UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Memorandum (September 6, 1940) on Recommendations for Exploration in the Mill City, Nevada, Tungsten District

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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INTRODUCTION

The Mill City tungsten district is in northwestern Pershing County, Nevada, on the eastern slope of the Eugene Mountains. Eight miles of paved road connect the mine with Mill City, on the Southern Pacific Railroad and U. S. Highway 40. The Nevada Massachusetts Company has owned all tungsten properties in the district since 1927. The amount of concentrates shipped by the company has given it first rank among domestic tungsten producers. Production of the district since discovery in 1917 is shown in the accompanying table. At present the Company is operating at the full capacity of its mill, 220 tons per day, and is constructing an additional mill for treatment of tailings. The capacity of the new plant will be 1,000 tons per day.

The geology of the tungsten deposits has been described by Hess and Larsen,[1/] and by Kerr;[2/] the mining and milling operations have been described by Heiser[3/] and Vanderberg.[4/]

Because of the district's importance in domestic tungsten production, the Geological Survey included a study of the Mill City area in the current program of strategic mineral surveys. The principal object of the study is to map the areal geology of the Eugene Mountains on a scale of 1:62,500 (approximately one inch equals one mile),

1. Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725-D, 1921.
2. Kerr, P. F., Geology of the tungsten deposits near Mill City, Nevada: Univ. of Nevada Bull., vol. 28, no. 2.
3. Heiser, O. F.: U. S. Bur. Mines Inf. Circ. 6280, June 1930, and 6284, June 1930.
4. Information not available, June 1975.

and to place the tungsten deposits in their setting of regional geology. As a part of this study, the tungsten deposits, which were mapped by P. F. Kerr in 1932, are being re-examined, and some of them are being mapped in detail as a possible aid to exploration by the Bureau of Mines. This work is incomplete, but the results to date of the detailed study are given in this preliminary report.

Throughout the work, Ott F. Heiser, manager of the Nevada Massachusetts property, has been extremely cooperative. The writer is indebted to T. B. Nolan, of the Survey, for valuable suggestions, and to J. F. McAllister for able assistance in the field.

GEOLOGY

The rocks of the district include a series of metamorphosed Triassic sediments over 4,000 feet thick, large intrusives of granodiorite, and thin dikes of granodiorite, aplite, quartz diorite, and andesite (see fig.1).[5] The Triassic beds strike N. 10°-30° E. and dip 60°-70° west. One mass of granodiorite 2,500-3,000 feet in diameter occupies the center of the district, and a second, larger body lies to the north, connected with the first by a narrow neck. The ore deposits are scheelite-bearing silicate rocks that have been formed from limestone members of the Triassic series by contact metamorphism. Both pre-mineral and post-mineral faults displace the beds, the faulting being most complex in the western half of the district.

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5. This map was prepared by the Stanford Geological Survey in 1932. It does not show 1939-40 revisions of geology.

Triassic sedimentary rocks

The Triassic series consists of hornfels, slate, and limestone. Hornfels, the most abundant rock type in the series, is a fine-grained, very hard, gray or dark green-gray rock that weathers to brown-stained angular joint blocks. Slates weather to dark gray or black chips and plates that split readily along cleavage planes. The Upper Triassic fossil _Monotis subcircularis_[6] has been found in a zone about 100 feet thick stratigraphically that extends through the eastern part of the district. No fossils have been found elsewhere

The limestone beds, widely spaced in the Triassic series, are 2 to 15 feet thick. They are dark blue, gray, or black, and where slightly altered, grade into white crystalline marble, in most places coarser in grain than the original limestone. The abundance of garnet and epidote distinguishes the highly metamorphosed scheelite-bearing silicate rocks. Individual limestone beds that have been mined or prospected are known in the district by local names; from east to west these are the East Bed, the east and west Sutton Beds, the Humboldt, Springer, Stank, Yellow Scheelite, Keys, Summit, and Hard Luck George Beds, and the West Beds.

