal amounts of light and dark minerals, the light consisting mainly of plagioclase (andesine) and the dark mainly of hornblende. One thin section shows a little quartz.

Diabase dikes.--Two diabase dikes cut the scheelite veins in the west part of the Union mine. These dikes range in width from 1 foot to 7 feet and persist from the surface to the bottom level, 1,000 feet below. The rock is fine-grained and dark-colored; in thin section it shows laths of labradorite enclosed in interlocking larger grains of augite to form a characteristic diabasic texture. From relations observed by him elsewhere in the Randsburg quadrangle, Hulin 2/ has inferred that these dikes are of upper Miocene age.

Miocene sedimentary rocks.--A variable thickness of barren conglomerate and sandstone, which were called the Rosamond series (Miocene) by Hulin, occurs in the Spud Patch area, in the eastern part of the district, where it overlies the quartz monzonite and underlies the tungsten-bearing alluvium. Large closely packed angular fragments of a red granite quite unlike the quartz monzonite are found in shafts and in one small outcrop in the area occupied in this series. In places, the fragments might be taken for parts of a mass of bedrock, but careful examination shows them to be boulders and pebbles in thick beds of gravel, interstratified with other beds that are more clearly sedimentary. Placer miners have recognized the distinctive nature of these beds, which are locally referred to as the Red Mountain flow. They are underlain by light-colored sandstones with occasional beds of conglomerate.

2/ Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle, Calif.: California State Min. Bur. Bull. 95, p. 72, 1925.

The Miocene beds thin rapidly westward. Information from miners indicates that their western limit is a normal fault dipping eastward. Several placer shafts southeast of the large placer dump have been sunk more than 125 feet into this material without reaching quartz monzonite. Unfortunately none of the shafts are now accessible, and most of them are partly filled with water.

Alluvium.--Quaternary alluvium overlies almost all of the district. Nearly half the area is covered with sandy material 1 foot to 4 feet thick formed by the disintegration of the quartz monzonite. The western and southeastern parts of the area mapped are covered with stratified alluvium 5 to 125 feet deep. The alluvium contains many different types of rocks and varying amounts of gold and scheelite, derived in part from the veins of the Stringer district and in part from the Atolia veins.

Structure

The most prominent structural feature of the northern Mojave desert is the Garlock fault, which extends from Tejon Pass northeastward through the Tehachapi Mountains and along the south side of the El Paso Range, from which it has been traced around the Avawatz Mountains near the south end of Death Valley. This fault is the boundary between two structurally and topographically distinct areas--the Basin-and-Range province on the north and the Mojave Desert province on the south. In the Randsburg quadrangle Hulin [3/] found that the chief movement on this fault had been horizontal, and he thought the south side had moved east as much as 5 miles. Most of the displace-

3/ Hulin, C. D., op. cit., p. 63, 1925.

ment took place in the Quaternary period, and the fault is still active. When the faulting began is not known, but it may have been as long ago as early Tertiary.

The Rand Mountains, which lie a few miles south of the Garlock fault, are carved from a south-sloping fault block bounded on the north by a normal fault. The range contains many persistent longitudinal fractures older than the frontal fault; some of these are filled with veins that carry tungsten and gold, some are occupied by rhyolite and latite dikes, and some are barren. Other faults of north and northeast strike, some of which are exposed in the Kelly mine at Red Mountain, contain gold and silver ore bodies or dikes.

All of these earlier faults appear to have been formed by regional compression in Cretaceous or early Tertiary time. Even those which are still active probably date from the same period, although their present magnitude is due to more recent stress.

The Atolia district lies 9 miles south of the Garlock fault, on the south slope of the Rand Mountains. With minor exceptions, the tungsten veins here and elsewhere in the Rand Mountains occupy north-dipping faults that strike from N. 75° E. to N. 75° W. The general trend of the belt is northeasterly, parallel to the Garlock fault, and displacement appears to have been mainly horizontal and in the same direction as that on the Garlock fault. The dip of the veins ranges from 45° N. to vertical, those in the east end of the district being steepest. In the Flatiron mine the Spanish vein is nearly vertical, and locally it overturns 85° S. There is no evidence to indicate the amount of pre-mineral displacement along the veins.

Post-scheelite faulting has taken place along the vein fractures and in cross faults. A measure of the post-mineral faulting along the vein is found in the Union mine, where a

diabase dike which cuts through the scheelite has been offset 15 feet along the vein. None of the many cross faults have large displacements; the horizontal shift rarely amounts to 25 feet and usually is much less. Between offset parts of veins these faults commonly contain dragged quartz and scheelite, which can be followed to find the offset vein. Some of the cross faults have been slightly mineralized, indicating that mineralization continued after they were formed.

The Paradox No. 3 vein is structurally exceptional in that it strikes northwest, dips southwest, and is broken by many small faults (see fig. 39).

The main St. Elmo vein, which contains no scheelite but has produced gold, strikes N. 40 E. and dips southeast. Although the northeast extension of the vein is deeply buried under alluvium, the eastern limit of the Miocene sedimentary rocks in the Spud Patch area coincides with the projected strike. The sharp change in grade of the bedrock channels in this zone suggests faulting along this line.

Many other mineralized fractures occur in the southern part of the Atolia district (for example, the Paymaster and Senator veins), but none of these contain scheelite. The vein matter consists mainly of carbonates and in some veins is reported to carry gold.

LODE DEPOSITS

The tungsten-bearing fissure veins at Atolia contain the largest bodies of high-grade scheelite discovered in the United States, and possibly in the world. They occur in a series of roughly parallel, locally branching fractures. With the exception of the Papoose vein, the original discovery in the district, all the veins are concealed under the widespread detrital cover.

The main production has come from a few veins occupying a narrow belt that crosses the area from east to west (pl. 35). Pockets of scheelite have been mined in the Stringer district, northwest of Atolia, from veins chiefly valuable for their gold content, and some scheelite has been recovered at the Yellow Aster mine, in the Randsburg district; but no detailed study has been made of these occurrences, for they are outside the area mapped and none of them promises large production. On a claim about half a mile north of the area mapped (shaft coordinates about 4,130 N., 10,430 W. of the Papoose shaft) C. E. Irwin discovered, in 1939, a small lenticular body of high-grade ore with a maximum thickness of about 10 inches. The vein, which dips steeply north and has been followed down for 90 feet, has probably produced several tons of concentrate. Other bodies may lie undiscovered between this property and the known Atolia veins.

