TUNGSTEN DEPOSITS OF THE MILL CITY DISTRICT,

EUGENE MOUNTAINS, PERSHING COUNTY, NEVADA

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ILLUSTRATIONS

Tungsten Deposits of the Mill City District, Eugene Mountains, Pershing County, Nevada

ABSTRACT

The Mill City district is situated on the east flank of the Eugene Mountains, 8 miles west of Mill City, Pershing County, Nevada. For 25 years this district has been one of the leading domestic producers of tungsten concentrate. About 1,150,000 tons of scheelite ore have been mined and 800,000 units of tungsten trioxide recovered.

The Eugene Mountains are underlain by Triassic shale and limestone, which have been intruded by small bodies of granodiorite and hornblende andesite. In the tungsten district the sedimentary rocks have been metamorphosed to hornfels, slate, marble, and tactite. The tabular scheelite ore bodies are confined to limestone beds that have been metamorphosed to tactite. The metamorphism and deposition of scheelite are believed to be due to solutions that migrated from the cooling granodiorite magma.

All commercial scheelite deposits are owned by the Nevada Massachusetts Company, Inc., and all mining and milling operations in the district are conducted by this company. The geology of each mine and undeveloped deposit is described in the report. A plan that may make possible a continued substantial production of tungsten concentrate during the present emergency is suggested.

INTRODUCTION

Location

The Mill City tungsten district is situated on the east flank of the Eugene Mountains, in northern Pershing County, Nevada. Eight miles of surfaced road connect Tungsten, the Nevada Massachusetts Company camp and mill site, with U. S. highway 40 at Mill City. Graded dirt roads lead to the mines. Mill City is a station on the Southern Pacific Railroad.

Water for domestic and industrial use is piped from wells, 4 miles east of Tungsten.

History of Mining

Emil Stank discovered tungsten in Springer Gulch, near the center of the district, in 1917. Development of the district was rapid; within a year three companies, the Humboldt Corporation, the Pacific Tungsten Company, and the Mill City Tungsten Mining Company, were mining ore, and two mills had been erected.

Following the armistice in 1918, the price of tungsten collapsed, and the district was inactive from then until 1924, when G. W. Poole leased the Pacific Tungsten Company property. The Nevada Massachusetts Company purchased the holdings of the Pacific Tungsten Company and the Mill City Tungsten Mining Company in 1925, and those of the Humboldt Corporation in 1928. The original Pacific mill was enlarged to treat 260 tons of ore daily, and since then has operated continuously, except for four months during 1933, when the price of tungsten declined again. A 1,000-ton tailing treatment plant was completed in 1941, and between 800 and 900 tons of current and accumulated tailings have been milled daily during the past 20 months.

Production

Production from the district during the period 1917-1942 has amounted to about 1,150,000 tons of ore containing nearly 800,000 units of WO_3.

Previous work

The Mill City tungsten district was mapped by the Stanford Geological Survey under the direction of P. F. Kerr in 1932. Kerr continued his investigation of the district, subsequently submitting a number of reports and recommendations to the Nevada Massachusetts Company, and publishing a description of the geology of the deposits. Ward Smith and J. F. McAllister surveyed the Eugene Mountains area in 1940-41, mapping part of the tungsten district in detail. The U. S. Bureau of Mines explored some of the least developed areas by drilling and sampling in 1941.

The writer had access to recommendations by Ward Smith and Paul F. Kerr based on results of exploration in the Mill City tungsten district and to the following published reports:

Hess, F. L., and Larsen, E. S., 1921, Contact metamorphic tungsten deposits: U. S. Geol. Survey Bull. 725-D, p. 245-309.

Heizer, Ott F., 1930, Methods and costs of concentrating tungsten ore at the Nevada-Massachusetts mill, Mill City, Nev.: U. S. Bur. Mines I. C. 6280, 13 p.

_____1930, Method and cost of mining tungsten ore at the Nevada-Massachusetts Co. Mines at Mill City, Nev.: U. S. Bur. Mines I. C. 6284, 13 p.

Kerr, Paul F., 1934, Geology of the tungsten deposits near Mill City, Nev.: Univ. of Nev. Bull. 28, no. 2, 46 p.

Vanderburg, W. O., 1936, Reconnaissance of mining districts in Pershing County, Nev.: U. S. Bur. Mines I C. 6902, 57 p.

Present Investigation

The writer and C. W. Chesterman were engaged in field work in the Mill City district from December 15, 1942 to June 4, 1943. Peter Joralemon assisted from February 5 to June 4. Geologic maps on a scale of 40 feet to the inch were made of all accessible underground workings. Transit surveys by Nevada Massachusetts Company engineers were used as a base for part of this work. The work of Smith and McAllister was expanded by making plane table topographic and geologic maps on a scale of 100 feet to the inch of areas in which tungsten deposits of possible commercial worth occur. A triangulation net established by the Stanford Geological Survey was used as a base.

A geologic map of the district, scale 400 feet to the inch, prepared for the Nevada Massachusetts Company by Paul F. Kerr, accompanies this report. It shows in some detail the geology adjacent to the area mapped by the Geological Survey. Data from maps by Smith and McAllister, Granger, the U. S. Bureau of Mines, and the Nevada Massachusetts Company have been incorporated in some of the illustrations accompanying this report. Some of the writer's ideas are in agreement with those previously advanced by Kerr, Smith, and Granger, but time does not permit specific acknowledgments.

