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TUNGSTEN DEPOSITS OF THE BENTON RANGE, MONO COUNTY CALIFORNIA

BY

DWIGHT M. LEMMON

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TUNGSTEN DEPOSITS OF THE BENTON RANGE, MONO COUNTY, CALIFORNIA

By Dwight M. Lemmon

ABSTRACT

Tungsten occurs in the southern part of the Benton Range in tactite bodies formed by the metamorphism of limestone. A series of altered sedimentary rocks of unknown age, containing schist, micaceous quartzite, limestone, and marble, has been intruded by late Jurassic granite. Of the four scheelite deposits found prior to 1940, only one, that at the Black Rock mine, has been productive, although another, on the Coos claims, is being developed. The geologic setting is favorable for the discovery of other deposits.

At the Black Rock mine the limestone and the tactite masses must have been folded into an anticline broken by many small faults. In the main workings three ore bodies have been found, in three different beds, the most productive of which underlies a conspicuous fault that parallels the bedding. Six isolated outcrops of ore that have not been prospected occur on the property, and they may indicate the presence of one or more additional ore bodies. The proved ore does not exceed 10,000 tons and averages less than 1 percent of WO_3. The possible ore reserves may amount to several hundred thousand tons if some of the isolated outcrops just mentioned prove to be connected underground or if new discoveries are made.

INTRODUCTION

The Benton Range is in the east-central part of the Mount Morrison quadrangle, in Mono County, Calif., between the Sierra Nevada and the White Mountains (fig. 83). The Black Rock mine (fig. 84), the main tungsten producer, is 8 miles south of Benton and 3 miles southwest of Yellowjacket Spring, which is in the White Mountain quadrangle. The mine is connected by a good dirt road with Hammil, which is a station on the narrow-gage Owens Valley branch of the Southern Pacific Railroad. The railroad extends southward from Benton Station, through Owens

Valley, to Owenyo, where it connects with standard-gage tracks. Bishop, a town of 2,500 people, lies 35 miles south of Benton by road.

Scheelite was discovered in the vicinity of the Black Rock mine in 1917,[1/] but the deposits were not developed at that time. A. E. Beauregard relocated the Black Rock property in 1928 and worked it intermittently until 1936, when he sold it to the

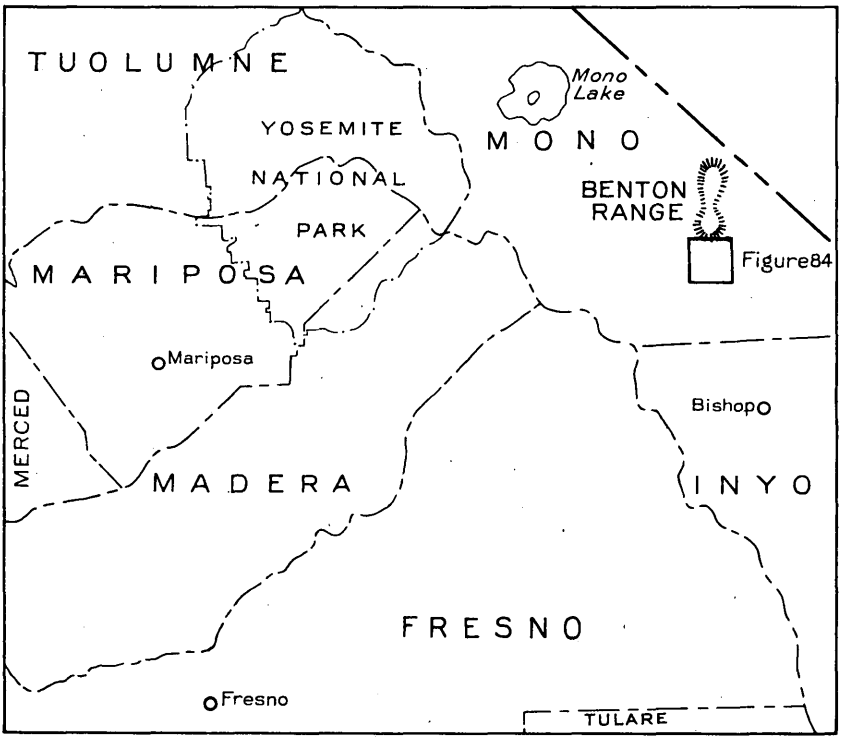

Figure 83.—Index map showing location of Benton Range.