The known portion of the main productive belt at Atolia extends about 2 miles along the strike of the veins, the limiting coordinates (pl. 35) being about 7,200 W. and 2,700 E. The two southernmost occurrences are at the I Guess shaft (3,950 S.), south of the Union mine, and at the Federal and Wedge Fraction shafts (2,100 S.). Parallel veins carrying small amounts of scheelite are distributed northwestward into the Stringer district, the northern limits of which lie about $2\frac{1}{2}$ miles northwest of the area represented on the map.

Both ends of the principal belt are covered, the west end by alluvium more than 125 feet thick, the east end by alluvium and by Miocene beds. The west end of the district has been extensively prospected along the strike of the ore zone in search of continuations beyond the Atolia Mining Co.'s property. Crosscuts from vertical shafts sunk through the alluvium have not found any scheelite. The location of the east limit of the

251029 O—40——3

scheelite mineralization has not definitely been proved by crosscuts, but no ore has been found east of the central portion of the Osdick claims, although several shafts have been sunk into the bedrock farther east.

Mineralogy

The mineral composition of the ores is simple. Scheelite is the only ore mineral. The gangue consists of quartz, carbonates (calcite, ankerite, dolomite, and siderite), and sporadic pyrite, stibnite, and cinnabar. Ores from the west end of the district contain considerable phosphorus, probably derived from attached pieces of the quartz monzonite, which contains apatite. No phosphate mineral has been identified in the veins themselves. At least one of the scheelite veins, that in the Rainstorm mine, contained a pocket of gold ore.[4/] Some other veins in the district, such as the St. Elmo veins, are gold-bearing but carry no scheelite.

It is possible for one thoroughly acquainted with the ores of the district to distinguish ore from different mines at sight. In general, ore from the Union mine has much fine-grained brownish quartz in the gangue and contains considerable carbonate. Ore from the Flatiron and Par mines has less gangue, it contains very little carbonate and less quartz than the Union ore, and the quartz is milky and rather coarsely crystalline.

Scheelite ($CaWO_4$) occurs in veinlets and forms massive solid chunks in the larger veins. The pure mineral is white, but it is usually admixed with more or less quartz and calcite. It is coarse-grained and some masses show large cleavage surfaces.

4/ Hulin, C. D., op. cit., p. 73, 1925.

No euhedral crystals have been found. F. L. Hess, in 1917, obtained a single specimen weighing a ton or more from the Million Dollar stope of the Union mine and sent it to the National Museum, Washington, D. C.[5/]

Quartz of several varieties is abundant in the veins. A fine-grained brownish quartz of chalcedonic appearance is common in some of the western ore bodies but is absent to the east, where a white, milky quartz is present. Small veins of comb quartz formed subsequent to the scheelite are found throughout the district. Many of the quartz veins in the western and central parts of the district contain no scheelite, but scheelite nearly everywhere accompanies quartz in the Flatiron and Par mines, to the east.

Calcite and the other carbonates are especially abundant as gangue minerals in the central and western ore bodies and in the barren veins north and south of the productive belt.

Pyrite is a very minor constituent of the ores, but it is abundant in the adjoining altered parts of the country rock. In the upper levels of the mines oxidation has destroyed much of this pyrite, leaving a limonite stain.

Stibnite (Sb_2S_3) is found locally in the central part of the field in veins as much as 6 inches thick, which also carry quartz and scheelite. It is fairly abundant in the Rainstorm mine and in the Viewpoint No. 1 mine.

Cinnabar (HgS) is rare in the district; probably not more than a few hundred pounds of it has been found. The writers did not find any cinnabar, although it is said to have been found in tungsten ore from several places, notably from a vein discovered while digging for the foundations of the mill ore

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5/ Mineral Resources U. S., 1917, part 1, p. 940.

bins near the Papoose shaft, from shallow workings in the central part of the field southwest of the Acaley mine, from the upper levels of the Union mine, and from placer workings in the Spud Patch.

Rock alteration

The quartz monzonite adjoining all the veins has been altered by hot ascending waters for distances ranging from a few inches to several feet from the walls. The most extensive alteration is found in the Union mine and in the central part of the district. In the Flatiron and Par mines the alteration is relatively slight. The altered rock is impregnated with sericite, pyrite, kaolin (?) and a little chlorite. Where not weathered it is usually greenish-gray in color, but it is commonly brownish near the surface owing to the oxidation of pyrite. At the surface it is commonly white because of the leaching of iron oxide and the corresponding prominence of kaolin, which may have been formed in part by surface waters.

Origin

The tungsten veins have been deposited from hot solutions, which rose from deep sources through fault fissures into regions in which the temperature and pressure were suitable for deposition of the scheelite and associated minerals. The veins are fissure fillings with little replacement of the country rock.

There is no conclusive evidence as to the geologic age in which these veins were formed. Hulin considered the mineralization to be connected with the nearby late Miocene volcanism. The ore bodies are certainly later than the late Jurassic (?) quartz monzonite and probably pre-upper Miocene, as they are cut, in the Union mine, by diabase dikes that are probably of

upper Miocene age. The texture of the ores suggests deposition near the surface, which implies a long time interval between the intrusion of the quartz monzonite and the emplacement of the veins--an interval long enough to allow the stripping off of most of the rock that originally covered the intrusive mass.

Grade of ore

The average grade of ore mined and milled by the Atolia Mining Co. in any one year since 1909 has ranged from 1 percent to 15 percent of WO_3 and has averaged 4.14 percent of WO_3. Some of the ore assayed 60 to 70 percent of WO_3 and was sacked in the mine and shipped without milling. At present the grade of ore milled is kept at about 2 percent of WO_3.

Ore shoots

Scheelite ore bodies occur as shoots in the veins. These shoots are broadest near the surface and narrow downward. Most of them are nearly vertical, but some of the eastern shoots pitch eastward parallel to cross faults (see pl. 36).