Acknowledgments

The writer gratefully acknowledges the cordial cooperation of the officials and staff of the Nevada Massachusetts Company. Maps, reports, records, and office facilities were always available. Stimulating discussions of geological and mining problems were very helpful. Especial thanks are due to C. H. Segerstrom, President, C. H. Segerstrom, Jr.,

Ott F. Heizer, General Manager, . G. Emminger, Superintendent, and Elton Clark, Geologist.

GEOLOGY

The Mill City district occupies low hills, partly covered by alluvium, on the eastern flank of the Eugene Mountains. This range is underlain by Triassic sedimentary rocks into which small bodies of igneous rock have been intruded. The tungsten district consists of rounded hills separated by rather steep canyons. The more prominent hills are underlain by the most intensely metamorphosed, and therefore most resistant, rocks; most canyons and low hills, by intrusive rocks or slightly metamorphosed shales. Maximum relief is 1,200 feet. Exposures of bedrock are almost entirely confined to ridge crests and canyon bottoms.

Rocks

Triassic sedimentary and metamorphic rocks.—An unmeasured thickness of shale, with intercalated limestone and sandstone beds, underlies the tungsten district. The Upper Triassic fossil *Monotis subcircularis* has been found in a narrow stratigraphic zone that extends through the eastern part of the district.

Throughout the district most of the shale has been metamorphosed to hornfels or slate. Compact, blocky, soft brown hornfels predominates, but near scheelite ore bodies, hard, banded, chertlike gray and green hornfels is common. Crudely cleavable metamorphosed shale, rather common in the district, is referred to as slate. The microtexture of both varieties of hornfels is similar. In the soft brown hornfels quartz, biotite, and hornblende predominate; in the hard gray and green hornfels quartz, actinolite, tremolite, and in places epidote and pyroxene, are most abundant. These differences may in part reflect original differences in the sedimentary rocks, but they are also believed to indicate a greater intensity of contact metamorphism. The shale is commonly greenish gray or purple, and fissile.

The distribution of hard and soft hornfels and shale has no direct relationship to bedding, nor is it zonal around intrusive bodies. Contacts are gradational, and cannot be mapped accurately. It seems probable that the hard hornfels was formed in fractured or permeable zones, where the metamorphosing solutions migrated most freely.

Limestone beds, from 1 foot to 30 feet thick, are irregularly interlayered with the shale. In some places the limestone beds have been metamorphosed to marble; where metamorphism has been more intense, to tactite, a medium to coarsely crystalline rock composed of garnet, epidote, and uartz, with small amounts of calcite, scheelite, and pyrite. Tactite zones in a limestone bed are most likely to be found where metamorphism of the adjacent shale has been intense.

Lenticular layers of pale green and gray silicate rock, which sometimes contain garnet, epidote, and a little scheelite, occur throughout the district. These rocks have probably been formed by metamorphism of calcareous shale or sandstone. Dense gray quartzitic beds are common in the metamorphic sequence.

Post-Triassic granodiorite and related igneous rocks.--In the tungsten district the meta-sediments have been intruded by two small stocks of granodiorite, and numerous dikes of granodiorite, quartz diorite, and aplite (pl. 1). The Olsen stock is about a mile in diameter. It bounds the area of known commercial tungsten deposits on the north. South of the Olsen stock is the smaller Springer stock, about 1,200 feet in diameter. Commercial tungsten deposits occur in altered limestone beds between the two stocks, and within a radius of 2,000 feet of them to the west, southwest, and east. The surface trace of each stock is irregular. The main intrusive contacts dip irregularly, but rather steeply, outward, where they have been exposed in underground workings.

Smaller, irregular-shaped masses of granodiorite, quartz diorite, and aplite are common throughout the district.

The typical granodiorite is a medium-grained phanerite. Constituent minerals identified in thin section are listed in order of decreasing abundance: oligoclase-andesine, quartz and orthoclase, biotite, hornblende, apatite, epidote, sphene, pyrite, and zircon.

The dikes are of more variable composition and texture. The majority are equigranular; a few are porphyritic. Many contain only a small amount of dark minerals; some consist almost entirely of quartz and albite.

Hornblende andesite.--The youngest rock in the district is intrusive hornblende andesite. Small dikes of this rock cut indiscriminately across all older rocks. The andesite is almost always porphyritic, containing phenocrysts of hornblende and plagioclase in a groundmass of the same minerals.

Fanglomerate and alluvium.--Fanglomerate overlaps the pediment along the eastern margin of the district. Sand and gravel have been deposited near the mouths of the canyons. Most slopes are covered by mantle from 1 foot to 10 feet thick.

Structure

The general strike of the Triassic rocks is N. 10°-30° E. In most of the district the rocks dip steeply to the west; in the southwestern part they dip steeply east. No adequate explanation for this structural feature, which may eliminate the Stank bed south of the present workings, has yet been advanced. Kerr considers it to be a post-granodiorite reverse fault (Stank fault). The fault does brecciate granodiorite on the northeast slope of Stank Hill, but near the Codd adit a granodiorite mass crosses the inferred position of the fault zone withour important dislocation. Nevertheless, dissimilarity of the strata of opposed dip suggests that a fault of major displacement lies between them (Pl. 1).

Smith's regional map shows that the area of westward dip in this part of the range is limited to the tungsten district. West of the district the dip is to the east. North of it west-dipping beds steepen and finally assume an east dip at the front of the range. South of it an east dip prevails from near the crest to the front of the range. Furthermore, in the southern part of the tungsten district, particularly in the south end of the Stank mine, the dip is nearly vertical.

The writer believes that this evidence indicates that the Stank fault is a pre-granodiorite thrust of considerable displacement. Greater movement (or resistance of movement) in the northern part of the district may have bent the rocks underlying the fault to a west-dipping attitude. Smith has mapped a transverse fault west of, and near the southern limit of westward dip. This may be a tear fault marking the southern limit of important movement along a thrust surface.