Tungsten Corporation of California, the present operators. A 150-ton mill was completed in December 1937 and has operated at about half capacity since then except for a 5-month period in 1939-40 during which the property was idle.

During the main productive period, 1938-40, the output was 4,178 units of WO_3 in 1938, 6,072 units in 1939, and 1,226 units

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1/ Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725-D, pp. 276-277, 1921.

in the first half of 1940. The production prior to 1938 may have amounted to as much as 1,000 units.

In October 1939 the writer, assisted by Mackenzie Gordon, Jr., and John V. N. Dorr 2d, mapped the surface geology at the Black Rock mine (pl. 88), surveyed the underground workings, and made a reconnaissance map of the surrounding township, using the Mount Morrison topographic sheet as a base. The area was

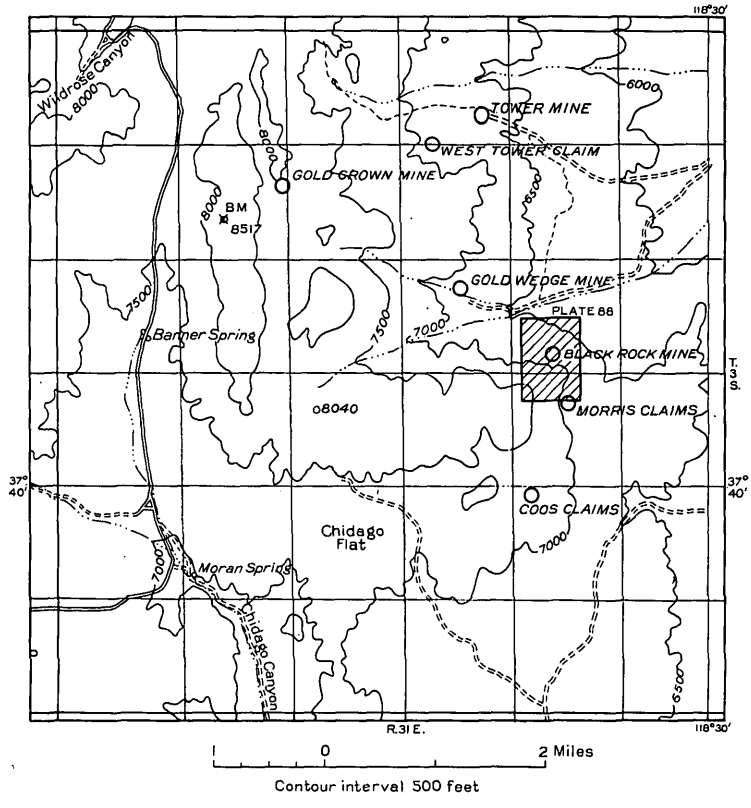

Figure 84.—Sketch map of part of Benton Range showing location of mines and prospects and of area covered by plate 88.

revisited for a few days in June 1940.

The writer is indebted to the Tungsten Corporation of California, operators of the Black Rock mine, for permission to use the results of their surveys and other information. His thanks are also due to A. E. Beauregard and others in the district for the benefits gained by discussing local problems with them.

GEOLOGY

Rocks

The east slope of the southern part of the Benton Range consists mainly of folded and faulted metamorphic rocks and of granite intruded into them. All these rocks are cut by dikes of aplite, rhyolite, and diabase. The metamorphic rocks are dominantly schist and quartzite associated with less abundant limestone and tactite. The tactite, commonly composed largely of garnet and epidote, has been formed by the metamorphism of limestone. Tertiary and Quaternary volcanic rocks consisting largely of rhyolite tuff and basalt flows now surround the range, and remnants of tuff are found within the range itself.

Although granite constitutes most of the northern part of the range, the metamorphic rocks predominate at the south end, and here the granite, which probably underlies the entire area, crops out only in isolated patches. The metamorphic rocks can be roughly divided into three units: (1) a lower schist and quartzite, (2) an intermediate limestone, now largely metamorphosed to tactite, which contains the tungsten ore, and (3) an upper schist and quartzite. The thickness of none of these units is definitely known, but the limestone appears to be at least 700 feet thick at the Black Rock mine.