The largest ore shoot discovered, that in the South vein of the Union mine, did not reach the surface. It has been mined on all the levels from the third to the fourteenth, a vertical distance of 850 feet. Its maximum exposed breadth is 1,260 feet, and its pitch length is 1,080 feet as far as the bottom of the mine, which has not yet reached the bottom of the shoot. The other shoots in the district have been much smaller; their average stope lengths probably do not exceed 100 feet. The maximum pitch length in many ore shoots is roughly equal to the stope length.

The thickness of ore mined by the companies has ranged from a few inches to 17 feet. The maximum was reached in one part of the South vein of the Union mine. The ore bodies in

the Union mine have been the widest, those in the eastern part of the district being thinner but of high grade. The Papoose vein was 5 feet thick at the surface. The Paradox veins have locally contained 2 to 5 feet of high-grade scheelite. Lessees can operate successfully upon very narrow stringers of high-grade scheelite, veins as little as 1 inch thick having been profitably mined. Where conditions permit, they blast the waste from narrow veins before they mine them, in order to prevent dilution of ore.

About three times as much ore has been mined in the western part of the district (Union and Amity mines) as in the eastern part (Papoose, Flatiron, Par, and Paradox mines). Production from the central part has been insignificant.

The scheelite veins are broken in many places by cross faults, few of which are mineralized. As the ore shoots appear to be localized near these faults, it seems probable that incipient cross fractures existed prior to mineralization and were a major factor in controlling ore deposition. Continued stress after the formation of the scheelite bodies caused post-mineral movement along these cross fractures, and most of the displacement now visible is due to this later movement.

Although the cross faults have been chiefly influential in localizing the ore bodies, certain features of the vein fractures themselves have been locally important. In the Flatiron, Spanish, and Par mines the vein walls swell and converge in plan, the centers of successive rolls commonly being about 10 feet apart. These rolls have been important as channelways and as sites of deposition. A flattening of the vein between the sixth and eighth levels appears to have localized the richest ore body in the Union mine (see fig. 37).

Possibilities of ore at depth

In the course of development it has been found that ore shoots throughout the field become leaner and smaller with depth. However, the ore shoot in the South vein of the Union mine still contains low-grade ore on the bottom level at a depth of 1,021 feet. Below the ninth level the ore bodies have been erratic and progressively leaner, but it is reported that on the fourteenth level, now under water, the ore was more uniform in character, although still of low grade.

In the Redondo Pete mine, now inaccessible, a small ore streak is reported to have been developed on the 500-foot level but to have supplied very little ore.

No other shaft in the district has been sunk deeper than 300 feet. No major ore bodies have been developed between the Amity mine and the Papoose mine, in which the ore pinched out at a depth of 190 feet. In the Flatiron mine ore was present a short distance above the fourth level, which is 262 feet below the collar of the shaft and is now under water. The Paradox mines have not been worked deeper than 167 feet.

Sufficient work to determine whether or not ore continues downward has not been done in the eastern and central parts of the field, but the richness of the Papoose and Flatiron ore bodies makes future exploration at depth seem inevitable in the east. There is no obvious reason for assuming absence of deeper ore in this zone.

Reserves

At present there is practically no ore in sight in the mines of the Atolia district, partly because the lenticular character of the high-grade ore shoots makes impracticable the systematic blocking out of reserves in advance of mining. For

example, despite reports [6] by former operators that the Flatiron mine had been exhausted prior to 1915 and that the Par mine had no ore below the third level or to the east or west, renewed operations on the Flatiron lease (including the Spanish and Par mines) during the 6 years 1934-40 have produced nearly $1,000,000 worth of tungsten, although probably at no time has there been more than a few hundred tons of ore in sight. The only proved reserve in the district is in the Atolia Mining Co.'s mill tailings, which are now being re-treated by flotation.

The Atolia district is not exhausted, but the easily discovered and richest ore bodies have probably been mined. Future production can be expected from the extension of present ore bodies in depth, new ore shoots in known veins, and ore shoots in veins yet to be discovered.

With prices at $25 to $35 per unit, annual underground production might equal that of 1937--roughly 20,000 units--for several years. The Flatiron, Papoose, Paradox, and Amity mines have the best chance for future production and will probably provide the bulk of the output. Inasmuch as these properties have not been developed in depth, it is likely that some of the ore shoots can be followed downward successfully, particularly in the Flatiron and Amity mines.

Diamond drilling is worth considering in the search for parallel ore shoots at depth, but it would require close-spaced holes because of the lenticular character of the ore bodies. In times of high prices lessees could probably produce considerable scheelite at Atolia by surface prospect trenches cut by bulldozers where bedrock conditions permit.

Reserves in the placer deposits are discussed in the section on placers.

6/ Hulin, C. D., op. cit., p. 127, 1925.

PLACER DEPOSITS

Distribution

The alluvium that blankets the Atolia district contains a large quantity of scheelite--a fact that is important in considering the tungsten reserves of the area. Although the scheelite content of the alluvium is very uneven and over much of the district is too small for profitable extraction at any probable peacetime prices, the presence of placer gold in relatively large quantities may make it possible to extract tungsten as a byproduct. The placers in the western part of the field were worked in the past primarily for gold; whereas those in the eastern half were worked for tungsten and the gold was not saved.

The thickness of the alluvium has been measured in many shafts and pits, especially in those of the Atolia Rand Placers, Inc. Few measurements unfortunately are available in the Spud Patch, where most of the placer mining has been done, for no logs were kept there and the bedrock is now covered in most of the openings. However, enough measurements are available throughout the district to serve as the basis of a contour map of the bedrock surface (pl. 35); and from this map some of the factors that have controlled the deposition of the placers can be determined.

The bedrock surface has a greater relief than the present surface and is furrowed by many sharply incised stream channels. The incisions of these streams were undoubtedly caused by temporary and probably short-lived rejuvenation, which could have been caused by one or more of several factors, among which are movement along the northeast-striking fault mentioned on page 216, a change in the drainage from the main Mojave Basin to the nearer Cuddeback Lake Basin, and possible climatic changes.

There are two distinct placer areas in the district: the Spud Patch, extending southeast from the Papoose mine, and the western area, extending from the Stringer district southward past the Union mine. The Spud Patch is the richer in scheelite and has provided most of the past placer output of that mineral. The alluvium of both belts contains gold.