Tungsten ore bodies occur on both sides of the Stank fault zone, within a radius of 2,000 feet of the two stocks, both of which lie east of the fault. This fact also suggests that the major displacement was pre-granodiorite, and that post-granodiorite movement along the zone has been local, and of relatively small displacement.

Less prominent faults of at least three periods are common in the tungsten district. Displacements that cannot be traced from one level of a mine to the next, or from one stratigraphic horizon to another, are believed to result from slumping or slipping of one or more beds, or parts of beds, before they had been completely lithified, and probably before overlying strata had been deposited. These displacements result in echelon segments of beds with gradually tapering, wedgelike terminations that have later been metamorphosed and mineralized. Generally, hard, banded hornfels lies between segments of ore beds, but sometimes the intervening hornfels is soft. Several displacements of this type affect the Springer bed.

Post-consolidation pre-granodiorite faults cut the Humboldt, Stank, Springer, Summit, and Sutton beds. The termination of an ore bed against these faults is similar to the termination against pre-consolidation faults. The only significant difference is that post-consolidation faults can be solved by ordinary methods of projection, and the position of displaced segments predicted. Ghostlike textures suggesting recrystallized fault breccia have been recognized in only two places. The most important faults of this group are low angle reverse faults with a northwest strike, and dips both to the northeast and southwest. No post-consolidation pre-granodiorite normal faults have been recognized.

Post-granodiorite faults of at least two periods are common. Displacements vary from a few feet to more than 50 feet. These have been classified as strike faults and transverse faults, according to their relationship to the trend of the sedimentary rocks. Some transverse faults displace strike faults, and some strike faults displace transverse faults. Most, if not all, post-granodiorite faults are normal.

Post-granodiorite strike faults are the most bothersome in mining, for often they cut ore beds at very acute angles to both strike and dip. Very gently raking gaps, several hundred feet long, are known, and in some cases the vertical distance between segments is more than 25 feet. A more complicated structure results when a strike fault cuts across a pre-granodiorite gap between two segments of an ore bed, thereby displacing the bed without touching it.

Offset along transverse faults is generally small, and displaced segments are easily found. The largest displacement of an ore bed by a fault of this group is 50 feet, measured in a horizontal plane.

The structural condition responsible for the southern termination of the Humboldt bed has never been satisfactorily explained. Geologic mapping of mine levels and stopes has suggested three possible explanations: (1) Displacement along two major pre-granodiorite faults, one of which must be normal, with dip and strike almost parallel to the bed; (2) lack of sedimentation; and (3) lack of sedimentation and faulting. Field evidence suggests that the Stank and Humboldt beds may be of the same age, and that during this time there was little or no limestone deposited in the Springer Hill area (Pl. II and VIII).

SCHEELITE DEPOSITS

For nearly 20 years the contact metamorphic scheelite deposits in the Mill City district were the most important domestic source of tungsten. The scheelite ore bodies occur in roughly parallel limestone beds that have been altered to tactite. The main production has come from a few beds that cross the district with a northerly trend. The productive zone is about a mile long and half a mile wide. It is bounded at the north end by the Olsen stock; the southern limit has not yet been determined. Proximity to the two stocks has probably determined the eastern and western limits. Three ore bodies, the Humboldt, the Stank, and the Springer, have produced more than 90% of the district total. A small tonnage of ore has been mined from the East and West Sutton, the Summit, and the George beds.

Mineralogy

The tungsten ores differ in composition, but all contain varying proportions of the following minerals, listed in approximate order of their abundance: quartz, garnet, epidote, calcite, pyrite, scheelite, actinolite, molybdenite, and pyrrhotite. Proportions of the different minerals in the ore differ markedly, even within a single ore shoot. Most of the ore is a medium- to coarse-grained aggregate of quartz, garnet, and epidote, with scattered crystals of scheelite. Near the hanging wall of the Humboldt ore body, the tactite is commonly fine-grained, and contains very little scheelite. Some of the best grade ore consists of scheelite crystals imbedded in glassy quartz and fine-grained epidote. Its appearance suggests the term "vitreous scheelite porphyry." In the North Sutton mine, a large part of the scheelite occurs along joint cracks or irregular fractures in the tactite.

The ore beds, before alteration, consisted predominantly of calcite. During alteration and scheelite mineralization, part of the calcite was replaced by silicate minerals, part was recrystallized, and part remained unaltered. Kerr recognizes several generations of recrystallized calcite. Most of the calcite in the ore bodies occurs as irregularly shaped unreplaced lenses of limestone or marble; some is intergrown with silicate minerals in the tactite. Younger calcite and stilbite crystals have been deposited along fracturesin the tactite and country rock.

Several types of garnet are found in the ore beds. Pale red garnet is commonly associated with wollastonite or tremolite in partly altered limestone. Scheelite is generally absent. Garnets typical of the ore bodies are cinnamon-brown and dark red-brown. These garnets are in part euhedral, and in part intergrown with quartz and epidote.

Dark green epidote crystals that vary in size from microscopic to several centimeters long are common constituents of the ore. Very small crystals are often scattered through quartz.

Scheelite occurs in poorly formed white crystals that vary from a fraction of a millimeter to a few centimeters in diameter. In most of the ore crystals average between one and two millimeters in diameter. A few yellow and honey-colored crystals have been found in the district. The fluorescent color of most of the scheelite is blue-white. Locally in the

Stank and Yellow Scheelite beds it is yellow.