Intrusive rocks

Intrusive granodiorite underlies the central part of the district, as well as a larger area to the north, and forms many dikes. The granodiorite of the larger intrusives is a medium-grained crystalline

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6. Identified by S. W. Muller, personal communication. Previously identified as _Pseudomonotis subcircularis_.

rock, composed mainly of plagioclase and quartz, with small amounts of hornblende, biotite, and orthoclase. Fresh specimens of the rock are gray and hard; weathered rock is stained light brown or tan, and crumbles easily. Kerr[7] has pointed out that some parts of the granodiorite and some dikes are more properly named quartz diorite. Aplite is fine-grained, with few dark grains.

Andesite is the youngest rock in the area. Typical weathered specimens from the surface are dark gray and contain numerous light feldspar and dark hornblende phenocrysts. In fresh andesite from the mines, the feldspar crystals are dark gray and hardly distinguishable from the gray groundmass.

Structure

The Triassic rocks strike N. 10°-30° E. and dip 60°-70° west except northwest of Stank Hill, where there are east-dipping beds. Both pre-mineral and post-mineral faults displace the beds, as shown on the geologic map (fig. 1). The majority of the faults strike N. 15°-45° W. and dip steeply southwest; the chief movements appear to have been horizontal. Pre-mineral faults break the Sutton beds northeast of the southern granodiorite into three segments that are offset 400-600 feet. A fault cuts off the southern end of the Humboldt ore body, and another truncates the Springer bed; the displaced segments have not been located. A pre-mineral fault also separates the northern end of the Humboldt ore body into two parts; as the footwall portion has produced the highest grade ore found in

7. Op. cit., p. 31.

the mine, a structural control of ore-bearing solutions is suggested. The Stank Fault is the most prominent fault on the map; it is post-mineral, and where it crosses Stank Hill is marked by a breccia zone 20-50 feet thick.

As the Triassic rocks are cut at all angles by the main granodiorite body, the bedding apparently influenced the direction of the intrusion only locally. The contact is in some places highly irregular, while elsewhere it follows a nearly straight line. The position of granodiorite in the valleys and hornfels on the hilltops is a consequence of the relatively low resistance of the granodiorites to weathering, and does not imply that the intrusive rock extends horizontally under hills capped with metamorphic roof pendants. On the contrary, mining in the Humboldt and Stank workings has shown that the granodiorite dips under the sedimentary rocks at 60°-70°. At these steep angles, the intrusive masses encroach on the ore beds rather gradually with increasing depth.

ORE BODIES

The ore deposits are limestone beds that have been altered by contact metamorphism to dark silicate rocks ("tactite") containing disseminated scheelite (calcium tungstate). All the ore deposits are at or near the contact of the granodiorite with the sedimentary rocks, the richest deposits being along the western margin of the southern body. The largest ore body, the Humboldt, is 1,500 feet long, and has been mined to a depth of 1,300 feet. Over 95 percent of the ore so far milled has been mined from the Humboldt, the

Springer, and the Stank ore bodies, all of which lie west of the southern granodiorite intrusive. These are being mined at present, and ore is also being taken from the South Sutton and the Sutton No. 2 (formerly North Sutton) mines at the eastern margin of the granodiorite. In addition to these producing mines, there is a sub-marginal deposit east of the granodiorite, at the Uncle Sam mine, and several partly prospected deposits west of the granodiorite, in the faulted area between the Springer and Stank mines.

Mineralogy

The scheelite is disseminated in a dark crystalline rock composed mainly of garnet, epidote, quartz, and calcite, with much actinolite and pyrite, and small amounts of chalcopyrite, pyrrhotite, and molybdenite. That this silicate ore formed by replacement of limestone is clear, for the lateral transition from ore to unaltered limestone can be seen in many places, and within the ore bodies are many residual masses of unreplaced limestone. Also, variations in the relative amounts of minerals make the original bedding plainly recognizable. The scheelite is unequally distributed; some dark silicate rocks are practically barren, while others contain as much as 10 percent tungsten. Other minerals in the ore also range widely, but as a rule scheelite-rich rocks are also rich in quartz. The fluorescence of scheelite in ultraviolet light is a great aid in distinguishing scheelite from quartz, which it closely resembles. Ultraviolet lamps are constantly used in the mines to assist in estimating the grade of ore.