The noncalcareous metamorphic rocks have a rude schistosity parallel to the bedding that suggests metamorphism prior to folding and intrusion. The bedding and schistosity are indistinct near the granite. The lower part of the limestone is siliceous; the upper part contains a prominent white to bluish-gray crystalline bed 100 feet thick. The limestone has been brecciated and tightly folded, as is most conspicuously shown in the crystalline bed. Where the limestone beds are near the granite intrusion, abundant tactite, composed largely of

variable amounts of garnet, epidote, amphibole, pyroxene, and calcite, has been formed.

No fossils have been found in the metamorphosed sedimentary rocks, and their age is unknown. The intrusive granite is probably Upper Jurassic, the age commonly assigned to the Sierra Nevada and White Mountain batholiths. The rhyolite and diabase dikes are connected with the Tertiary volcanic rocks. The scheelite bodies, being genetically related to the granite intrusion, are also probably of Upper Jurassic age.

Most of the granite is a light-colored, even-grained, nonporphyritic rock composed of quartz and feldspar with small amounts of biotite. In the small mass west of the Black Rock mine, biotite and other dark minerals are nearly lacking, and the rock might be called an alaskite. A small body of granite porphyry containing feldspar phenocrysts several inches long in a matrix of quartz and feldspar with scattered flakes of biotite occurs southeast of Chidago Flat, in parts of secs. 26, 27, 34, 35, and 36, T. 3 S., R. 31 E.

Structure

The Benton Range is a fault block bounded on the east and west by normal faults. Although the crest is 8,307 feet above sea level, 3,800 feet higher than the adjoining part of Owens Valley, the range is dwarfed by the White Mountains to the east and the Sierra Nevada to the west, the crests of both of which are more than 13,000 feet above sea level.

The internal structure of the range is complicated by folding, faulting, and intrusion. North-pitching folds have repeated the limestone three times, outcrops of it being found both east and west of the belt in which the Black Rock mine is located. Intricate folding of thin limestone beds near the Tower mine suggests that thrust faulting has occurred there, though no thrust fault has actually been found.

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Ore deposits

General features.--The only productive scheelite deposits thus far discovered are at the Black Rock mine and on the Coos claims, now being developed by the Bishop Tungsten Co., though scheelite has been found in small amounts on the West Tower claims (Otey group) and on the Morris claims north and south, respectively, of the Black Rock mine. The known occurrences of scheelite are rather few, and all of them lie within a rectangular area 3½ miles long by 2 miles wide, but outcrops of tactite and metamorphosed limestone that may contain scheelite occur almost throughout T. 3 S., R. 31 E. (See fig. 84.) It seems likely that additional deposits will be found in this favorable geologic environment.

Veins near the tungsten deposits have been worked on a small scale for gold, silver, and lead. They are mainly in the Gold Crown and Gold Wedge gold mines, the Tower silver and lead mine, and the mines of the Chidago district which have produced gold, silver, and lead. Only the Gold Crown mine and a few small properties in the Chidago district are now being operated. Several million dollars in silver has been produced from Blind Spring Hill, which is about 5 miles northeast of the area here described.

Origin of the tungsten ores.--The tactite bodies were formed by metamorphism of the limestone during intrusion of the granite. Probably the scheelite itself was introduced at a late stage in the process and the ore bodies were localized primarily by the physical characteristics of certain beds, especially porosity and fractures. The localization of ore shoots was probably determined in part by minor cross fractures.

Most of the tactite is barren. The ore bodies, which constitute an insignificant part of the tactite zones, do not form prominent outcrops, but several barren tactite beds 20 to 100

feet thick project above the detritus-covered slopes. The intensity of metamorphism varies along the strike of some of these barren beds, possibly with distance from the underlying granitic intrusive.

MINES AND PROSPECTS

Black Rock mine

Structure.--At the Black Rock mine the metamorphosed sedimentary rocks have been folded into a north-plunging asymmetric anticline with a core of limestone and tactite and with limbs of overlying schist (pl. 88). The west limb of this anticline has been intruded by a mass of granite with an outcrop about a mile long and half a mile wide. The granite is in contact with the schist at the surface, and it presumably cuts across the limestone and the ore at a relatively shallow depth.