Several generations of quartz occur. Some is intergrown with other silicate minerals forming the tactite. Younger veins of (1) quartz, (2) quartz and epidote, and (3) quartz, pyrite, and epidote, with sometimes a few grains of scheelite, cut both tactite and country rock.

Pyrite is a common constituent of the ore, and is widely distributed through the hornfels of the district. A little actinolite, molybdenite, and pyrrhotite occur locally in the tactite. Wollastonite and tremolite occur in slightly altered zones in the limestone; scheelite is not present in these zones.

Size and Shape

The scheelite ore bodies are tabular and dip steeply. The largest ore body, the Humboldt, has a maximum length of 1,500 feet, and has been mined to a depth of 1,400 feet. The average width of ore has been about 6 feet. The Springer ore body is oval-shaped. It averages 3 feet wide, has a maximum length of 700 feet, and has been mined to a depth of 1,000 feet. The Stank ore body is neither as compact nor as well outlined. It has an average width of 4 feet. Within the ore body there are sizable blocks of unreplaced limestone and marble. It has been mined to a depth of 1,100 feet. The greatest length of ore exposed on any level is 800 feet, but the shoot may continue beyond the present workings.

Grade

More than 1,150,000 tons of ore have been mined from the district. Average recovery has been 13.9 pounds of WO_3 per ton of ore. Milling of tailings is expected to increase this yield to 16 pounds. If the final recovery is 90% of the contained WO_3, average grade of ore mined to date will have been 0.875% WO_3

Current ore from the Humboldt-Springer mine averages 0.75% WO_3; from the Stank, 0.8%-1.0% WO_3; and from the North Sutton, 0.45%-0.55% WO_3 .
A small tonnage of 0.25% WO_3 ore is partly developed.

Origin

The grouping of commercial tungsten deposits around the two stocks suggests that scheelite was carried by, and deposited from, solutions migrating from the cooling granodiorite. It is believed that recrystallization of limestone to marble, alteration of marble (and limestone?) to tactite, and deposition of scheelite took place in successive or partly overlapping stages, as the character of the invading solutions changed.

Localization

The scheelite ore bodies are confined to zones in limestone beds that have been altered to tactite. Most of these tactite zones are ore.
Localization of the ore bodies is believed to be due to primary, secondary, and tertiary controls.

The primary control was the presence of limestone beds within the radius of migration of solutions from a cooling granodiorite mass. Had either of these prerequisites been lacking, no scheelite ore bodies would have been formed.

The secondary control was the presence of channelways along which tungsten-bearing solutions could migrate from their origin within the cooling igneous body to a place where temperature, pressure, and chemical conditions permitted deposition. The distribution of the ore bodies suggests that the contact of limestone with a granodiorite stock had little influence in altering the limestone and depositing scheelite. Rather, scheelite-bearing solutions were funneled along permeable channelways from a deeper source to a favorable locus of deposition. Like margins, pre-granodiorite fault zones, and other zones where metamorphism of the hornfels has been intense may have served as channelways. Small amounts of scheelite were deposited in these channelways.

After the solutions penetrated limestone beds in regions of favorable temperature and pressure conditions, factors of tertiary importance controlled the localization of scheelite deposition. Permeability of the limestone is believed to have been most important. Relatively impermeable hornfels walls confined the flow of solutions to the limestone beds. Impermeable zones in the limestone were not replaced. Variation of chemical composition and physical characteristics of the limestone beds may also have exerted a control.

Possibility of Ore at Greater Depth

Several lines of evidence indicate that present mining operations are near the bottom of the Humboldt ore body. The Stank ore body terminates against granite at the north end, but may continue to a greater depth farther south. The North Sutton ore body has only been mined to a depth of 200 feet; it seems likely that it may continue to a depth comparable with the Humboldt or Stank, or 1,000 feet to 1,500 feet. The George, Summit-O'Byrne, and other beds that have not been extensively developed may contain substantial tonnages of ore below the present lower limit of exploration.

Reserves

Enough ore is measured and indicated with reasonable certainty to assure a continued mill supply, equal to the present rate (April, 170 tons daily; May, 135 tons daily), for about two years. The present outlook is gloomy because of increased costs and a critical shortage of labor, but future possibilities are promising. Substantial reserves of 0.4%-0.5% WO_3 ore are inferred in the North Sutton mine. Furthermore, worthwhile tonnages of ore may be developed in the Springer, George, and Summit-O'Byrne beds. The possibilities are probably as great as they were a decade ago, but exploration and development work have been forced to a minimum by present condition.

Low-Grade Ore

Partly developed ore in the Humboldt-Springer and Stank mines, estimated to average 0.25% WO_3, can be mined only at a considerably higher price for scheelite. Most of the low grade ore in the district occurs as fringes bordering commercial ore bodies, or as irregular blocks within them. There is little likelihood that any large minable bodies of low-grade ore will be found in the district.

MINES

All mines decribed in this report are owned by the Nevada Massachusetts Company, Inc. Other properties at the north end of the district and another at the southeast edge have been described elsewhere.

The amount of underground development and diamond drill hole exploration in the district is shown in the table on page 17. There is about 11 1/2 miles of drifts and crosscuts, 4,400 feet of shafts, and 3 miles of diamond drill holes in the district. One-third of the level workings is crosscuts.

Mine workings and diamond drill holes, in feet, in the Mill City district.