Localization of ore bodies

The ore bodies all lie in a narrow zone around the granodiorite (see fig 1). The width of the zone is most definitely shown in deposits that extend from the contact out to unmineralized limestone. The South Sutton ore, for example, grades into unaltered limestone about 500 feet from the granodiorite. The Sutton beds north of the intrusive (Sutton No. 2-Baker adits) are partly mineralized as far out as 1,000 feet. The Stank bed is mineralized for 1,200 feet southward from the main granodiorite, although there are small intrusions much closer to the ore. The Humboldt ore body extends 1,500 feet southward from the northern granodiorite body, but near the shaft the bed is within 200 feet of the southern intrusive. It is thus possible that the Humboldt bed lies within the contact zones of both the northern and southern intrusives. The Springer ore body is not in contact with granodiorite, but no part of it is more than 1,000 feet away from the intrusive. These approximate figures indicate that the ore-bearing zone surrounding the granodiorite body is 500 to 1,200 feet wide.

The ore zone continues downward parallel to the boundary of the granodiorite intrusive. The granodiorite dips 60°-70° under the sedimentary rocks in the Humboldt and Stank workings where mining has reached depths of 1,200 and 1,300 feet respectively. No other contact has been mined deeply enough to determine its attitude.

Not all limestone within the zone is mineralized and scheelite-bearing. In the Humboldt mine, for example, although sections of of the bed at considerable distance from the granodiorite are altered, there are some barren blocks of limestone-marble rock at the contact. Also, proximity to the contact does not assure high-grade ore because the scheelite is as unevenly distributed as the other minerals. The intensity of mineralization and the amount of scheelite in the limestone seem to have been partly determined by obscure structural features of the ore beds. It seems probable that pre-mineral fractures guided the movement of mineralizing solutions and partly determined the position of high-grade ore shoots. In general, it appears that a limestone that lies in the contact zone is a potential ore body, and conversely, limestones that are more than approximately 1,200 feet from the main granodiorite are probably unmineralized and barren.

Grade and size of ore bodies

The average tungsten content of the ore milled in the district has been slightly below one percent. In one block of ore mined in 1932-33, the tungsten content ranged from 5 to 13 percent, the highest ever found in sizable amounts. Ore bodies that average under one-half of one percent are sub-marginal at the normal price of tungsten.

The dimensions of the three largest deposits are as follows: The Humboldt body is 5-6 feet thick except in one block 300 feet long, where it is 10-15 feet thick. The ore body has a maximum length of 1,500 feet near the surface, and tapers downward between granodiorite on the north and a fault on the south. It has been mined to a depth of 1,300 feet. The Springer body, 3-5 feet thick, has a maximum length of 600 feet, and has been mined to a depth of 800 feet. The Stank ore bed, 3-5 feet thick, is not uniformly mineralized, but sections 300 feet long have been stoped. It has been followed downward for 1,200 feet.

The deposits in the two Sutton beds are smaller. Each bed is 3-5 feet thick. At the South Sutton mine, where both beds are being mined at 200 feet below the surface, the beds are broken into segments, the largest of which is 200 feet long. At the Sutton No. 2, one bed has been stoped from the adit to the surface for a length of 150 feet, and a second stope 40 feet long is now being mined.

Reserves

Although reserves of commercial grade are presumably blocked out in the Humboldt, Springer, Stank, and South Sutton mines, no estimate of reserves can be given for these deposits because they have not been examined underground. In the Sutton No. 2, the only working mine that has been examined, a block now being stoped from the adit to the surface contains a maximum of 3,000 tons of commercial ore.