The outcrop of the limestone-tactite zone is about 1,200 feet wide. Most of this width is occupied by tactite, much of which is very resistant to erosion. Persistent beds of light-colored, massive, crystalline limestone lie on both flanks of the fold, and a few beds of shaly limestone are found near its axis. The generally poor exposures, coupled with metamorphism and faulting, make correlation of individual beds impossible without more surface stripping or underground development. The contact between the schist and limestone at the north end of the structure is broken by small faults of indeterminate character, and there is considerable faulting within the fold.

A much-altered rhyolite dike that crops out above the glory hole is crossed by the workings on level C. This dike cuts through the ore body and the overlying limestone and tactite. Several diabase dikes also are present in the mine and cut the ore body, but they appear to be cut off by the hanging-wall

fault. Other deeply weathered diabase dikes have been found in surface cuts but cannot be mapped without trenching.

Ore bodies.--The mine is developed by four adits. The lowest of these, level A (pl. 89), is 290 feet long and contains no ore, but it is probably at least 100 feet too short to reach the ore body discovered in the workings on level B (pl. 89), 119 feet above. A little ore has been produced from a short development drift on level B, but most of the ore has come from the workings reached from level C (pl. 89), which lies about 800 feet south of the lower levels and is not connected with them. Three scheelite zones were intersected in the long level C adit, but only the one farthest west has been developed. This western zone has been stoped up to level D (pl. 89), and to the surface 190 feet above, where there is a glory hole from which much of the ore has been taken.

The western ore zone dips 25° W. Its hanging wall is a large pre-mineral fault that apparently follows the bedding in the massive, light-colored, unaltered crystalline limestone above the fault. The ore consists largely of a mass of crushed tactite breccia as much as 15 feet thick. It includes some massive tactite ore, the thickness of which is variable but which attains a maximum of 20 or 25 feet. The breccia contains pieces of limestone in a matrix of gouge. Both the ore and the hanging-wall fault are offset by at least one steep fault, the displacement on which is about 30 feet.

The other two ore zones found in the level C adit appear to dip more steeply than the western zone and are not bordered by large faults. The ore in them is much harder than that in the western zone and is not brecciated. The body nearest the portal is exposed at the surface and in a small glory hole, but this hole unfortunately is mainly in the footwall of the ore. The middle ore body is 190 feet wide, but only about 15 feet of

its middle part is of commercial grade; the rest is of very low grade, containing not more than 0.1 percent of WO_3.

In addition to the four partly developed ore bodies mentioned thus far, there is at least one other that is undeveloped. Scheelite has been found in five outcrops distributed along a distance of 2,000 feet from north to south, but the outcrops are all surrounded by overburden and probably do not represent five separate ore bodies. No systematic sampling has been done, and no adequate trenching program has been undertaken, to determine whether the isolated outcrops are connected beneath the surface. That some of them are connected seems likely because the ore zones are softer in general than the adjacent barren garnet rocks and do not crop out prominently.

The ore produced has probably contained, on the average, about 0.5 percent of WO_3, but its grade varies widely; some small bodies contain as much as 1.0 percent of WO_3, and some large masses contain as little as 0.1 percent.

Minerals.--The ore at the Black Rock mine is a scheelite-bearing tactite, which consists, in the main, of the same silicate minerals as the adjoining barren tactite. The chief minerals in the ore, listed in order of abundance, are garnet, amphibole, diopside, calcite, epidote, quartz, and scheelite. In addition there are variable amounts of sulfides, chlorite, and probably nontronite.

Scheelite, the only ore mineral, forms crystals disseminated through the tactite. A few of the crystals are as much as half an inch in diameter, but most of them are microscopic.

Garnet, probably in the grossularite-almandite range, is the most abundant mineral, constituting more than 80 percent of the ore.

Amphibole, dark greenish in hand specimens, is everywhere abundant.

Diopside, identifiable only microscopically, occurs in minor quantities.

Pyrite, the commonest sulfide, is locally abundant.

Chalcopyrite is present in minute quantities only, for copper-stained surface material is rare.

Molybdenite has not been identified in the Black Rock mine, although it is common on the Morris claims, 2,000 feet southeastward, where it forms rosettes an inch in diameter.