The Spud Patch channels trend east and formerly headed farther west than they do now. They show a marked steepening at the west edge of the Spud Patch. This steepening, coupled with other evidence, suggests a buried fault, the movement along which disturbed the drainage and caused thick accumulation in the Spud Patch.

The Spud Patch was worked intensively by lessees during the last war and has been worked intermittently since then by drift mines through shafts that reach productive beds at depths ranging from 5 to 60 feet. Hess 7/ wrote 25 years ago--

> In general, the gravel is sufficiently cemented by carbonate of lime (caliche) to allow drifting without timbering, though some thin beds are loose. Miners estimated that at $20 a unit a bed 3 feet thick and 55 feet below the surface would yield wages--that is, about $4 to $4.50 a day--if it produced 15 pounds of concentrate carrying 63 percent of WO_3 per cubic yard.

Not more than 20 percent of the shafts are shown on the map (pl. 35). Inasmuch as the deeper shafts are now caved or filled with water, it was impossible to obtain much first-hand information as to bedrock conditions in this area. The scheelite occurs at several horizons and is most highly concentrated along the east-trending channels. At no place has scheelite been found within or below the Miocene sedimentary rocks, which underlie much of the alluvium of the Spud Patch.

In 1926 the Atolia Mining Co. constructed a placer plant in the Spud Patch to wash alluvium stripped from part of the area between the Papoose mine and the present dump of placer tail-

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7/ Hess, F. L., Mineral Resources U. S., 1916, part 1, p. 791.

ings. Operations were restricted to areas where the alluvium was less than 25 feet deep, so that it did not include the deeper channels. Recovery in the plant averaged roughly 1.5 pounds of scheelite per cubic yard; no attempt was made to save the gold. The alluvium beneath the old Papoose mill tailings was left, but it may be worked when the tailings are removed.

Information on gold content in the main Spud Patch is lacking, but an area sampled by M. S. Draper on the Wedge, Trade Dollar Extension, Wonder, and Old Glory claims, on the south edge of the Spud Patch, is reported to have indicated 2,069,400 cubic yards with an average gold content of $0.71 per yard. Part of this area was successfully worked for scheelite during the last war.

In the western placer area, between coordinates 3,000 W. and 7,000 W., gold and scheelite are concentrated in relatively deep and narrow channels, some of which are so narrow that their exploitation by large machines is difficult.

A broad deep channel near the western border of the area mapped was probably excavated by a stream heading about 3 miles north, in the Stringer district, where veins carrying both gold and scheelite have been worked. This channel is completely filled with alluvial material or "wash", and there is no available information on its gold or tungsten content.

In the placer area near the Union mine the scheelite content is less, and no very rich streaks like those in the Spud Patch are known. Accurate figures on results of sampling by Atolia Rand Placers, Inc., were not available to the writers. The sampling and subsequent operations demonstrated, however, that the narrow subsurface channels discovered in the drilling campaign contained much higher concentrations of gold and scheelite than the interstream areas. Reported recoveries [8]

8/ Salt Lake Mining Review, p. 11, Sept. 4, 1934.

per yard in the pilot mill were: gold, $0.73; scheelite, $0.60, or about 1 pound at the reported price of $12.50 per unit. About $0.59 was left in the tailings. The large plant made much poorer recovery, and the prominent piles of tailings from the placer operations south of the Union mine may be reworked in the future.

The writers have little specific information as to the physical nature of the gold and scheelite in the placer deposits. Recovery of gold from placer operations in the western area has been far below the values determined by fire assay, and this low recovery is probably due to the finely divided state of the material. Most of the scheelite, on the contrary, is rather coarse, especially in the Spud Patch, where single pieces, called "spuds" by the miners, weighing as much as 115 pounds have been found. The only available size analysis of scheelite was made by the Pacific Placers Engineering Co. on samples cut from test holes between the Union mine and the Stringer district. Screen tests of concentrates from 13 samples showed that an average of 74 percent of the scheelite was larger than 35 mesh.

The scarcity and high cost of water have hampered placer operations, especially the recovery of fine gold. Dry placer methods for recovering the gold have been tried for many years, but on the whole results have been discouraging. Water was shipped into the district by railroad for many years, until the Atolia Mining Co. sank wells near Cuddeback Lake and began pumping water for mill use. The distance pumped is about 7 miles and the vertical lift about 650 feet.

Reserves

Past operations and sampling programs show that the district contains large quantities of alluvium carrying 1 pound to 1.5 pounds of scheelite per cubic yard and that all the placer

area will probably average more than one-fourth pound of scheelite. A rough estimate of the total placer material present in the area mapped, excluding the westernmost deep channel through the Sun shaft, indicates about 28,000,000 cubic yards, of which 11,000,000 is in the Spud Patch. The conservative estimate of one-fourth pound of scheelite per yard implies that the total of placer scheelite in the district amounts to 280,000 units.

These figures do not take into account the placers northwest and southeast of the area mapped, which might materially increase the total. It is said that the lowest gold value found in prospecting between the Stringer district and Cuddeback Lake is $0.35 per yard and that some scheelite occurs with the gold almost everywhere in the intervening area.

It is evident that at present prices the placer material of the district is unworkable for scheelite alone but inasmuch as gold is commonly present in promising quantity much of the scheelite may be profitably recovered as a byproduct when the problem of saving the very fine gold with little water is solved.

MINES

In the following mine descriptions properties are grouped according to ownership. Although most of the productive mines are controlled by the Atolia Mining Co., surrounding claims are held singly or in groups by other companies and individuals. Among the larger groups of adjoining claims are those of the Atolia Rand Placers, Inc., Osdick, Federal mine, American Gold & Tungsten Corporation, Blackhawk Mining Co., and St. Elmo groups (see pl. 37).

The amount of development in each of the mines about which the writers have information is shown in the table on pages 230 and 231. There is about 10 miles of drifts and crosscuts and 2⅛ miles of shafts and raises in the district. Approximately 18 percent of the level workings is crosscuts.