Mine	Level workings				Shafts			Total	D.D.
	No.	Drifts	X-cuts	Total	No.	Max. Inclined Depth	Total Inclined depth	Workings	Holes
Humboldt-Springer	16	21,555	10,545	32,100	2	1,740	2,015	34,115	8,970
Humboldt Tunnels	6	765	640	1,405	0	0	0	1,405	0
Springer Tunnels	3	480	200	680	0	0	0	680	0
Stank	13	9,955	6,140	16,095	5	1,225	1,625	17,720	2,355
North Sutton	2	2,095	335	2,430	1	140	140	2,570	1,915
South Sutton	3	2,010	475	2,485	1	240	240	2,725	0
Orphan	2	315	260	575	0	0	0	575	0
Summit	2	65	600	665	0	0	0	665	130
O'Byrne	2	165	35	200	1	60	60	260	0
Uncle Sam	2	185	255	440	0	0	0	440	285
West Beds	2	235	0	235	0	0	0	235	1,965
Springer Gulch Prospects	8	750a	200a	950a	4	75a	225a	1,175a	945
Florence Prospects	5	175	0	175	2	60a	100a	275a	0
Total		38,750	19,685	58,435	16		4,405	62,840	16,615

"a": approximate.

Humboldt-Springer Mine

The Humboldt-Springer mine, which has produced about 60% of the ore mined in this district, has been worked to a vertical depth of 1,330 feet. The mine is developed through a 2-compartment inclined shaft, an adit, and 17 levels. The shaft is now being deepened, and another level will be opened at a vertical depth of 1,420 feet below the collar (1,700 feet level). Part of the older workings are inaccessible.

The ore produced at the Humboldt mine has come from three parallel beds, the Humboldt, the Springer, and the George. Originally the Humboldt and Springer beds were developed by separate workings. After the Nevada Massachusetts Company acquired control, the workings were connected. Since that time all

<u>Humboldt ore body</u>.—The Humboldt bed has yielded about 45% of the ore mined in the district. It can be traced for 1,750 feet on the surface, from the Olsen stock at the north end to a cutoff of uncertain origin at the south. (See Pl. ll and lll.) From the surface to the 725-foot level the bed averages about 1,700 feet long; about 75% of this zone has been stoped. A substantial tonnage of low grade ore remains between the surface and the 200-foot level. Below the 725-foot level the southern termination of the bed slopes 40° north, and the granite contact at the north end slopes steeply south. Consequently, the bed is reduced from a length of 1,750 feet on the 725-foot level to a predicted 750 feet on the 1,700-foot level, and it may be eliminated several hundred feet below the deepest workings. (See Pl. V.)

The main ore shoot extends from the surface to midway between the 1,450-foot and 1,575-foot levels, and from the southern termination of the bed to an irregular northern margin. In some places the northern margin extends to the granodiorite contact; in others it is several hundred feet south of the contact. The ore body is cut by several small dikes, and displaced from a few feet to more than a hundred feet by pre- and post-granodiorite faults. A few small shoots of ore lie between the main shoot and the granodiorite. Width of ore varies from 4 feet to 12 feet, averaging 6 feet. Grade of ore from individual stopes has varied from 0.25% to 10% WO_3, averaging 0.75%. In the lower part of the mine the transition from ore to slightly altered, very low-grade limestone and marble is rapid. Small irregular lenses of marble and low-grade tactite occur here and there in the main ore shoot.

No large extension of the main ore shoot is expected below the present bottom of the mine. A short "root" may continue for a few hundred feet, but it probably does not contain more than 10,000 tons of ore. Judging from the ore exposed on the 1,500-foot level, the grade of part of the ore in this "root" may be subcommercial.

Inconclusive evidence suggests that a pre-granodiorite normal fault has displaced the southern end of the Humboldt bed. A considerable amount of crosscutting and diamond drilling has laready been done in an attempt to find the anticipated segment. The exploratory program will be continued by crosscutting and drilling from the 1,700-foot level. The writer is inclined to believe that lack of sedimentation may account for the southern termination of the bed, and that continued exploration will not be fruitful.

<u>Springer ore body</u>.--The Springer bed lies between 200 feet and 250 feet west of the Humboldt bed. It can be traced, with some displacements, from a fault in Springer Gulch to the north face of the Humboldt train tunnel, a distance of 1,400 feet. (See Pl. Vi and VII.) A wide, almost barren, garnet bed is exposed in the saddle west of Sta. G on Humboldt Hill. This may be a segment of Springer bed north of the low-angle pre-granodiorite reverse fault. The Yellow Scheelite bed in the Stank mine may be a continuation of the Springer bed.

The Springer ore body is oval in shape. It has been mined to a vertical depth of 980 feet, and for a maximum length of 725 feet. The bed is now being developed on the 1,100-foot level, 100 feet vertically below the deepest stopes. Average width of the bed is 3 feet; average grade has been about 0.75% WO_3. The northern half of the ore shoot on the 725-foot, 850 foot, and 975-foot levels has been low-grade; the block between the

850-foot and 975-foot levels, estimated to average 0.25% WO_3, was not mined. If the northern part of the shoot on the 1,100-foot level is low-grade, only 5,000 to 7,000 tons of ore will have been developed by a 600-foot long crosscut. Several small wedges of a few hundred to a few thousand tons of ore also remain in the upper levels. To reach the projected position of the ore body on the 1,200-foot level, a 700-foot crosscut must be driven.

Where the bed has been exposed north of the ore shoot by drifting or diamond drilling, it has been narrow, faulted into small segments, and of only fair grade. A bed that may be the Springer is exposed at the surface south of the post-granodiorite Springer fault. A continuation of the Springer ore shoot may lie in this structurally complicated area.

Because the tonnage of ore produced per man is small, and because considerable work must be done to develop more ore, it seems most practical to temporarily discontinue mining in the Springer bed, after the ore now in sight has been stoped.

