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TUNGSTEN DEPOSITS IN THE SIERRA NEVADA NEAR BISHOP CALIFORNIA

A PRELIMINARY REPORT

BY
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CONTENTS

	Page
Abstract	79
Introduction	79
Geology	82
Reserves	88
Mines and prospects	89
Deposits near Pine Creek	89
Pine Creek mine	89
Adamson claims	91
Pine Creek Canyon prospects	92
Tungstar mine	93
Millovitch prospect	94
Carpenter and Brown prospect	95
Prospects on the southeast side of Mt. Tom	95
Deposits north of the Pine Creek area	96
Round Valley Peak deposit	96
Hilton Creek prospect	97
McGee Mountain prospect	99
Other prospects	100
Deposits south of Bishop	100
Pickup mine	100
Rossi mine	102
Coyote valley prospects	103

ILLUSTRATIONS

		Page
Plate	13. Index map of southern California showing location of Bishop region and plate 14	82
	14. Map of parts of the Bishop, Mt. Goddard, and Mt. Morrison quadrangles showing location of tungsten properties	In pocket
	15. Geologic map and section of the vicinity of Pine Creek mine, Inyo County, Calif.	In pocket
	16. Geologic map of the Pine Creek pendant	In pocket
	17. Photograph showing the Pine Creek pendant on the north side of Pine Creek, Inyo County, Calif.	90
	18. Geologic map of level A of the Pine Creek mine	90
	19. Geologic map and sections of the Tungstar mine	98
Figure	7. Geologic sketch map of Round Valley Peak deposit	96
	8. Geologic map of Hilton Creek deposit	98
	9. Geologic map of the Pickup mine	101

TUNGSTEN DEPOSITS IN THE SIERRA NEVADA NEAR BISHOP, CALIFORNIA

A PRELIMINARY REPORT

By Dwight M. Lemmon

ABSTRACT

Scheelite ore bodies occur at widely separated localities in the Sierra Nevada near Bishop, Calif. The scheelite is found in altered sedimentary rocks at or near the contact between granitic rocks and limestones that are partly changed to silicate rocks composed largely of garnet. Mineralization was closely connected with the intrusion of the granite, the latest of the varied intrusives that make up the rocks of the Sierra Nevada.

The deposits in the High Sierra, at altitudes of 10,000 to 13,000 feet, are now the most productive and contain large reserves. They occur along the borders of a discontinuous septum of metamorphic rocks which extends along the crest of the Sierra Nevada for nearly 50 miles. The great vertical extent of parts of this septum exposed in deep canyons indicates that some of the ore bodies may extend to many hundreds or even to thousands of feet in depth.

The Pine Creek mine of the United States Vanadium Corporation has the largest proved reserve of any tungsten mine in this country, and now has a milling plant capable of producing annually at least 2,500 tons of concentrate, containing 60 percent of WO_3, from low-grade ore. The proved reserves of milling ore on the property amount to several million tons. The combined reserve tonnage of all the other deposits described in this report is probably at least 750,000 tons containing about 0.5 percent of WO_3, and these reserves will presumably be increased by downward development of the known deposits and discovery of new ore shoots. These estimates are based on surface exposures, for most of the deposits are entirely undeveloped.

INTRODUCTION

The area described in this report (see pl. 13) is in a part of the Sierra Nevada that lies in Inyo and Mono Counties, Calif., and includes Bishop, a town of 2,000 people at the north end of Owens Valley. The region is readily accessible from Los Angeles and from Reno, Nev., by surfaced U.S. Highway 395, and is also served by a narrow-gauge branch of the Southern Pacific Railroad that passes through Laws, 4 miles northeast of Bishop.

This report describes the tungsten deposits adjacent to Pine Creek and near the crest of the Sierra Nevada. Also included are brief summaries of other prospects in extensions of the same narrow belt, and of mines and prospects southwest of Bishop. The region covered includes parts of the Mt. Morrison, Mt. Goddard, and Bishop quadrangles (pl. 14).

About two months in the autumn of 1939 and summer of 1940 were spent in the study of the deposits described in this report. Mackenzie Gordon, Jr. and John Van N. Dorr 2d assisted in the field work in 1939, Donald Wyant in 1940. All productive tungsten deposits, and most of the known occurrences, were visited. A topographic and geologic map of the vicinity of the Pine Creek mine (see pl. 15) was made by alidade-stadia survey, and a regional geologic map, of which plate 16 is a part, was started on an aerial photograph base.

Mine owners and operators, prospectors, and many local residents have aided the field work by giving information, by providing lodging, and by furnishing guidance or transportation into the less accessible parts of the region. The writer is particularly indebted to A. E. Beauregard and Joseph Smith of Laws; to D. B. Adamson, C. N. Aldo, Charles Bretz, B. W. Holeman, A. H. Petersen, Ray W. Phelps, H. A. Van Loon, and A. T. Wilkerson of Bishop; to Blair Burwell, Don Emigh, J. M. Hill, Baxter Lewis, and M. N. Shaw of the United States Vanadium Corporation; to W. B. Lenhart, J. B. Gruedel, and W. B. Phelps of the Tungstar Corporation; to E. H. Carpenter; and to J. L. McCullough of Independence. His thanks are also due to F. C. Calkins and H. G. Ferguson, of the Geological Survey, for much helpful advice and criticism during the preparation of this report.

Some of the deposits included in this report have been described by Knopf [1] and by Hess and Larsen.[2] The writer has recently published preliminary reports on productive deposits in the nearby Tungsten Hills [3] and Benton Range.[4] Tucker and Sampson [5] included the tungsten mines in their report on the mineral resources of Inyo County. The general geology of portions of this area or of adjoining regions has been described in papers by Knopf,[6] Mayo,[7] Chapman,[8] Gilbert,[9] and Erwin.[10]

Tungsten was discovered at the Pine Creek mine in 1916. A mill was built and the mine partly developed in 1917, but operations were discontinued when the price of tungsten dropped at the close of the war. Many of the other deposits described in this report were discovered during the 1916-18 excitement, but none were productive at that time. The Pine Creek mine has again been operated since 1936; the Tungstar mine started production in December 1939; the Rossi mine was operated from 1936-39; and the Hilton Creek, Chipmunk, and Shannon Creek deposits produced small amounts of shipping ore during 1940.

The production figures available at the present time are incomplete, but the total to 1941 is thought to be on the order of

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1/ Knopf, Adolph, Tungsten deposits of northwestern Inyo County, California: U. S. Geol. Survey Bull. 640, pp. 229-249, 1917.

2/ Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, pp. 268-274, 1921.

3/ Lemmon, D. M., Tungsten deposits in the Tungsten Hills, Inyo County, California: U. S. Geol. Survey Bull. 922-A, pp. 497-514, 1941.

4/ Lemmon, D. M., Tungsten deposits of the Benton Range, Mono County, California: U. S. Geol. Survey Bull. 922-S, pp. 581-593, 1941.

5/ Tucker, W. B., and Sampson, R. J., Mineral resources of Inyo County: California Jour. Mines and Geology, vol. 34, pp. 368-500, 1938.