Mine workings, in feet, in the Atolia district

MINE	Level workings				Shafts			Total workings
	Drifts	Crosscuts		Total	Total	No.	Maximum depth	
		Total	No.					
Atolia Mining Co.								
Acaley	405	269	8	674	191	2	137	865
Amity	1,675	228	10	1,903	908	7	410	2,811
Attila	100	.....	.....	100	50	1	44	150
Elder lease	352	155	2	507	177	1	136	684
Flatiron	3,968	1,238	33	5,206	834	6	262	6,040
Goldstone	1/ 623	.....	.....	1/ 623	160	1	.....	1/ 783
Little Papoose	407	102	2	509	130	1	127	639
Mahood	386	25	2	411	120	1	100	531
Moonstone No. 1	110	.....	.....	110	93	1	81	203
Moonstone No. 2	125	.....	.....	125	77	1	66	202
Neglected Fraction	149	.....	.....	149	164	2	75	313
Papoose	2,791	1,195	(21)	3,986	632	3	361	4,618
Papoose No. 5	517	235	(6)	752	130	1	124	882
Papoose (east edge of mill)	110	.....	.....	110	70	1	57	180
Par and Spanish	3,101	285	(22)	3,386	477	3	210	3,863
Paradox No. 1	572	.....	.....	572	330	2	167	902
Paradox No. 3	1,291	480	(14)	1,771	384	4	167	2,155
Paradox (miscellaneous)	208	287	(5)	495	398	4	113	893
Piute No. 1	247	20	(1)	267	167	1	163	434
Rainstorm	604	.....	.....	604	244	2	141	848
Star No. 1	293	.....	.....	293	138	1	88	431
Star No. 2	240	.....	.....	240	131	2	78	371
Union	20,289	2,951	(86)	23,240	3,037	7	1,021	26,277
Viewpoint	330	20	1	350	127	1	116	477

Osdick group								
Big Ben	141	133	(6)	274	190	1	185	464
Skylark	640	95	(1)	735	174	1	167	909
Federal group								
Federal	427	45	(1)	472	287	2	169	759
Monitor	204	.....	.....	204	188	1	180	392
Ready Cash	.....	.....	.....	.....	80	1	79	80
West of Paradox No. 1	10	.....	.....	10	95	1	90	105
Miscellaneous								
I Guess	40	.....	.....	40	77	1	75	117
Manxman	205	60	(3)	265	191	2	97	456
O'Neill	.....	327	(1)	327	155	2	85	482
Redondo Pete	1/ 300	1/500	(1)	1/ 800	1/ 500	1	1/500	1/1,300
Sun	137	406	(2)	543	176	1	176	719
Top Notch	110	40	(1)	150	269	1	165	419
Total	41,107	9,096	(241)	50,203	11,551	71	1,021	61,754

1/ Estimated.

Atolia Mining Co.

The Atolia Mining Co. owns 55 patented claims and 1 unpatented claim (the Cora Dee). From these claims 95 percent of the scheelite produced in the district has been mined. The Union mine has been most productive, followed in order by the Papoose, Amity, Par and Spanish, and Flatiron mines.

Union mine.--The Union mine, which has been the chief producer in the district, was worked to a vertical depth of 1,021 feet. The mine is developed through one main inclined shaft (see fig. 37). This shaft branches between the ninth and tenth levels, the steeper branch extending to the bottom of the mine on the fourteenth level and the flatter branch extending to the eleventh level. Of the six shafts that have been sunk only the No. 1 main shaft and the Old No. 1 shaft (now abandoned) extend below the fourth level. The main shaft has recently been retimbered, and the main haulageways have been kept open, but parts of the older workings of the mine are inaccessible. In February 1940 water stood between the eleventh and twelfth levels at an altitude of 2,585 feet, 753 feet below the collar of the shaft. The volume of water was not large enough to constitute a serious mining problem in the bottom levels.

The ore produced at the Union mine has come from two veins--the North vein, which carried scheelite at the surface, and the South vein, which was barren at the surface but very productive below the fourth level. The two veins intersect in the eastern part of the property and converge downward. The maximum horizontal separation between ore shoots in the western part of the

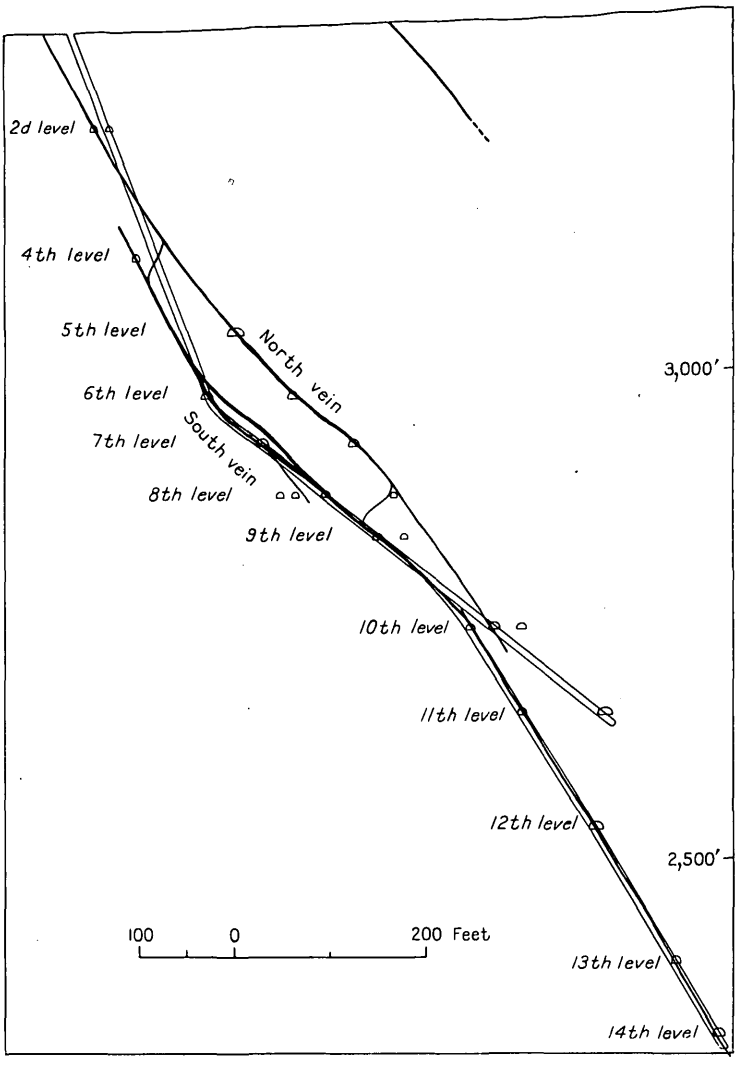

Figure 37.--Section through the Union No. 1 shaft.

mine is about 180 feet on the fourth level and 50 feet on the tenth level. The width of the ore has ranged from 1 inch to as much as 17 feet. Lenses of nearly pure scheelite 5 to 10 feet thick have been mined from parts of the South vein, which has produced nearly as much ore as all the rest of the district combined.