George bed.--The George bed lies between 200 feet and 300 feet west of the Springer. It crops out intermittently between the Olsen stock and the Stank fault, a distance of almost a mile. It varies from 3 feet to 30 feet in width. The mineralization of the George bed is very spotty. Zones of good ore alternate with zones that are almost entirely barren marble or limestone. A few small stopes of good ore were mined on the 500-foot and 600-foot levels.

A sub-level, 50 feet above the collar of the Humboldt shaft, is being driven along a strike fault that has displaced the George bed. The gap between the two segments of the bed is almost horizontal, and several hundred feet of drifting were required to intersect the bed above the fault.

If an ore shoot is partly outlined on the sub-level, it would probably be worthwhile to crosscut and explore the bed on the 300-foot level. A shoot of ore might also be found by continuing the 400-foot level southward under good surface ore on the south side of Springer Gulch.

Stank Mine

The Stank mine has been worked to a vertical depth of 1,100 feet. The mine is developed by an inclined shaft to the 700-foot level, and by a winze (sub-shaft) from the 700-foot to the 1,200-foot levels. The original or No. 1 shaft was sunk to the 200-foot level. It has been abandoned. The Yellow Scheelite and Keyes shafts, also abandoned, are about 100 feet deep. The north ends of all levels but the 200-foot are inaccessible.

Stank ore body.--More than 95% of the ore produced at the Stank mine has come from the Stank bed. The bed can be traced intermittently on the surface from the Springer stock at the north end to the Codd adit at the south. (See Pl. VIII.) No outcrops or float have been found south of the Codd adit, but the bed is in the face of three levels that have been driven farther south. (See Pl. IX and XI.)

The bed varies in width from 3 feet to 7½ feet, averaging 4½ feet. Grade of ore averages between 0.75% and 1.0% WO_3. Alteration to tactite and mineralization with scheelite has been less complete than in the Humboldt and Springer ore bodies. Large blocks of unaltered or very low-grade limestone and marble occur within the limits of the ore body. In the list below the first number of each group of three is the level number; the second is the relative length of drift on the level, the longest level, the 300-foot, taken as unity; the third is the percentage of bed on the level that has been minable ore: 100, .45, 34%; 200, .49, 70%; 300, 1.0, 48%; 400, .89, 69%; 500, .73, 93%; 600, .82, 67%; 700, .73, 80%; 850, .20, 100%; 1,000, .70, 79%; 1,100, .40, 30%; 1,200, .41, 67%. The 800-foot and 900-foot levels are inaccessible.

The ore body terminates at the north end against granodiorite. Diamond drill holes indicate that this granodiorite is a tongue from the Springer stock. The attitude of this tongue so nearly parallels the bed that there is little likelihood of finding a worthwhile segment of the bed between the northern margin of the ore body and the stock. The southern limit of the body has not yet been determined. It is predicted that near the surface the ore shoot may be terminated by the Stank fault, but that at greater depth the shoot will terminate due to lack of mineralization before the bed is cut off by the fault. There is little information from which to predict how far south beyond present faces the ore body may continue. In general, the ratio of waste to ore has increased toward the south end of the mine, but commercial ore zones are expected to continue for at least a few hundred feet south of present workings.

The Stank ore body is cut by two prominent granodiorite dikes, the Stank and the Codd, and a gently dipping hornblende andesite dike. Pre- and post-granodiorite faults displace the bed. Between the surface and the 850-foot level the bed is separated into two segments by a pre-granodiorite fault. From the surface to the 500-foot level the displacement is uniform; between the 500-foot and the 850-foot, and particularly on the 700-foot level, post-granodiorite strike faults and the Stank dike cut the pre-granodiorite fault zone into segments, complicating the structure and increasing the difficulty of mining. (See Pl. XI and XII.) A crosscut is now being driven between the two main segments on the 850-foot level. Work on the 1,000-foot, 1,100 foot, and 1,200-foot levels has been confined to the hanging wall segment of the bed.

It is predicted that between the 400-foot and 700-foot levels the Stank ore body continues for 200 feet south of the Codd dike. (See Pl. IX.)

Yellow Scheelite bed.--The Yellow Scheelite bed lies 175 feet west of the Stank bed and 350 feet east of a bed believed to be the George. This sequence is similar to the Humboldt-Springer-George sequence north of the Springer stock and the structurally complex Springer Gulch area. The writer believes that the Yellow Scheelite bed is a lenticular continuation of the Springer.

The bed has only been found between the Springer stock and the pre-granodiorite fault at the north end of the Stank mine, and between the surface and the 200-foot level. Width averages 2-2½ feet, and grade is between 0.5 and 0.75% WO_3. The bed has not been found in diamond drill cores at greater depth or farther north in the mine. It seems probable that the bed is lenticular, and should not be considered as a potential source of ore.

Keys "bed."--In the early days of the district a mortician obtained a lease and sunk a shaft on a narrow, poorly mineralized lens of pale silicate rock, probably an altered calcareous shale bed. No ore from this bed has ever been milled, and it contains no reserve.

North Sutton (Sutton No. 2) Mine

The North Sutton mine is developed by a 1,200-foot adit and an 150-foot inclined shaft. Development has been confined to the West Sutton bed, one of two parallel limestone beds that normally lie about 40 feet apart. A few surface pits indicate that the East Sutton bed does not contain an ore shoot in this vicinity. Failure to intersect the East Sutton bed in diamond drill holes and in a crosscut suggests that it is either lenticular or considerably faulted.

West bed can be traced from a salient of the Springer stock to a pre-granodiorite fault north of the Baker adit. (See Pl. 1.) There are no exposures of the bed between the Baker and Uncle Sam areas. Ore float is found along the projected position of the bed in a reentrant in the stock a few hundred feet north of the mine.