Reserves of sub-commercial grade blocked out in the Sutton No. 2 amount to about 3,000 tons, in the Uncle Sam about 2,000 tons.

Among the known ore deposits of the district, the Sutton No. 2 and the Uncle Sam segments of the two Sutton beds are the least developed. Only one-fourth of the west bed in the Sutton No. 2 segment has been explored, and only one-fifth of the west bed in the Uncle Sam segment. In each case, there is probably additional ore horizontally along the segment and downward below the present workings. There is, furthermore, a possibility of the east bed being mineralized.

There may be undiscovered deposits in the district because a number of the limestones are incompletely explored. Several of these beds lie in Springer Gulch between the Springer and the Stank mines in what appears to be a section of the ore zone. The East Bed is known to be mineralized and scheelite-bearing at one place, which lies outside the known limits of the main ore zone. There are seven limestones in the group known as the West Beds, but they are almost unmineralized at the surface and appear to lie outside the ore zone.

Recommendations for exploration

The possibility of exploring undeveloped extensions of the ore bodies in the Humboldt, Springer, Stank, andSouth Sutton mines is not considered here, as the Company continually searches for all possible block of ore adjacent to the workings. Work that might be done in other parts of the district is described below.

The Sutton No. 2 deposit (fig. 2) is about 2,500 feet east of the Humboldt mine, on a segment of the Sutton beds about 1,200 feet long. The Sutton No. 2 adit extends for 350 feet N. 15° E. along what appears to be the west bed. At 250 feet from the portal a raise connects with the surface and a crosscut extends 85 feet westward. The Baker crosscut adit, 1,200 feet north of the Sutton No. 2, is

100 feet long. Several trenches expose the bed between the two adits.

The beds are cut off by granodiorite on the south at the adit portal, and they end at an unexposed pre-mineral fault on the north. The segment between the granodiorite and the fault is about 1,200 feet long. Northward beyond the fault, the next segment of the Sutton beds is offset 400 feet eastward. Several dikes 1-4 feet thick of aplite, granodiorite, and andesite cut the beds. The beds strike N. 15°-20° E., and dip 60°-70° west. The body now being mined at the Sutton No. 2 adit is 3-4 feet thick except near the adit face, where it is nearly 15 feet thick, probably because faulting has increased the dimensions.

This segment of the west bed is mineralized along most of its length, but the scheelite content is uneven. The first 90 feet along the Sutton No. 2 adit were stoped to the surface, the next 160 feet were left because the ore is too low-grade, and the next 40-50 feet are now being stoped. The unmined block between the two stopes contains about 3,000 tons of sub-commercial ore. Inasmuch as the adits have explored only one-fourth of one bed, further exploration would probably develop large reserves.

Exploration on the surface would require (1) trenches along the strike of the west bed to show the extent of mineralization and (2) pits to locate the east bed and determine whether or not it is mineralized. Exploration of the bed at depths below the adits would require diamond drilling from the west through slate and hornfels. Drilling would supply information as to the rate at which the ore body is cut off by granodiorite on the south or by the pre-mineral fault on the north, as well as the extent of mineralization downward within the bed. The profiles (fig. 4) accompanying the map of the area (fig. 2) show that three drill holes 220, 265, and 330 feet long would reach the west Sutton bed 100 feet below the Sutton No. 2 adit, and a fourth 260 feet long would reach the bed 100 feet below the Baker addt.

<u>The Uncle Sam deposit</u> is about 3,000 feet northeast of the Humboldt Shaft, on a segment of the Sutton beds which lies northeast of the southern granodiorite body and within the ore zone (fig. 1). The Uncle Sam adit is a crosscut 200 feet long, leading west into a drift that follows the west bed for 160 feet. A raise connects the drift with a deep trench 30 feet long. Five hundred feet south of the Uncle Sam are two short adits, 30 and 10 feet long. Except in these workings and in a few shallow pits, the beds are covered with surface wash, but a train of scheelite float indicates that the beds are continuous between the Uncle Sam and the southern adits.