6/ Knopf, Adolph, and Kirk, Edwin, A geologic reconnaissance of the Inyo Range and the eastern slope of the Sierra Nevada, California: U. S. Geol. Survey Prof. Paper 110, 1918.

7/ Mayo, E. B., Geology and mineral deposits of Laurel and Convict basins, southwestern Mono County, California: California Jour. Mines and Geology, vol. 30, pp. 79-88, 1934.

8/ Chapman, R. W., The contact-metamorphic deposit of Round Valley, California: Jour. Geology, vol. 45, pp. 859-871, 1937.

9/ Gilbert, C. M., Welded tuff in eastern California: Geol. Soc. America Bull., vol. 49, pp. 1829-1862, 1938.

10/ Erwin, H. D., Geology and mineral resources of northeastern Madera County, California: California Jour. Mines and Geology, vol. 30, pp. 7-78, 1934.

100,000 units [11/] of WO_3. The Pine Creek mine has been the most productive, followed by the Tungstar mine and the Rossi mine. Production from other properties has been insignificant.

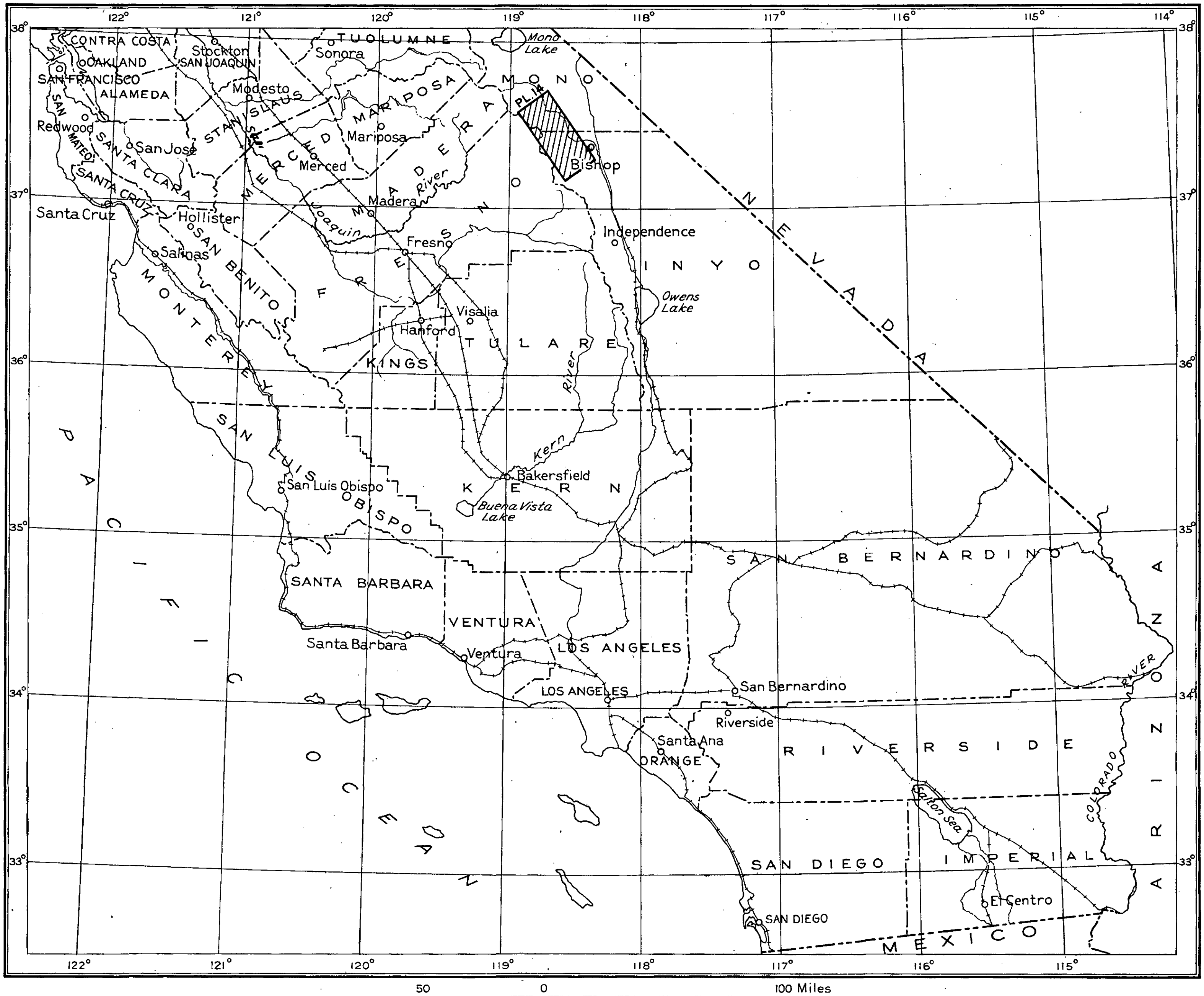
The abrupt, rugged topography of the east side of the Sierra Nevada, with a relief of 10,000 feet, has hindered the development of the many prospects along the crest of the mountains. The cost of roads is generally prohibitive, and the expense of building aerial tramways is high. Small deposits of moderate grade have been worked profitably in the foothill region, where it is possible to use central milling facilities, but along the crest, at elevations of 9,000 to 13,000 feet, deposits must be large or of high grade to be profitable.

GEOLOGY

The Sierra Nevada near Bishop is composed dominantly of Jurassic granitic rocks, including granodiorite, granite, and quartz monzonite. There are lesser masses of more basic rocks, largely diorite, but also including gabbro and quartz diorite. The general sequence of intrusion is from basic rocks to acidic rocks: from diorite through granodiorite and quartz monzonite to granite, the latest major intrusive.

A discontinuous septum of metamorphosed sedimentary rocks can be traced from the Mammoth area south nearly to Independence. This septum, individual segments of which are frequently called roof pendants because they represent remnants of the roof rocks that were invaded by the plutonic complex, consists of altered limestone, shale, and sandstone, probably ranging in age from Cambrian to Triassic. Individual pendants vary from small bodies a fraction of an acre in size and only a few tens of feet deep to great elongated masses several square miles in area and a mile or more deep.

11/ A unit is 20 pounds of WO_3. A 1-percent ore contains one unit to the ton.



INDEX MAP OF SOUTHERN CALIFORNIA SHOWING THE LOCATION OF BISHOP REGION AND PLATE 14

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Hornfels predominates among the metamorphosed sedimentary rock types, but quartzite, schist, and marble are also common. The limestone and marble are usually altered near the granitic contacts to silicate rocks composed essentially of calcium-iron-aluminum silicates formed by additive thermal metamorphism. These contact zones contain the tungsten ore bodies.

A large segment of the septum of metamorphosed sedimentary rocks, called the "Pine Creek pendant" (see pl. 16), extends from Wheeler Crest (see pl. 14) south to Horton Creek. This pendant, 5½ miles long and about 1 mile wide at the maximum, is exposed in the deep trench of Pine Creek down to an elevation of 7,500 feet, more than a mile below its highest points.

The north end is interrupted by granitic rocks, which separate it from another small portion of the septum that extends northward toward Rock Creek for another mile before being curved, broken, and offset several miles eastward. Where the Pine Creek pendant is interrupted, granite and quartz diorite finger into the metamorphic rocks, and the general contact appears to dip south.