In the western part of the mine the ore has been cut by two diabase dikes. One of these is very persistent, the other erratic. The persistent dike strikes N. 20° W., dips 79° NE., and ranges in thickness from 2 to 6 feet on different levels. The other dike is mostly 1 or 2 feet thick; it has been found only on the seventh, eighth, and ninth levels. Post-mineral movement along the vein fractures has offset the dikes, the north side moving westward as much as 15 feet.

The two ore shoots in the mine are controlled by cross fractures, two of which have considerable importance. The persistent diabase dike occupies the more westerly of these, but no igneous rock has been injected into the other.

Most of the ore mined has been found between these two fractures, which were active during mineralization as well as later. Presumably they served to relieve stress along the vein in the intermediate area, thus allowing deposition of scheelite from the ore-forming solutions.

The ore shoot in the South vein on the lower four levels of the mine is limited to the west by the persistent diabase dike and to the east by the cross fault (pl. 36). The fourteenth level was never driven westward to the dike. On the tenth level are indications of ore west of the dike, and ore was stoped 190 feet west from a sublevel reached through a winze. No ore has been mined east of the main eastern cross fracture.

In general both ore shoots are roughly V-shaped down the dip. The richest portions of both veins (seventh and eighth levels) occur where the veins dip as low as 40° N. This flattening has probably influenced the deposition of the largest scheelite bodies.

On the seventh level the North and South ore bodies are connected by a vein containing about 1 inch of scheelite ore, but as yet, despite considerable prospecting, no ore shoot has been found in this vein.

There are numerous short crosscuts in the mine, but no long crosscut has been driven in search of ore shoots in parallel structures. Some horizontal diamond-drill holes, probably none more than 200 feet in length, were drilled several years ago from various places in the mine. No positive results were obtained, and no record was found of the number of holes, footage, location, or results.

Scheelite occurs near the surface in several veins north of the Union No. 1 shaft, notably in the veins 325 feet north, 850 feet north (Star No. 1 mine), and 1,640 feet north (Top Notch claim). Part of this north zone could be prospected to good advantage by diamond-drill holes from the lower levels of the Union mine, and the area to the south might also be worth investigating. Surface indications of exposed veins are not promising, but the fact that the South vein ore body did not crop out should be remembered in searching for new ore shoots. Positions of known ore shoots should be taken into account in any prospecting program, for ore shoots in parallel veins are likely to be controlled by the same cross fractures.

Amity mine.--Ore stoped above the third level (130 feet deep) has made the Amity mine the third most productive in the district. Six short veins, including two north-trending ones, have been worked from the surface to the first level, but only

one of these veins has been developed on the second and third levels. Much of the mine is now inaccessible, for debris carried by a cloudburst filled the old main shaft several years ago. Since then the third level has been connected with the seventh level of the Union mine through a raise, the fourth level has been started east from the raise, and a new shaft has been started from the surface. It is hoped that productive ore shoots will be found below the third level, for two small quartz-scheelite veins have been discovered on the fourth level and small veins were followed up the Amity raise from the Union mine.

Ore produced from the Amity mine has been very rich, averaging 11.62 percent of WO_3. Ore in some places was several feet thick, for the open stopes on the first level are large.

Acaley mine.--In the Acaley mine the main vein is successively offset northward by gently dipping faults (see fig. 38) along which movement is essentially pre-mineral, for between the offset portions of the main vein these faults contain small veins of slightly crushed quartz and scheelite, not over 1 inch thick. Most of the ore has come from above the first level; no ore has been stoped beneath the second level, where much of the development has been along barren fissures. The shaft is now filled below the second level, but available surveys show that at least 50 feet of crosscutting northwestward would be needed on the third level to intersect projected extensions of the upper ore shoot.

Rainstorm mine.--The Rainstorm mine, developed on three levels, now has no exposed ore. The productive vein, which strikes N. 78° E. and dips 60°-70° N., is cut by two faults 75 feet apart. The western one, intersected in the shaft on the second level, strikes N. 60° E., dips 70°-90° SE., and has an apparent horizontal displacement of about 25 feet, the southeast side having moved northeastward. The other, which has a

similar attitude and an unknown but probably small displacement, marks the eastern limit of ore found to date. The vein has been stoped to a depth of at least 165 feet, below which the shaft is filled. No gently dipping faults similar to those in the Acaley mine, to the south, have been found.

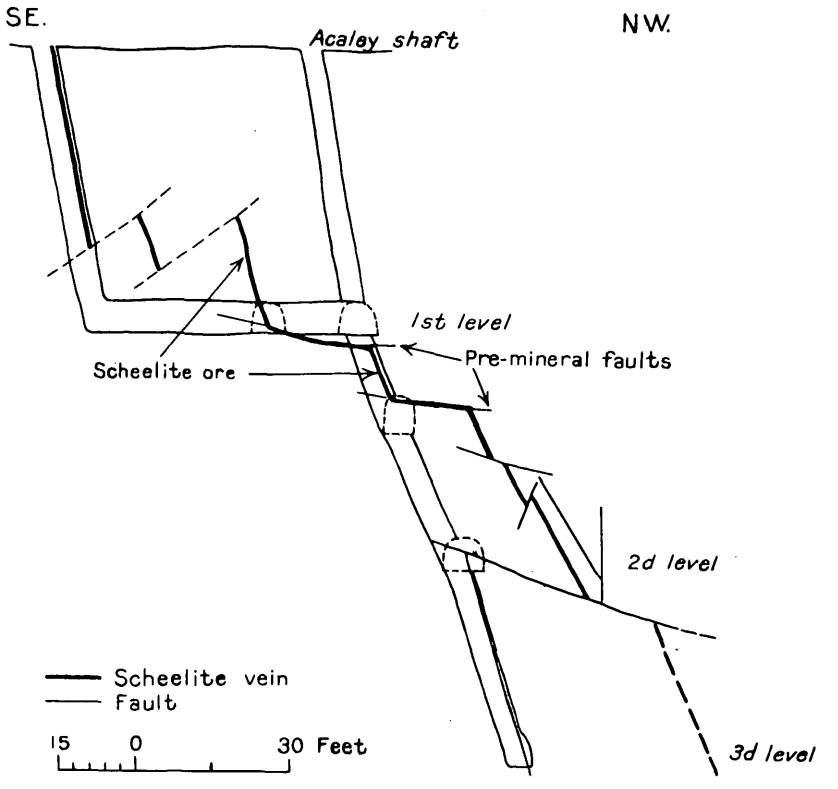

Figure 38.--Section through the Acaley mine.