At the Uncle Sam adit, the two beds are 60 feet apart; the east bed is five feet thick, the west bed about three (fig. 3). On the north, the beds strike N. 20° E. and dip 65°-70°; on the south, they curve to N. 50° W. as they approach an unexposed fault which offsets the next segment of the beds 400-600 feet eastward. Granodiorite lies northwest and southwest of the segment of beds, but not in line with its surface trend.

The west bed, which is followed by the drift, is more mineralized than the east bed. Above the drift there are more than 2,000 tons of ore of sub-commercial grade. As the beds of the Uncle Sam area are at least 700 feet long, the drift has explored the near-surface part of only about one-fifth of one bed. Further exploration on the surface would require trenches through soil one to three feet deep. Trenches not over 10 feet long should serve to locate the west bed if placed where the ultraviolet light shows abundant scheelite float.

Exploration downward is complicated by the fact that the exact position and the dip of the fault that cuts off the beds on the south and the attitudes of the granodiorite contacts on the north and south are unknown, and both or either may cut off the beds below the surface. Diamond drill holes to test the downward continuation of the beds would be drilled from the west through slate and hornfels. To cut the beds at a 60° angle 100 feet below the Uncle Sam drift would require drilling 225 feet; other drill holes north and south of the adit would be approximately the same length.

The Springer Gulch beds lie between the Springer shaft and Stank Hill (fig. 1). They are a group of limestones that strike N. 20°-30° E. and dip 50°-70° west. The area contains four, and possibly five limestones. Two beds that lie west of the Springer ore body are known to be ore-bearing on the 600 Level of the mine, but are only slightly mineralized on the surface. West of these there seem to be three limestones, but one may be a faulted segment of another. These have been prospected only on the surface, where they are slightly mineralized.

Although no ore deposit has been developed in this area, the position of the limestones in the main ore zone suggests that there may be a concealed ore body below the surface. To determine whether these beds contain ore would require drilling. As the beds are displaced by faults and intrusions, a detailed map (scale, 1 inch equals 100 feet) is being made in the hope of approximately locating segments that can be explored. Perhaps when the map is completed, definite recommendations can be made for drilling.

The East Bed is a thick limestone that is traceable for hundreds of feet south of the district. What appears to be its northern extension has been uncovered in trenches at the range front 3,000 feet east of the southern granodiorite body in an area covered with surface wash (fig. 6). Here the bed, which dips 25° west, is mineralized. If additional trenches should show that the mineralization continues, drilling to determine the extent of the ore body would be warranted.

The West Beds lie outside the main ore zone. Therefore, they seem to be the least likely to contain ore. The beds dip east at 60°-70° on the Stank Hill ridge top, and curve to vertical down the slopes. On the steep hillside, the exposures are only fair, but from what can be seen the beds appear to be nearly unmineralized through a vertical range of over 200 feet. If these beds are drilled at all, the holes should be drilled from the west at 45° and planned to cut the beds at considerable depth.

Summary. Among the areas suggested for testing, the Sutton No. 2 and the Uncle Sam deposits are the most likely to yield returns in ore reserves blocked out. Exploration in the Springer Gulch area may also yield data from which a tonnage of reserves can be calculated, but it is probable that unless exploration is intensive, the results will indicate only the position, and not the extent of ore bodies. As this area is in the zone of rich deposits, it seems worth recommending for exploration, but only as secondary to the testing of the Sutton No. 2 and the Uncle Sam. The discovery of valuable deposits in the East Bed or the West beds would imply either a considerable extension of the mainore zone or perhaps a new zone related to a different granodiorite body. Exploration of these beds might thus serve to establish new ore bodies, but the returns seem very uncertain.