At the south end near Mt. Tom the pendant is also surrounded by granitic rocks and the southern extension is offset 2 miles southwestward. This end is broader than the north end, and is also more broken by the granitic intrusions. In longitudinal section, the pendant is shallow at both extremities, and deepest near the center.

Near the Pine Creek mine the quartz diorite is an even-grained, dark-gray rock with about 20 percent of irregularly distributed black minerals. Microscopic examination shows that the rock contains about 67 percent of plagioclase (oligoclase), 11 percent of quartz, 11 percent of hornblende, 10 percent of biotite, and 1 percent of accessories (including zircon, sphene, apatite, and pyrite). The dark outcrops of quartz diorite are

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commonly veined by light-colored aplite dikes that are a few inches to a foot thick.

The granite is an even-grained, light-colored rock speckled with evenly distributed, small biotite flakes up to 0.1 inch in size. A section of a typical specimen from southeast of the Pine Creek mine is composed of 58 percent of orthoclase and microcline, 18 percent of plagioclase (oligoclase), 18 percent of quartz, 5 percent of biotite, and 1 percent of accessories (zi con, sphene, pyrite, and apatite). There are a few scattered hornblende crystals, and a small portion of the biotite is altered to chlorite. The centers of some feldspar crystals contain a little sericite. A specimen of granite from the face of the south drift on level A of the mine near the edge of the south ore body contains nearly double the usual percentages of quartz and biotite, but the ratio of orthoclase to plagioclase remains about 3 to 1.

The pendant is made up mostly of metamorphosed argillaceous and arenaceous sedimentary rocks, which now consist mainly of hornfels but comprise some impure quartzite and a few beds of schist. A prominent limestone body, which has a maximum thickness of nearly 1,000 feet but tapers to the north and south, forms the northwest side of the pendant at the Pine Creek mine, and a thinner continuation of it extends southward along the west contact across Pine Creek canyon. Another thin, lenticular bed of limestone is found farther east near the crest of the ridge on the Adamson claims. (See pl. 15.) In a third segment of the pendant, a thick mass of limestone occurs on the southeast side of Mt. Tom on the Horton Creek drainage. (See pl. 16.)

Some scheelite has been found in each of these limestone areas, and also in isolated patches of tactite on Mt. Tom and Gable Creek. The Pine Creek mine, at the north end of the pendant, contains the largest known ore body. None of the other deposits have the same favorable geologic setting for large tonnages of ore, although from time to time they may be large producers of tungsten concentrates from small, high-grade bodies.

In the northern part of the pendant, the steep, even talus slopes which occupy much of the area mapped as hornfels (see pl. 15) are composed of loose, partly platy blocks 6 to 18 inches in size. The hornfels is for the most part a thin-bedded, fine-grained, dark-colored rock composed essentially of quartz and mica but containing a little pyrite, which causes it to weather reddish brown. Locally beds of lighter-colored, coarser-grained quartzite and of tremolite schist are found, but they are relatively insignificant and are difficult to trace.

In contrast to the even slopes in the hornfels, the topography in the marble is characterized by cliffs, rugged spires, and absence of talus. The rock where least altered is dark gray and rather coarsely crystalline, and contains thick beds rich in diopside crystals that form ellipsoidal bundles with a maximum length of half an inch. Locally, lenticular bodies of silicated rock 5 to 15 feet thick and 100 feet or more long extend along the bedding. This rock is mostly fine-grained and dark gray, and weathers reddish brown; it consists of quartz, albite, diopside, and pyrite. The bedding visible on weathered surfaces of the marble dips in general steeply eastward, parallel to that of the hornfels, but it is sharply contorted in places along the west contact with granitic rocks.

The contacts between the granite and the quartz diorite are easily distinguished because of the sharp color difference. The quartz diorite, which was intruded first, now occurs only in discontinuous masses along the contact between the pendant and granite and in a narrow elongate body which lies in the granite a mile to the west. (See pl. 16.) The contact between limestone and granitic rocks dips eastward about 80°, at about the same angle as the limestone; but the rocks are not strictly concordant, for the strike of the contact diverges from that of the beds at a small angle and in two places turns abruptly from its nearly straight course to form deep embayments in the limestone.

It is frequently possible to identify three zones of metamorphism in the limestone-granite contact zones:[12/] (1) a sharply defined zone of dark silicates (called tactite [13/]) extending away from the granite for a distance ranging from a few inches to 100 feet or more; (2) an intermediate, narrower, less well defined zone of light-colored silicates; and (3) a zone of marble, recrystallized without addition of material. The second zone may be absent, and usually has gradational contacts with the third.

The dark silicate, or tactite, zone contains various proportions of some of the following minerals: Garnet (usually almandite), diopside (varying toward hedenbergite), epidote, hornblende, clinozoisite, idocrase, quartz, fluorite, sphene, scheelite, pyrite, pyrrhotite, chalcopyrite, molybdenite, and bornite. The adjoining light-colored silicate zone contains tremolite, wollastonite, colorless diopside, clinozoisite, idocrase, colorless garnet, quartz, and calcite. The third zone consists chiefly of recrystallized calcite with minor amounts of quartz and silicates formed from impurities originally present in the rock. Scheelite, ($CaWO_4$), which is the only tungsten-bearing mineral recognized, and the sulfides usually occur only in the tactite zone.

It is thought that the main alteration was brought about at a late stage by hot solutions penetrating the granite-limestone contacts after the granite shell had solidified, that these solutions penetrated the limestone mainly by way of fault fissures and bedding planes, and that a progressive change in solutions caused the minerals to form in the following general order: Garnet, diopside, hornblende, idocrase, quartz and

12/ Hess, F. L., and Larsen, E. S., op. cit., pp. 251-255.
13/ Hess, F. L., Tactite, the product of contact metamorphism: Am. Jour. Sci., 4th ser., vol. 48, pp. 377-378, 1919.

scheelite, sulfides, and veins of quartz and calcite. The ore minerals were introduced after the crystallization of the main bulk of the tactite, and their distribution was governed by the channels open at that time.

In some deposits the contact rocks replace nearly pure limestone; here the minerals present indicate that the altering solutions introduced silicon, iron, aluminum, titanium, tungsten, and sulfides, in quantities decreasing with distance from the contact. At the same time, there must have been removal of some lime (CaO) and carbon dioxide (CO_2).

Within a short distance along the strike the width of a tactite body may range from a few inches to many feet without important change in general structure or country rock. This indicates that the granite at the contact was not directly responsible for the metamorphism but had largely solidified before the formation of the contact rocks by later ascending solutions. The more permeable portions of the contact received greater additions of material, now represented by a thicker contact zone. The channels for the introduction of solutions had to remain open to permit formation of ore bodies, for the ore-bearing so- lutions were introduced near the end of the process. The absence of scheelite or other ore minerals in many tactite bodies indicates that the channels were sealed before tungsten and sulfide solutions reached them. Continued shearing of the brittle earlier minerals, among which garnet predominated, helped keep passageways open until the final mineralization. In some posits post-mineral faulting continued the same general shearing, but in others, where post-mineral faulting is absent, there is no existing proof that shearing occurred prior to the deposition of scheelite.