Goldstone mine.--The Goldstone mine was inaccessible in 1940 and no maps of it exist. Although most of the development was prior to 1914, some additional work was done by lessees in 1937.

Papoose mine.--The Papoose mine, the scene of the first discovery in the district, was for the years 1908 to 1911 the leading scheelite mine in the world. High-grade ore cropped out at the surface and was continuous to the fourth level, a depth of 190 feet, where it was cut off by a gently dipping fault. In search of an extension to the ore body the shaft was continued to the sixth level and a winze was sunk below that. Crosscuts aggregating 567 feet in length were driven on the fifth level, but no ore was found in any of these lower workings. Except for the reopening of the second level in 1937 under a lease, the mine has not been operated for many years. At present the main shaft is open to the fourth level but is filled below. The third and fourth levels are caved at the shaft, but the second level is open as far as the west face.

At the time of the original work no geologic maps of the mine were made, although the workings were surveyed. The inaccessibility of the lower levels makes solution of the fault problem difficult. The maps show most of the work to the east and south. Possibly the west and north portions of the mine should be explored below the old ore body, particularly in consideration of the type of cross faults found in the Piute No. 1 mine, to the north. The length of the ore shoot at the surface suggests that ore should continue below the fourth level.

Flatiron, Spanish, and Par mines.--The Flatiron, Spanish, and Par mines, originally developed separately, were abandoned as exhausted in 1915. They were reopened under a lease in 1934 and for the next 5 years were very productive. The Par and Spanish mines, now joined and operated as a unit through the Par shaft, are connected with the Flatiron mine by raises, for drifts in the two mines do not lie at the same altitude. New ore bodies have been located by vigorous development, which has included considerable crosscutting.

The Flatiron mine has worked both the Flatiron and Spanish vein systems, which intersect at acute angles (see pls. 35 and 36). The Par mine is confined to the Spanish vein. The Flatiron vein is barren on the third level though very productive in the upper levels. One ore shoot on the Spanish vein in the Flatiron mine was profitable nearly to the fourth level, and the lower extension of the shoot is a promising prospect for ore at greater depth.

Ore from these mines is lenticular in character but of uniformly high grade. At the east end of the Par mine the vein is faulted beyond the ore zone.

Paradox No. 1 and No. 3 mines.--The Paradox No. 1 and No. 3 mines adjoin but are not connected. They have been developed since 1936. In the Paradox No. 1 mine a single ore shoot in a north-dipping vein has been worked. The ore was of high grade and 2 feet thick in the widest part but was much leaner on the bottom level than on the upper two levels. Other small ore bodies may be found by intelligent prospecting, for there has been little development in the mine except in the one ore shoot worked.

The Paradox No. 3 mine is structurally the most complex in the district. The main vein dips 57° SW. from the surface to a point below the first level, where it is intersected by an irregular, gently dipping fault, and the veins found on the second level at a depth of 117 feet are apparently unrelated to the main vein. Above the gently dipping fault the thick high-grade ore body was broken by numerous small faults (fig. 39). The veins found below the fault are not broken but contain very little ore.

Osdick group

The Osdick group, owned by P. J. Osdick, consists of seven unpatented lode claims on the east boundary of the Atolia Mining Co.'s property. Alluvium 20 to 60 feet deep covers the surface. Two veins discovered in placer operations were prospected through several shafts, the most important of which are the

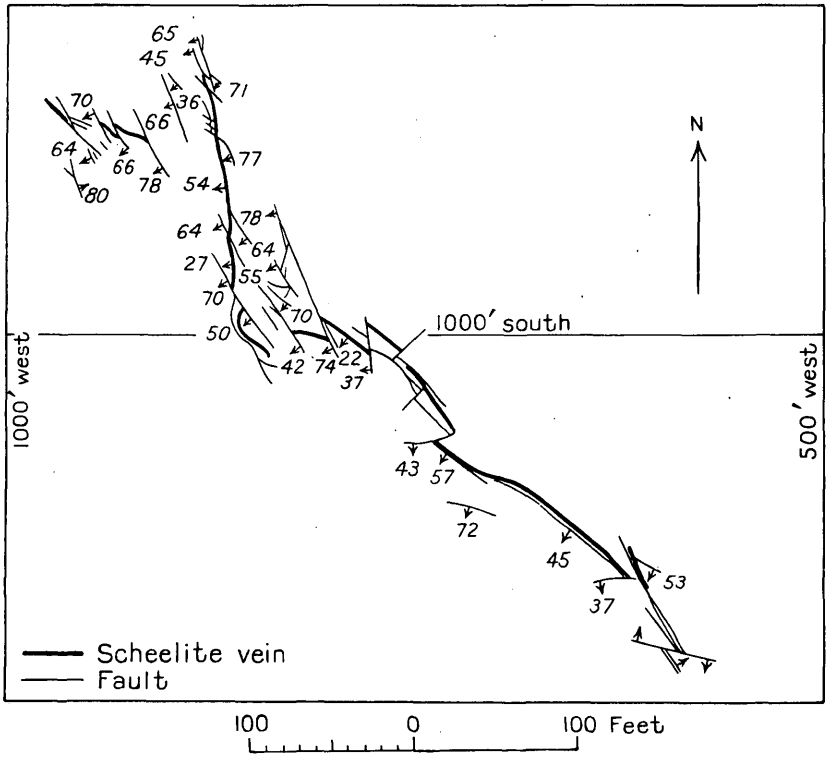

Figure 39.--Veins and faults on the first level of the Paradox No. 3 mine.