Powellite ($CaMoO_4$) is probably the source of the fraction of a percent of MoO_3 that is present in the concentrates, for the mineral is abundant on the Morris claims, and both molybdenite and powellite are common associates of most of the scheelite ores in the Bishop area, 35 miles south of Benton.

A pale-green microcrystalline mineral found in parts of the oxidized ore bodies and also in some of the adjoining rock appears to be nontronite, essentially a hydrous ferric silicate. The same mineral occurs on the Coos claims and in the oxidized parts of many tungsten ore bodies in the Bishop region.

Epidote is scarce or absent in the ore, though it is abundant in some of the tactite beds.

Reserves.--The Black Rock mine contains the only appreciable proved ore reserve in the range. Information concerning probable and possible ore is meager because of lack of development. No estimate of possible tonnage can be made in the absence of adequate surface trenching and underground development, for the surface above and between known ore bodies is covered with detritus several feet thick. If the known ore bodies prove to be partly interconnected, there may be several hundred thousand tons of ore in reserve. The depth at which granite cuts off the ore beds is unknown, but the width of the surface exposures indicates that some of the beds probably extend many hundred feet beneath the outcrop. The west ore body is probably cut

off by granite within a few hundred feet, on the dip, below level C.

Little ore is blocked out in advance of mining; not more than 10,000 tons of ore, which averages less than 1 percent of WO_3, can be considered as proved. Most of this proved ore lies in the west ore body above level C.

Morris claims

Adjoining the Black Rock mine to the south are several unpatented claims, held by Sam Morris and associates, on which traces of scheelite have been found, at a different stratigraphic horizon from the Black Rock ores. Surface debris, which is thicker here than at the Black Rock mine, may cover extensions of some of the Black Rock ore bodies, but no attempt has been made to find them.

The main workings consist of two open cuts, 40 and 25 feet long, an adit 60 feet long, and many pits. The larger open cut is in tactite that contains molybdenite and powellite but no scheelite. The powellite has been formed by oxidation of molybdenite. It fluoresces strongly with ultraviolet light but can be distinguished from scheelite by a yellower color in fluorescent light and by the way it powders when rubbed with the fingers. The powellite on the Morris claims appears to be tungsten-free. The adit, also barren of scheelite, intersects a garnet zone containing many seams and vugs that are lined with light-brown epidote crystals. Many of the joints and seams are thinly coated with fluorescent hyalite opal.

Coos (Granite) claims

The Granite, Granite No. 1, and Granite No. 2 claims, owned by the J. A. Coos estate but now under lease to the Bishop Tungsten Co., lie south of the Black Rock mine, on the ridge between

the Morris claims and Chidago Flat. A small mass of metasedimentary rocks, consisting of quartz schist and of thin-bedded limestone in which lime silicates have been formed along bedding planes, is engulfed in granite. The beds strike N. 18° W. and dip 27° NE. The ore zone appears to be 70 feet wide at the surface on the top of the hill, and its stratigraphic thickness is about 35 feet. The deposit is cut by a rhyolite dike 10 feet thick and is overlain by several feet of loose surface material.

The ore is oxidized, soft, and rusty and consists largely of thin-bedded limestone with minor amounts of lime silicates. Although the ore is reported to contain more than 1 percent of WO_3, the appearance of much of it when examined with an ultraviolet lamp suggests a lower content.

In July 1940 there were a few surface trenches and pits on the top of the hill. A short adit about 50 feet below the crest was being driven across the ore zone from the north, and a shaft had been started to the west, but not enough work had been done to delimit the deposit. There was about 8,000 tons of probable ore in sight, and there might be another 20,000 tons of ore on the property. The favorable limestone beds may be cut off within 100 feet beneath the outcrop and also within a short distance along the strike.

Otey (West Tower) claims

Scheelite has been found in small tactite bodies and in quartzose lenses on the West Tower claims, owned by J. W. Otey, in secs. 3 and 10, T. 3 S., R. 31 E., near the northern limit of the metamorphic rocks. The only workings on this property are a shaft 26 feet deep and a few shallow pits. The best ore was found in the shaft, but it pinched out in the bottom, and the ore body was apparently limited to the shaft cross section by a dike and a fault. No continuation has been found on the

surface, but this may be due to the complex structure, which makes it difficult to follow ore zones. More extensive surface prospecting seems warranted.