At the Pine Creek mine quartz diorite, the earlier intrusive, exerts a blanketing effect on the tactite which decreases below commercial width and grade where the quartz diorite intervenes between limestone and granite. On the surface in the main ore bodies the tactite in direct contact with granite is as much as 60 feet thick, but south of the open pit, where quartz diorite is present, the tactite thins to 2 feet in a short distance. Solidification of the quartz diorite may have formed a contact zone that was comparatively impermeable to the later replacing ore solutions emanating from the biotite granite.

RESERVES

The Pine Creek mine of the United States Vanadium Corporation contains the only large proved ore body in the Bishop region. This ore body is many times larger than any other that is known to exist in the region. Completion of the milling plant that is now being built will permit annual production in excess of 2,500 tons of 60 percent WO_3 concentrate. The developed part of the ore body, as it contains several million tons, would feed the mill for more than 10 years at this rate. Nothing is known of the extent of the ore beneath the main adit level, but the shape of the pendant suggests that ore bodies may be found as deep as 2,000 feet beneath the present workings, thus expanding the possibilities of the mine two or three times.

The combined tonnage of probable ore indicated by surface exposures of all the other deposits described is about 750,000 tons, the average grade of which approximates 0.5 percent of WO_3. Underground development in several of the deposits may double this amount, for prudent estimates of only 50 to 200 feet have been allowed for downward continuation because of the geologic uncertainties connected with this type of ore body. Small high-grade masses, such as the one in the Tungstar mine, are difficult to evaluate before mining, and from time to time both known and newly discovered prospects of this type may be important short-term producers.

The known facts concerning the size of the ore bodies are given under descriptions of individual deposits.

MINES AND PROSPECTS

Deposits near Pine Creek

Pine Creek mine

The Pine Creek mine of the United States Vanadium Corporation lies on a branch of Morgan Creek at an elevation of 10,750 feet. It is reached by a steep private road 7 miles long from Pine Creek at Brown's Camp, the terminus of a 20-mile surfaced road from Bishop (pl. 17). A former road, now abandoned, crossed a 12,000-foot divide from Rock Creek on the north.

The mine is developed by four adits at elevations of 10,750, 11,052, 11,135, and 11,371 feet; by sublevels; and by a large open cut. The three lower adits are connected by raises.

The 400-foot embayment in the granite-limestone contact divides the mine into two parts and separates what are called the north and south ore bodies. The south ore body is 400 feet long, over 400 feet deep, and ranges in width from 4 to 60 feet. On the main adit level (see pl. 18) it is entirely surrounded by granitic rocks, which probably cut it off at depth.

The north ore body is 2,500 feet long on the surface, where its width ranges from 10 to 60 feet. Underground it has been developed for 1,000 feet along the strike, and the workings are still in ore at the north limits. On the lowest level, 600 to 700 feet below the surface, the ore is in places more than 100 feet wide.

Up to the summer of 1940 there had been no stoping in the north ore body, all recent production having come from development headings in the north ore body and from the open cut on the south ore body. The south ore body was partially developed and stoped in 1917.

The ore bodies are cut by many steep post-mineral shears, marked by gouge seams but without large offsets. An older set of flat shears, perpendicular to the ore bodies, has been filled with quartz and is now tightly sealed.

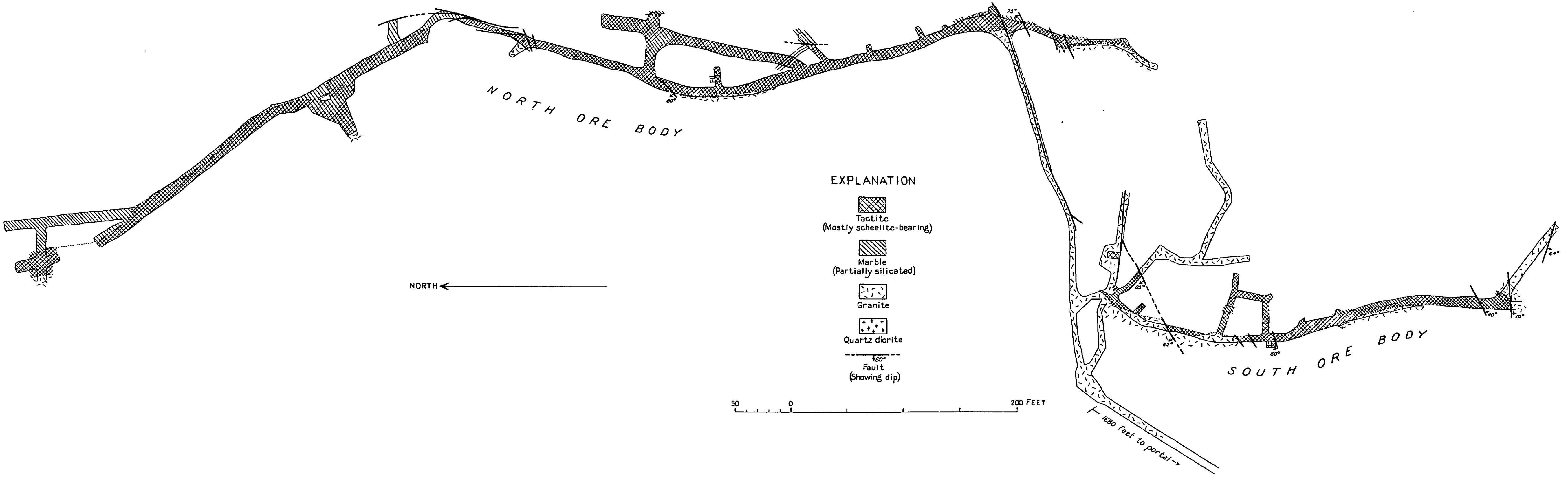
The south ore body rakes southward between the surface and level A. The north ore body will probably also rake in the same direction, for the angle at which granite pitches beneath the north end of the pendant seems to control the ore shoots.

The tactite is composed essentially of garnet with less diopside and minor quantities of scheelite, pyrite, chalcopyrite, molybdenite, bornite, powellite, quartz, and calcite. The ore mined contains, on the average, about 0.5 percent of WO_3, 0.5 percent of MoO_3, and recoverable quantities of gold and copper. The general range in tungsten content is from a trace to 1 percent of WO_3 or more, and the molybdenum content reaches a maximum of 2 percent of MoO_3. Small high-grade masses of molybdenite, more erratically distributed than the scheelite, are found locally in the ore bodies.

The ore is a uniformly medium grained rock with scheelite disseminated throughout in very small grains averaging about 0.01 inch in diameter. The sulfides also are finely disseminated but they also form some fairly large masses. The small grain-size of the scheelite necessitates fine grinding, which makes recovery by gravity concentration low because of loss in slimes. To solve this metallurgical problem, which also includes recovery of the sulfides, the company now makes low-grade scheelite concentrates, as well as sulfide concentrates, by froth flotation and then treats the scheelite concentrate chemically to make a commercial product.