The West bed is variable in width and grade. Width varies from 3 feet to 15 feet, averaging 7 feet or 8 feet. Ore mined to date has averaged 0.52% WO_3. Most of the bed in this vicinity has been altered to silicate minerals, but the distribution of scheelite is irregular. Much of the scheelite occurs as films along joints and irregular fractures in the silicate rock.

The ore body is cut by narrow dikes and a few faults of small displacement. The most important structural feature from the standpoint of mining is the occurrence of hornfels "horses," both small and large, within the ore bed. The writer believes these are lenses of shale that were deposited here and there in the limestone bed. A few may have been faulted in by movement along slips that cut the bed at a very acute angle to both strike and dip.

The working adit is a drift along the bed between the granodiorite salient and the pre-granodiorite fault. All ore between the adit level and the surface has been stoped, except a few thousand tons near the surface at the north end. On the 125-foot level about two-thirds of the predicted length of the ore body, 800 feet, has been drifted, and two stopes have been completed. (See Pl. XVI.) At the present rate of operations all ore above this level will be broken within a year. To assure continuous production from the mine it is imperative that the shaft be sunk several hundred feet, and one or more levels be opened as quickly as possible. This is the least disturbed ore body in the district, and to continue sinking the shaft in ore involves almost no risk.

South Sutton (Sutton No. 1) Mine

The South Sutton mine, now inactive, is developed by an adit 950 feet long and an inclined shaft 215 feet deep. The upper part of a small ore shoot has been mined from each bed. (See Pl. XIV.) Grade of ore averaged 0.5% WO_3.

Both beds can be traced by intermittent outcrops for 1,200 feet south of the ore bodies, but only a few small mineralized lenses occur. (See Pl. XIII.) Both beds have been drifted on the adit level for 450 feet north of the ore shoots. One short, narrow lens of ore was found on the East bed; the West bed was barren.

It is likely that both ore shoots continue below the 200 foot level, but under present conditions it is impractical to develop them. The grade of ore is probably about the same as in the north Sutton mine, but the amount of ore per vertical foot is much less. Also, the South Sutton ore bodies are considerably faulted and more costly to mine.

Orphan (North Sutton No. 1) Workings

The Orphan workings explore faulted segments of the Sutton beds between the South Sutton mine and the Springer stock. (See Pl. XIII.) About 10,000 tons of 0.75% WO_3 ore have been mined from short adits and glory holes.

There is little likelihood that any substantial tonnage of ore could be mined from underground workings in this structurally complex area. It is possible, however, that some low-grade ore could be produced by surface stripping in the area where the beds have been duplicated and thickened by faulting.

Intrusion of the Springer stock is believed to be responsible for the structural complexity of this area.

Uncle Sam Mine

The Uncle Sam mine is in a faulted segment of the Sutton beds south of the Olsen stock. (See Pl. 1.) Development consists of a 200-foot crosscut, and a 165-foot drift in the West Sutton bed. A raise follows ore from the drift to the surface, where a few hundred tons of ore have been glory holed. U. S. Bureau of Mines sampling indicates a grade of 0.5% WO_3.

Scheelite ore float can be traced for several hundred feet north and south of the Uncle Sam mine. It seems likely that other ore shoots, or faulted segments of this partly developed shoot, may be found in the area (between the road and the Olsen stock, Pl. 1). The East Sutton bed contains no scheelite at the surface, in the crosscut, or in the drill core.

The Uncle Sam area is considered to be a good prospect for 0.5% ore. The surface should be trenched to indicate the continuity of the ore zone. If trenching discloses ore beyond the limits of present exploration, the drift should be continued. A 100-foot shaft is almost certain to develop 2,000 tons of ore, and it may develop several times this amount.

Summit-O'Byrne Bed

The writer considers the Summit-O'Byrne bed to be the best slightly developed prospect on the property. This bed lies west of the Stank fault and dips east. It is expected to terminate at the fault along a line that inclines gently south. At the Summit mine the cutoff is near the surface, but at the O'Byrne shaft it is expected to be 450 feet below the surface. (See Pl. X.)

On the north side of Stank Hill the bed has been developed by an adit. (See Pl. XVIII.) A small shoot of 1% WO_3 ore was mined from between the adit and the surface. This shoot terminated against hornfels along a line that sloped gently north. The termination is believed to be at a pre-granodiorite reverse fault similar to the one in the north end of the Humboldt mine. If this interpretation is correct, a continuation of the ore shoot may lie between this fault and the Stank fault.

The Summit bed can be traced on the surface for 400 feet beyond the stoped area. Of this length 250 feet is good ore and 150 feet is unaltered limestone. A U. S. Bureau of Mines drill hole intersected almost barren tactite 100 feet beneath the limestone outcrops.

The O'Byrne bed on the south side of the hill is believed to be a continuation of the Summit bed. No bed is exposed for 400 feet along the projected strike near the crest of the hill. A granodiorite dike, 125 feet wide, passes through part of this gap. South of this dike the O'Byrne bed can be traced with almost continuous exposure to the bottom of Stank Canyon, a distance of 800 feet. Six hundred feet of this length is mineralized with scheelite. The O'Byrne adit and shaft follow a 2½-foot ore zone estimated to average 0.75% WO_3.

This ore zone, exposed intermittently for a length of 1,500 feet and through a vertical range of 200 feet, is not likely to terminate just below the surface. It is more probable that a continuous ore body lies between the surface and the Stank fault. Within the ore body zones of good ore are expected to alternate with zones of unaltered or very low-grade limestone.