Skylark, which is 167 feet deep, and Big Ben, which is 185 feet deep. The number of units of WO_3 produced is unknown, although Mr. Osdick reports a monetary return of nearly $250,000 from the Skylark mine and the rich placer deposits near the Skylark shaft, mostly during the wartime boom of 1916-18.

Skylark mine.--The Skylark mine explores a vein belonging to the Flatiron system and has produced considerable scheelite from a depth of less than 150 feet. The alluvium on bedrock near the vein was very rich, especially near the Skylark shaft, which enters bedrock at a depth of 27 feet. Little ore remains in sight in the mine, and the remnants are of low grade. Only annual assessment work has been done in recent years.

Big Ben shaft.--The Big Ben shaft, from which there has been no production, followed a narrow vein containing not more than 4 inches of quartz and scheelite to the first level. No ore was found on the lower levels, although there are a few traces of scheelite. This vein is an eastern continuation of the Spanish vein, in which profitable ore shoots have been mined in the Flatiron, Spanish, and Par mines.

Federal mine group

The Federal mine group, owned by J. C. Raynor, N. H. Meyers and G. T. Ingram, includes 14 unpatented lode claims south of the Atolia Mining Co.'s property. The most extensive underground workings are in the Federal mine. There are several other shafts, in some of which scheelite has been found, notably the Wedge Fraction, Monitor, and Ready Cash. None of the veins has made large production, and several small ore shoots are cut off by faults at shallow depths.

The Federal mine is developed by two unconnected shafts 83 feet apart and by several hundred feet of drifts from the west shaft. In both shafts small ore bodies seen near the surface were found to be faulted off about 40 feet below. The main shaft has been sunk 242 feet on the incline--170 feet vertical depth--and drifts have been run on two levels. The shaft and workings deeper than 40 feet follow barren fissures that carry considerable carbonate but no scheelite. The extension of the

near-surface ore body might be found by crosscutting south, preferably on the first level, where such a crosscut was once started. It is not likely that scheelite ore bodies will be found by drifting or sinking on the fault, for no dragged scheelite has been found below the point where the vein was lost.

Atolia Rand Placers, Inc.

Redondo Pete shaft.--Atolia Rand Placers, Inc., subsidiary of the Molybdenum Corporation of America, although controlling a large placer acreage, has only one developed and patented lode claim--the Redondo Pete claim. In 1917 the Blackhawk Mining Co. leased this claim from the former owners and sank a vertical shaft. This shaft, abandoned in 1919, is now inaccessible. The following information is derived from various sources considered reliable.

The single-compartment vertical shaft was sunk to a depth of 500 feet, and levels were run at depths of 300 and 500 feet. On the 300-foot level a drift was run several hundred feet west on a fracture intersected in the shaft, but no ore was found. On the 500-foot level a crosscut was driven 500 feet south and two veins carrying scheelite were intersected about 300 and 400 feet from the shaft. The operators ran raises in the south vein and stoped a little ore, which produced about 5 tons of 60-percent WO_3 concentrate. The property was abandoned in 1918, when the price of tungsten fell. The War Minerals Relief Commission eventually paid a large claim for the development work.

Blackhawk Mining Co.

The Blackhawk Mining Co. owns a tier of eight patented lode claims south of the Redondo Pete shaft. Several shallow shafts have been sunk on the northern two claims, Long's Folly and Long's Folly Extension, which lie in the belt of scheelite veins, but no important ore bodies were found. The remaining claims lie south of known scheelite veins but are of value for the blanket of alluvium, which contains placer gold and scheelite. None of the underground workings were accessible in 1940.

St. Elmo mine group

The St. Elmo mine group, consisting of six patented claims, contains no known scheelite veins. The St. Elmo mine, discovered in 1895, reputedly produced nearly $250,000 in gold from pockets close to the surface. The mine was abandoned for many years, but late in 1939 and early in 1940 a lessee was prospecting for new ore bodies. The workings consist of several shafts, the main vertical one being 300 feet deep, and of several thousand feet of drifts and crosscuts. At least two quartz veins were worked. The one at the main shaft strikes N. 10° E. and dips nearly vertically. The other, 150 feet to the east, strikes N. 45° E. and dips southeast. The ore body was apparently narrow but of high grade. Specimens from the dump show white quartz with free gold and limonite, which suggests that much of the gold occurred in pyrite before oxidation.

One of the St. Elmo veins can be traced half a mile northeast, but no other ore shoots have been found.

American Gold & Tungsten Corporation

Top Notch claim.--The American Gold & Tungsten Corporation owns four unpatented lode claims north of the Union mine. The only known scheelite veins occur on the Top Notch claim. Although the Top Notch shaft, which constitutes the main underground development, is reported to have produced a little scheelite near the surface, the lower workings are barren. The shaft, 165 feet deep and inclined 38° N., follows a vein which contains considerable altered material, mainly carbonate, and adjoining which the quartz monzonite has been pyritized and sericitized. A vein that lies 150 feet north of the Top Notch shaft contained more scheelite but has been developed only by a shallow inclined shaft.

Several shallow prospect shafts to the east have been sunk in search of gold ore in a vein which strikes N. 32° W., dips 40°-60° NE., and appears to be continuous southeastward past the Redondo Pete shaft toward St. Elmo. This vein may offset the scheelite veins east of the Amity mine.

Miscellaneous prospects

Sun and O'Neill shafts.--In 1916 the Tungsten Development Co., now dissolved, attempted to find westerly extensions of the tungsten belt. Several vertical shafts were sunk through the thick alluvium,which was 127 feet thick in the Sun shaft, into the quartz monzonite, and considerable crosscutting was done. In the Sun and O'Neill shafts, the only ones examined for this report, several strongly kaolinized east-west fissures are intersected by the workings, but no scheelite is visible.

None of the other shafts sunk to intersect extensions of veins in the Union mine have found scheelite. The westernmost known occurrence in this zone is in the Star No. 2 shaft of the Atolia Mining Co.

I Guess shaft.--The I Guess inclined shaft, which is 75 feet deep and without lateral workings, prospects a north-dipping vein consisting mainly of fine-grained brown quartz but containing some carbonate and scheelite. Although no ore is exposed in the shaft the vein is of interest because it is the farthest south of those known to contain scheelite.

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