The great width and irregularity of the ore bodies make it advisable to explore the wall rocks in order to make sure that part of the ore has not been isolated by small granite fingers. When the mine is worked at greater depths, it will also be

PINE CREEK PENDANT ON THE NORTH SIDE OF PINE CREEK, INYO COUNTY, CALIF.



GEOLOGIC MAP OF LEVEL A OF THE PINE CREEK MINE

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(Faces p. 90)

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advisable to drill systematically eastward into the limestone on the hanging-wall side of the ore, for other contact zones may lie in this part of the pendant at lower levels. The light-colored silicate lenses found at the surface east of the open cut may be surface expressions of underlying zones of this type. Use of short diamond-drill holes by the company has already proved valuable in exploration: holes drilled westward from level A in 1940 indicate a large mass of ore separated from the north ore body by a thin shell of granite. (Not shown on level map, pl. 18.)

Adamson claims

A group of eight undeveloped mining claims covering the tip (see pl. 15) of the pendant north of the Pine Creek mine are held by D. B. Adamson. On extensions of the same contact as the Pine Creek ore body, tungsten-bearing tactite occurs in a few small thin bodies which are probably cut off by granite at depth. Another tactite bed 15 to 20 feet wide lies farther west, near the crest of the ridge, at an elevation of 12,300 feet. This bed, interstratified with hornfels, contains coarse scheelite crystals for 350 feet south from the contact with quartz diorite. The tactite, with a little molybdenite but no scheelite, extends another 300 feet before disappearing beneath talus. The original limestone bed was probably a lens, for no continuation can be seen beyond the talus on ridges farther south. The depth beneath the ore croppings to diorite or granite will probably average at least a hundred feet; the ore shoot possibly rakes southward along the contact. The ore body is estimated to contain nearly 50,000 tons of ore to a depth of 50 feet, which seems to be a conservative minimum depth. A composite grab sample taken by Mr. Adamson is reported to have assayed 1.5 percent of WO_3.

Near this ore body, on the east side of the ridge and 150 feet below the crest, is a small mass of quartz-diopside rock about 15 feet wide and 50 feet long. Distributed through this rock are irregular masses of scheelite as large as a man's fist. Two tons of sorted ore shipped from this body in 1937 yielded about 20 percent of WO_3. Mr. Adamson's samples indicate that the body contains 3 to 5 percent of WO_3, but the difficulty in obtaining a representative sample in this type of ore body is obvious. There are about 750 tons of ore in sight to a depth of 10 feet; the further downward extent is unknown but probably measurable in tens of feet.

Although ore of good grade, containing at least 50,000 units of WO_3, is in sight, these claims are still undeveloped because of their inaccessibility. The ore exposures are 1,500 feet higher than the end of the United States Vanadium Corporation's road, and 5,500 and 1,500 feet respectively above possible mill sites on Pine Creek and on Tamarack Lake to the north. Heavy winter snows would probably limit operation to six months of the year.

Pine Creek Canyon prospects

Several small undeveloped tungsten prospects lie in the gorge of Pine Creek at the west border of the pendant about three-quarters of a mile west of Brown's Camp and the Tungstar mill (see pl. 16). In the bottom of the canyon is a lenticular body of scheelite-bearing rock 10 to 20 feet wide and perhaps 150 feet long at the contact between granite and marble. The ore is a light-colored, medium-grained aggregate of quartz, fluorite, epidote, diopside, calcite, light-colored garnet, scheelite, and a trace of sphene. The best ore exposed, in a prospect pit on the north edge of the creek, is reported to assay over 3 percent of WO_3 for a width of 10 feet. Not enough work had been done by 1940 to prove the size of the ore body.

A quarter of a mile to the north, on the wall of the canyon, are several small discontinuous lenses of tactite 20 to 50 feet long and a few feet wide, none being of sufficient size to encourage exploitation. The ore contains abundant plagioclase feldspar in addition to the minerals found in the other prospect.

These deposits differ from others in the region in the absence of dark silicates and the abundance of fluorite, quartz, and feldspar.

Tungstar mine

The Tungstar mine is on the west shoulder of Mt. Tom, at an elevation of about 12,000 feet. The mine is reached by trail from the mill, which is at Brown's Camp, on the Pine Creek road, about 5,000 feet lower and 2½ miles distant by air line. A small aerial tram connects the mine and mill.

The ore bodies are two tactite lenses between granite and quartz diorite (pl. 19). Only the lower one of these, the Greene ore body, had been mined in July 1940. Its dimensions on the surface are roughly 100 feet long and 20 to 40 feet wide, and the greatest depth below the outcrop at which ore has been developed is 60 feet.

The mine workings consist of an adit 135 feet long, an intermediate sublevel 50 feet above the adit and 100 feet long, two raises aggregating 150 feet, and an open-cut stope averaging 30 feet deep, 30 feet wide, and 100 feet long. The adit contains no ore, but the intermediate level is mostly in ore. The downward limits of the ore body are unknown, but the shape of the part that has been worked suggests that the ore will be cut off by granite at slight depth. By February 1941 approximately 17,000 tons of ore averaging 2.6 percent of WO_3 had been produced since the beginning of operations in December 1939.[14/] The ore contains unusually coarse masses of scheelite, and is also rich in sphene.

The upper, undeveloped mass, known as the Stevens ore body is 200 feet long and 30 to 95 feet wide at the surface. It is composed of irregular, scheelite-bearing silicate zones in barren marble. Although the parts that carry scheelite appear to be good ore, half the body is barren; the broken rock, therefore, will probably have to be sorted to maintain a high grade, for the distribution of scheelite does not lend itself to selective mining. Although, in the absence of mine workings, no definite information is available as to its depth, this ore body, like the lower one, is probably shallow. It is estimated to contain 30,000 tons of rock above the lowest surface cropping, or 15,000 tons of ore if half be considered waste; but because of its probably shallow depth it cannot be assumed to contain a much greater tonnage than this.

Millovitch prospect

Scheelite-bearing tactite has been found in a 15-foot shaft (see pl. 16) sunk in tactite-rich talus about a mile southwest of the Tungstar mine, at an elevation of 11,800 feet. Two short trenches extending from the collar of this shaft have exposed about 20 feet of tactite and 7 feet of marble, which strikes N. 55° W. and dips 88° NE. Although the tactite presumably follows the bedding in the marble its extent is unknown. Several pits and shafts down the slope have failed to reach bed rock, and the overburden appears to be thick.

The ore consists essentially of quartz and garnet with a few vugs containing epidote crystals as much as an inch in size.

14/ Lenhart, Walter B., Milling scheelite at Tungstar mine: Mining Cong. Jour., vol. 27, No. 4, pp. 67-71, April 1941.

Scheelite crystals are visible in most of the rock, which appears to carry about 2 percent of WO_3.

Small isolated croppings of unconnected tactite lenses, some of which carry scheelite, have been found on the trail to Horton Creek and on the ridges east and west of the discovery shaft. All these bodies appear to be small, and none can safely be assumed to extend even a few feet beyond their observed outcrops.

A good trail to this prospect was built from Horton Creek in 1940.