The Summit-O'Byrne area is very accessible. A narrow gauge spur connects the lower Summit adit with the Stank tram line, and a horizontal grade could be maintained in extending the Stank road to the O'Byrne shaft. Rather than sinking a shaft in ore, as the procedure in the past has been, it might be wise to develop this ore body by drifting south along the George (?) bed from the bottom of Pick Handle Gulch, periodically crosscutting or drilling west through the Stank fault until the Summit-O'Byrne bed is intersected, then drifting along this bed. This drift could then be used as a haulage level near the predicted bottom of the Summit-O'Byrne ore body, and at the same time some ore might be developed along the George (?) bed.

Prospects in the West Beds

Several limestone beds west of the Summit-O'Byrne are collectively referred to as the West beds. The eastermost bed of this group has been prospected by two short adits on the north slope of Stank Ridge. Here the ore zone is only from 1 foot to 2 feet wide, but it averages between 0.5% and 0.75% WO_3. It is probable that this shoot may contain a few thousand tons of minable ore.

This bed cannot be traced southward across the ridge, but a wider bed, occupying about the same stratigraphic position, has been prospected on the south slope. Several feet of 0.5%-1.0% WO_3 ore are exposed in two cuts. Another small shoot containing a few thousand tons of ore may occur here.

Small lenses of scheelite-bearing tactite have been prospected in other limestone beds of this group. None of these showings encourages further prospecting. Three U. S. Bureau of Mines drill holes intersected these beds at depths as great as 550 feet below the outcrop; all intersections were barren, unaltered limestone.

It is the writer's belief that the West beds (except for the easternmost one) were too far from the source of the mineralizing solutions to have been extensively altered and mineralized with scheelite. Ore shoots may occur in these beds at greater depth, but the cost of comprehensive exploration, which would be almost blind, would be prohibitive. The probability that the scheelite-bearing solutions migrated from a center or centers, and not from all granodiorite contacts, further decreases the probability that commercial ore bodies occur in the West beds within reasonable prospecting distance of the surface.

Springer Gulch Area

The Springer Gulch area is a structurally complex sedimentary wedge lying between the Springer stock, the Springer fault, and the projected position of the Stank fault, or a parallel fault. As a promising prospect it is second only to the Summit-O'Byrne area.

A bed believed to be the George has been prospected in several places. Faulted shoots of good ore are partly developed in two adits and two shallow shafts. A faulted shoot of ore in a bed farther west has also been prospected by a short drift. These segments contain 3 to 5 feet widths of 0.75%-1.0% WO_3 ore alternating with zones of marble or limestone, and resemble the George bed where it is less disturbed.

It seems worthwhile to prospect this area from the north end of the Humboldt-Springer mine. The George south drift on the 400-foot level could be driven beneath the best surface ore with only a few hundred feet of drifting.

Florence Area

Two groups of seven or eight limestone beds each are exposed north of the Olsen stock. (See Pl. 1.) They may be the same beds on opposite limbs of an isoclinal fold overturned toward the west. There is one cogent argument against this interpretation of the structure of this area: The beds in the east group vary from 3 feet to 10 feet in width, those in the west group from 6 feet to 30 feet. The dip of the east group is steeper than the dip of the west group.

Small lenses of tactite ore have been prospected in both groups of limestone. None of the prospects has exposed a worthwhile tonnage of ore of commercial grade. Small pockets of 1%-2% WO_3 ore have been taken from a 50-foot inclined shaft and two short adits in the east group. In each, the ore lens is surrounded by barren limestone. Two adits prospect the only promising showings in the west group of beds. Both adits follow a 3- to 5-foot band of tactite in a much wider limestone bed. Most of the tactite is very low grade, but small pockets of good ore occur in it.

Commercial bodies of ore may occur at greater depth in this area. The west group is considered to be the most promising, for it is truncated by the Olsen stock, just as the Humboldt, Springer, and George beds are. Furthermore, the beds, though poorly exposed, seem to be relatively undisturbed. The east group does not contact the granodiorite at the surface, but some of the beds may at a depth of only a few hundred feet. These beds are cut by a number of faults of small displacement; a better grade of ore might be expected if some of these are pre-granodiorite in age, and also because the beds are narrower than those of the west group.

Mill (East) Beds

The Mill beds are two parallel limestone bands, each from 10 feet to 30 feet wide, separated by a 10- to 20-foot layer of hornfels. They crop out almost continuously for a mile south of the Nevada Massachusetts Company mill. (See Pl. 1.) In this area they are unaltered, barren blue limestone. South of a 1,000-foot concealed interval they again crop out on the Forge property, and here, in the vicinity of a small granodiorite mass, they contain lenses of scheelite ore.

A bed of almost barren tactite, believed to be one of the Mill beds, is exposed in trenches near the upper limit of the fan. These exposures are 3,000 feet north of the last outcrops of the Mill beds approximately along the projected strike, and 2,200 feet east of the border of the Springer stock. U. S. Bureau of Mines assays of samples cut in these trenches showed only a trace of scheelite. Examination under ultraviolet light substantiates this finding.

The bed exposed in the trenches dips 25° to 30° west, and it is possible that scheelite mineralization may occur nearer the granodiorite at not too great depth. As a blind prospect, this area is believed to be more favorable than the West beds area. The Mill beds are known to be mineralized with scheelite on the Forge property, and it is possible that the almost barren tactite mentioned above may be the fringe of an ore body nearer the Springer stock. An exploratory program would involve surface trenching or bulldozing to disclose the continuity and attitude of the bed(or beds), followed by drilling to the projected position of the bed (or beds) nearer to the granodiorite.

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