Attempts to estimate ore reserves in the Mill City district are favored by the tabular form, uniform thickness, and one-time continuity of the mineralized limestone beds. The ore is easily recognized, and the use of the ultraviolet lamp makes possible a rough separation of high- and low-grade ore. Unfavorable features are the interruption of beds by faults and intrusions, and the unpredictable vagaries of mineralization and ore deposition within the beds. The value of any ore reserve, either commercial or sub-commercial, that may be developed, is enhanced by the fact that the deposits are in an active mining and milling district.

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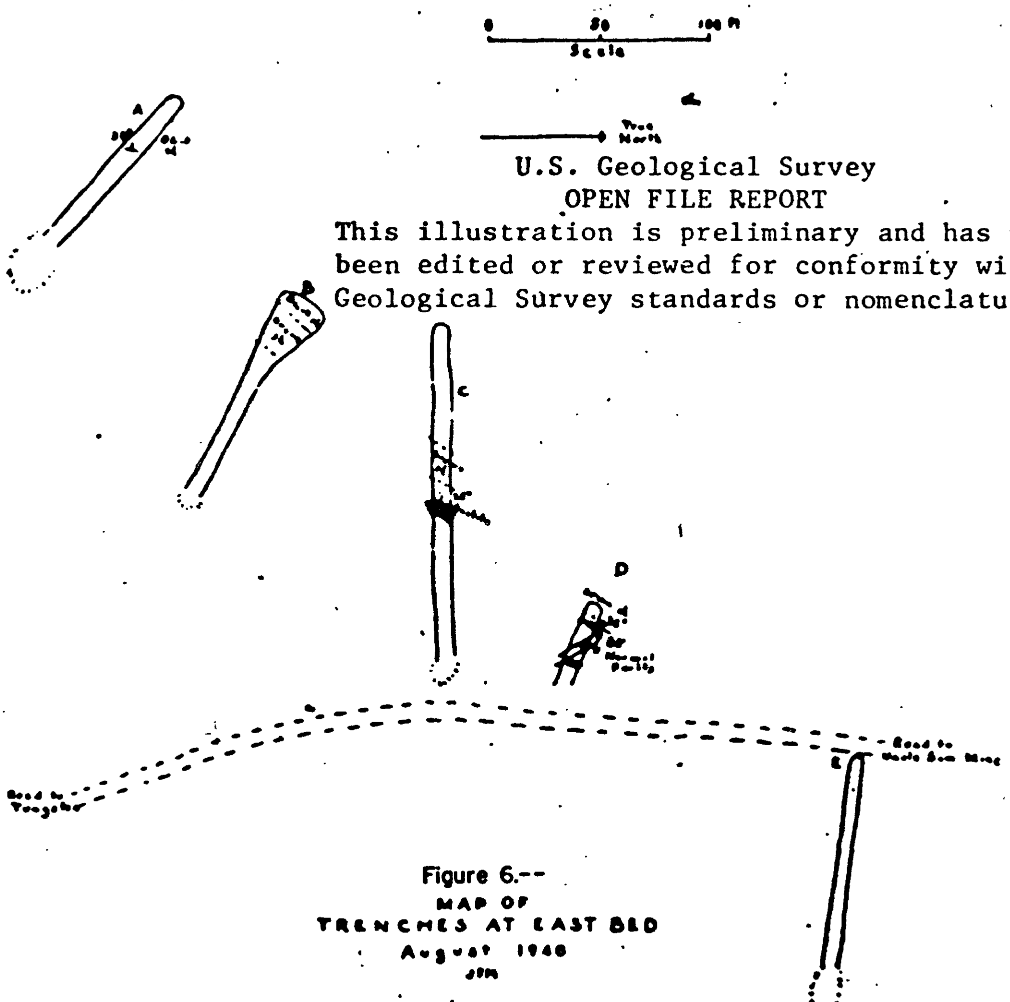

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This illustration is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

Figure 6.--
MAP OF
TRENCHES AT EAST BED
August 1948
JRM