Carpenter and Brown prospect

A small, undeveloped, high-grade scheelite deposit, discovered by E. H. Carpenter, lies on the east side of the first small lake on the west fork of Gable Creek, at an elevation of 10,800 feet (see pl. 16). The deposit is a mass of tactite, only 30 feet wide and 60 feet long, lying between granite and a slightly larger mass of marble that strikes northward and dips 80° east. The ore consists of coarsely crystalline epidote, quartz, less garnet, and coarse scheelite in crystals as much as an inch in size. The ore body may yield an appreciable production from the few thousand tons of ore in sight, for this ore is very rich in scheelite, probably containing 2 to 5 percent of WO_3.

Prospects on the southeast side of Mt. Tom

Thick limestone lenses on the southeast side of Mt. Tom are associated with abundant contact rock, some of which contains scheelite. Claims have been staked here by Ben Rossi, Robert Moore, and others, but they had not been developed up to 1940.

Deposits north of the Pine Creek area

Round Valley Peak deposit

A large body of tungsten-bearing tactite is covered by three claims, owned by D. B. Adamson, which lie on the east side of Wheeler Crest, east and northeast of Round Valley Peak, at an elevation close to 11,000 feet. In July 1940 there were no

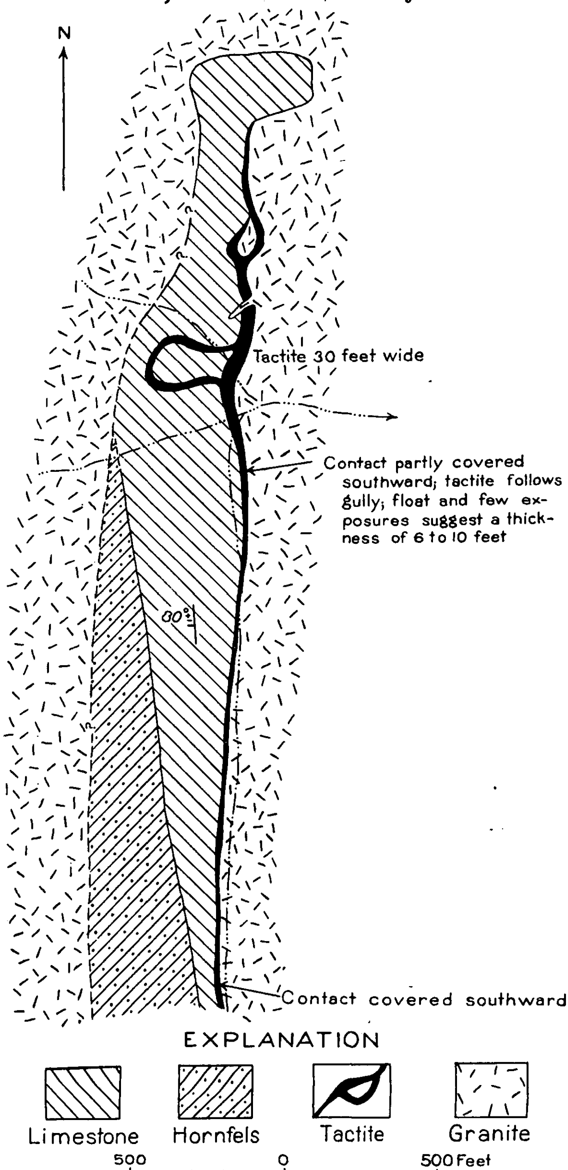


Figure 7.—Geologic sketch map of Round Valley Peak deposit.

workings on the property, and there was no road or trail to it, but it could be reached without difficulty on foot or on horseback from the road along Rock Creek.

The tactite is in contact with granite on the east side of a narrow pendant of hornfels and marble (see fig. 7). The pendant, which is about three-quarters of a mile long and one-eighth of a mile wide, occupies a smooth, gently sloping upland surface bordered on the east by the abrupt mile-deep escarpment into Round Valley. Tactite may extend for 3,000 feet along the steeply-dipping contact, but the south half of the contact is covered by a thin layer of overburden. The north 400 feet of the tactite body, well-exposed in a rugged outcrop 20 to 40 feet wide, is cut by a gulch to a depth of 175 feet below the top of the cropping. The tactite, which is unusually coarse-grained, consists essentially of garnet, epidote, and quartz. Scheelite crystals from 0.1 to 1 inch in size are visible throughout most of the rock. The tactite is thought to contain about 0.5 percent of WO_3, but no thorough sampling has been done.

The exposures indicate at least 250,000 tons of tactite, distributed as follows: 125,000 tons in the block north of the junction of the three gulches shown on the sketch map and above their level; 60,000 tons in the same ore body to a depth of 50 feet beneath the gulch; 65,000 tons in the block extending 1,000 feet south of the gulch to a depth of 50 feet beneath the croppings. The size and shape of the pendant suggest that it extends downward continuously to several times this depth.

Hilton Creek prospect

A steeply-dipping tactite body 1,050 feet long and ranging from 3 to 22 feet in width lies just west of Hilton Creek, at elevations of 10,000 to 10,350 feet, on claims held by R. W. Phelps and by Dan Nichol. A passable private road 5 miles long was built in 1939 from the highway to within 300 yards of the outcrop. In the fall of 1939 and summer of 1940 the Bishop Tungsten Co. as lessee trucked a few hundred tons of ore from this property to its mill south of Bishop.

The tactite extends along the contact between granite on the east and a narrow belt of limestone on the west (see fig. 8). The limestone, which has a maximum outcrop width of 200 feet near the ore zone but pinches out to the south, is interbedded

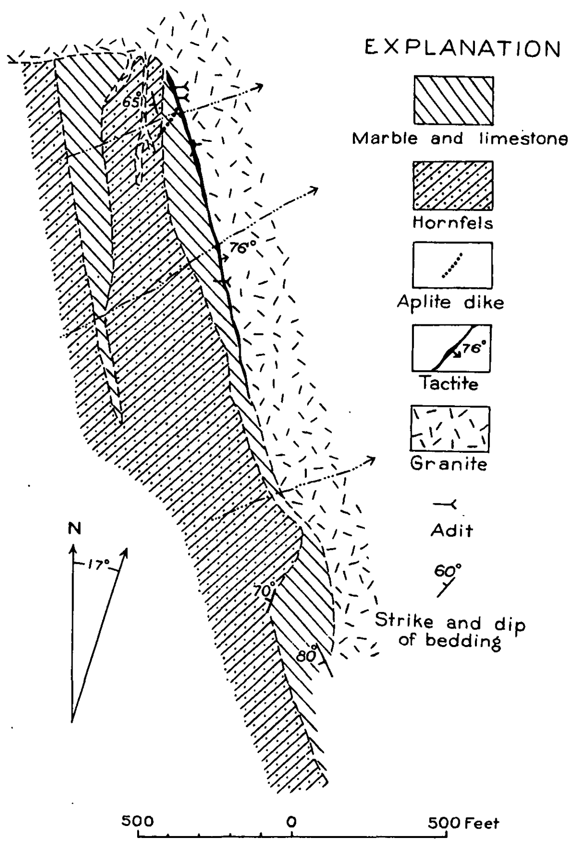
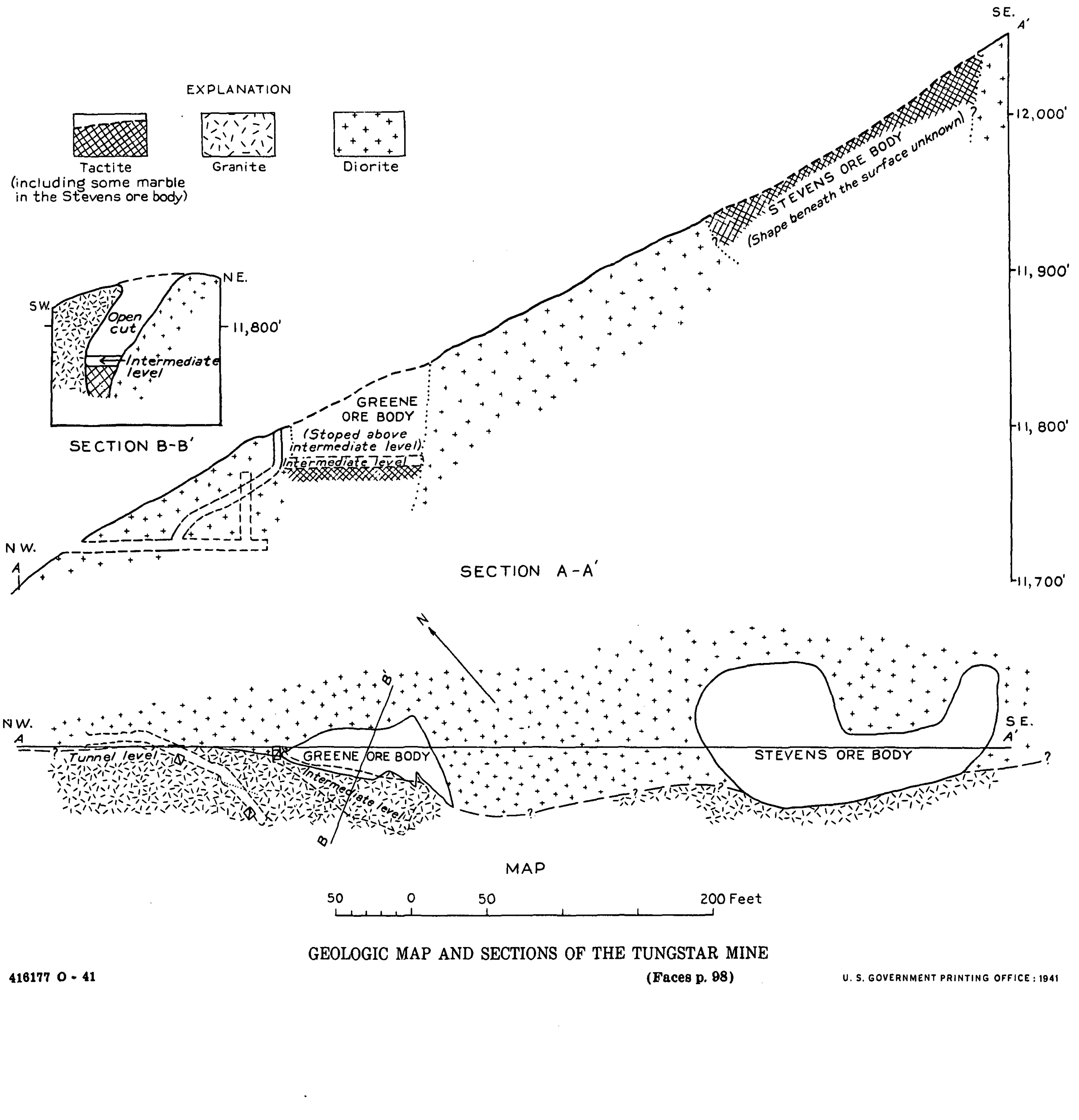


Figure 8.—Geologic map of Hilton Creek deposit.

with a great thickness of hornfels, which forms most of the mountain. This hornfels contains some other thin limestone beds not known to be mineralized. An indentation in the granite-limestone contact locally pinches out the limestone at the north end of the main tactite zone, and where the limestone reappears, 1,100 feet to the north, there is no continuous body of tactite, although a few small lenticular masses containing some molybde-



GEOLOGIC MAP AND SECTIONS OF THE TUNGSTAR MINE

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(Faces p. 98)

U. S. GOVERNMENT PRINTING OFFICE : 1941

nite and very little scheelite have been found. Half a mile further north, the contact passes beneath a moraine.

The Hilton Creek tactite body is of minable width and grade for 260 feet south from the indentation in the contact. For this distance the rock probably averages 0.8 percent of WO_3, for a width of 8 feet. Some scheelite is present for another 140 feet south, but beyond that the tactite diminishes to a few inches in width.

The only workings on the property consist of four short adits, two of which did not reach ore, a small open cut, and several prospect pits and trenches. One of the adits follows the tactite for 45 feet along the strike. Another, a crosscut at the north end of the body, is entirely in granite, and a little scheelite is visible in the granite, at the face, which lies 10 feet past a point 45 feet vertically beneath the surface cropping.

Although lack of ore in the north adit suggests that this part of the ore body is cut off by granite beneath the cropping, the evidence is not conclusive; and, since the granite contains scheelite at the face, the adit should be continued to the contact, probably only a few feet farther west. From a point 100 feet south of this adit to the limits of the tactite, the contact appears to dip consistently 70° to 80° E.; the limestone may, therefore, extend to a depth of several hundred feet. The tactite zone, which probably rakes southward, may contain about 10,000 tons of ore for each 50 feet of depth beneath the croppings.

McGee Mountain prospect

The six Tiptop claims, which overlook Long Valley from the crest of McGee Mountain at an elevation of 10,000 feet, belong to R. W. Phelps, Cecil Thorington, and Morris Harlan. A partially masked elliptical outcrop of tactite 350 feet long and

200 feet wide surrounded by granite, contains a little scheelite in irregular, narrow zones that trend east and west. Most of the tactite is barren, and the low-grade streaks exposed in two trenches appear to be small. The contact rocks contain visible thulite, the pink, manganese-bearing zoisite.

On the east edge of the pendant is a single streak of high-grade ore about 6 feet wide, 15 feet long, and exposed to a depth of 10 feet. This body, which appears under the ultraviolet lamp to contain at least 5 percent of WO_3, may amount to 90 tons. There is little possibility of the lens continuing downward, for granite crops out at its lower edge.

Other prospects

Scheelite has been reported from several localities on Bloody Mt. and Laurel Mt., near Laurel and Convict creeks,[15] but most of these occurrences are small, and none were being actively prospected in 1940.

H. A. Van Loon [16] has reported the discovery, in the fall of 1940, of a large body of scheelite-bearing tactite west of the upper reaches of McGee Creek, but this area has not yet been visited by the writer. The deposit apparently lies south of Mt. Baldwin and at an elevation of about 11,000 feet. Here the wide limestone belt extending southward from Laurel Mt. across Convict Creek and Mt. Baldwin abuts against granite.

Deposits south of Bishop

Pickup mine

The Pickup mine, formerly known as the Chipmunk, is at an elevation of about 6,000 feet in the forks of the second canyon south of Bishop Creek, about 6 miles southwest of Bishop. The property, readily accessible by a newly constructed road, was

15/ Mayo, E. B., op. cit., pp. 83-84.
16/ Personal communication, December 1940.

being developed in 1940 by Tungsten Consolidated. An adit which was being driven toward the ore zone had been driven in quartz monzonite for a distance of 165 feet from the portal when the map (fig. 9) was made, although limestone and tactite are exposed on the surface, immediately above. A thin body of limestone and silicate rock was struck a short distance beyond this

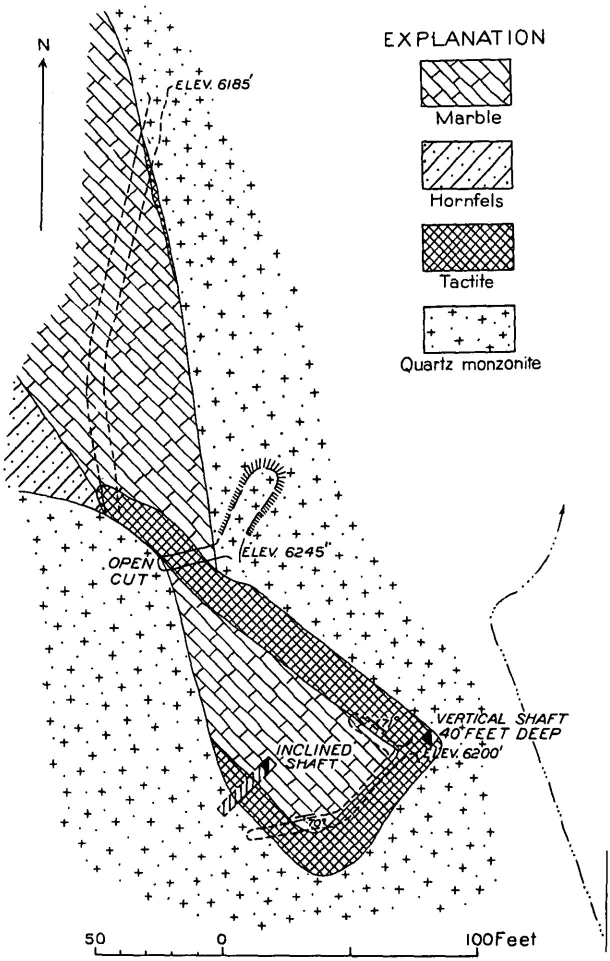

Figure 9.—Geologic map of the Pickup mine.

point, but the ore did not extend to the adit level. Other workings on the property consist of a 100-foot adit, a 40-foot vertical shaft, and several pits and cuts.

The irregular block of sedimentary rocks, composed largely of marble and light-colored silicates, extends 450 feet in a northwest direction and has a width of 20 to 250 feet. The surrounding granitic rock is a gray quartz monzonite consisting of quartz, andesine, orthoclase, and biotite. The southeastern extremity is bordered by a horseshoe-shaped body of tactite 10 to 15 feet wide and 255 feet long. This tactite is a moderately coarse-grained aggregate of quartz, garnet, epidote, and hornblende with scheelite in coarse crystals as much as 1½ inches in size. The dump of the shaft shows much pyritized rock, but the other ore exposures contain only minor amounts of metallic minerals, including magnetite, pyrite, pyrrhotite, sphalerite, and chalcopyrite.

There is probably about 10,000 tons of ore above the lowest adit, which is 60 feet below the highest prospect cut. Possibly 9,000 tons more is indicated by the shaft, which contains ore 25 feet deeper. How deep the ore continues before being cut off by granitic rocks is unknown, but it seems wise to be cautious about planning deep-level adits until the extent of the ore is proved. The small shaft was half full of water in 1940, but the flow can probably be handled easily with a pump.

Rossi mine

The Rossi mine, once known as the Mineral Dome prospect, is at the north base of a low hill three miles south of Bishop. Scheelite occurs in a belt of garnetiferous rock that is about 400 feet long in a northeasterly direction and has a maximum width of about 150 feet. The tactite zone is bordered by granite and alluvium, and is largely concealed by granite sand and large granite boulders that have slumped from the ridge to the south. A 100-foot shaft inclined steeply southward from the center of the body is in granite at the bottom. An irregular, unplanned series of small stopes and short drifts penetrate the tactite for 100 feet east from the shaft. The present workings suggest that the ore body and granite contact dip northward, in the opposite direction from the inclination of the shaft.

This property was operated by a lessee, the Bishop Tungsten Co., from 1936 to 1939 but was idle in 1940. The production may have amounted to at least 10,000 units of WO_3. The ore mined probably averaged about 1 percent of WO_3, although some of it was much richer, some 50-pound masses consisting of nearly pure scheelite.

Although no ore is blocked out in the mine and the workings are in such poor condition as virtually to necessitate starting again from the surface, there are still good possibilities for discovering more ore by exploring both laterally and downward. Nearly half the surface area is still unprospected and should be examined after being stripped of its overburden. The downward limits of the pendant are unknown but probably are not deep.

Coyote Valley prospects

Scheelite has been found in secs. 7, 18, 19, and 20, T. 8 S., R. 32 E., in eight widely separated lenses which lie on the northwest side of Coyote Creek Valley, at elevations of 9,400 to 10,500 feet. These lenses are spaced along the irregular contact between granite and a large pendant of meta-sedimentary rocks on claims held by A. H. Petersen and John Udder. The only workings on them are a few trenches and pits. The area can be reached by trails from the mouth of Rawson Creek, from the head of Big Pine Creek (southeast of the area mapped), and from the South fork of Bishop Creek near Andrews Camp.

Topographically this upland region, which is a remnant of an old erosion surface, is characterized by broad valleys and gently rolling hills, with elevations of 9,000 to 11,000 feet. The glaciers that cut large cirques along Coyote Ridge covered the old surface of Coyote flat with till, leaving a hummocky topography with undrained depressions. In the vicinity of Lookout

Mountain the upland surface is free of glacial till, but even here bedrock exposures are poor because of the accumulation of soil and debris over the meta-sedimentary rocks.

The structure of the pendant, which consists essentially of hornfels with small amounts of limestone and skarn, is obscure. The known tactite occurrences are limited to lenses, no one of which appears to be large, the surface croppings ranging from 10 to 50 feet in width and from 25 to 200 feet in length. Six of the lenses, assumed to be from 25 to 50 feet in depth, are estimated to contain from 600 to 30,000 tons apiece, and their total content is estimated at 65,000 tons. The most promising exposure, near the creek in sec. 20, is 20 to 25 feet wide, and 200 feet long, and it may contain 25,000 tons of ore above the lowest cropping. Two trenches 40 feet apart across the center of the body reveal scheelite throughout their length, the average grade possibly being 0.75 to 1 percent of WO_3.

The geologic setting suggests that more of these lenses may be found by continued prospecting. If sufficient tonnage could be developed, use of central milling facilities would be feasible for haulage roads could be constructed at low cost on this rolling upland.

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