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DEPARTMENT OF THE INTERIOR
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TUNGSTEN DEPOSITS IN THE MINERVA DISTRICT, WHITE PINE COUNTY, NEVADA

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ABSTRACT

The Minerva district is on the west slope of the Snake Range in eastern Nevada, near the Utah border. Scheelite occurs in ore shoots in quartz veins that cut through limestone of Middle Cambrian age. The only igneous rocks exposed in the area are dikes and sills of rhyolite, younger than the tungsten deposits. Of the seven veins known, five have been productive, and two of these are responsible for most of the district yield. Since the discovery of tungsten in 1915 until 1944, the district yielded 82,000 units of WO_3, sold for approximately $1,726,565. Except for about $63,000 worth produced in 1916-18, the major production has been since 1936. The average grade of ore has been nearly 1 percent of WO_3, with a range from 0.5 percent to 2.0 percent or more. The quartz veins are as much as 30 feet in width, but the maximum width of ore has been only 10 feet, and the average nearer to 5 feet.

The veins, which strike east and dip north, are offset by many post-mineral normal faults with displacements as great as 400 feet. These faults disrupt ore shoots that were formerly continuous for pitch lengths of 900 feet or more.

On properties of Tungsten Metals Corp., reserves with 0.5 percent or more of WO_3 were estimated in collaboration with the Bureau of Mines on December 1, 1943, at 1,200 tons of measured ore containing 900 units of WO_3, 15,320 tons of indicated ore containing 11,705 units, and 53,900 tons of inferred ore containing 42,195 units. Reserves with a grade less than 0.5 percent of WO_3 amount to 9,000 tons of indicated ore containing 3,6000 units. Reserves at other properties in the district were estimated at 400 tons of indicated ore containing 400 units, and 1,600 tons of inferred ore containing 1,600 units. In these estimates, no account is taken of entirely untested portions of veins that may be found, by future exploration, to contain additional tonnages perhaps equal to the total cited.

INTRODUCTION

Location

The Minerva district is near the Utah border in White Pine County, Nev., 45 miles southeast of Ely, which is on the standard gauge Nevada Northern Railroad (fig. 1). Minerva, the mill and townsite of Tungsten

Fig. 1. Index map of Nevada showing location of the Minerva district.

Metals Corp., at an elevation of 5,800 feet, is 1 mile south of Shoshone Post Office in Spring Valley, and is reached by a level dirt road extending 15 miles from surfaced U. S. Highway 93. The mines, in the lower portion of the Snake Range at elevations of 6,300 to 7,500 feet, are 2 to 5 miles from the mill.

History and production

Although silver ore was discovered in 1869 at the Indian Silver mine, now included in the east portion of the Scheelite Chief vein, operations here and at Bromide Flat, east of the Hilltop vein, were not extensive; silver production was meagre, and the district was abandoned by 1876. 1/

1/ Lincoln, F. C., Mining districts and mineral resources of Nevada: Nevada Newsletter Publishing Co., Reno, p. 254, 1923.

Scheelite was found in the veins in 1915 by C. E. Millick, A. G. Millick, and Jasper M. Fox, and mined on a small scale in 1916. The Nevada Scheelite Co. held the property in 1917, the Minerva Tungsten Co. in 1918. A 150-ton mill, located below the Chief mine, was completed in 1918 shortly before the collapse of the tungsten market. Production for this period is unknown to the writer, but is believed to be less than $100,000 worth of concentrate valued at the high prices then prevailing; Nevada bullion tax records

show production only in 1916, amounting to $7,651.[2/] Except for a small-scale

2/ Couch, B. F., and Carpenter, J. A., Nevada's metal and mineral production: University of Nevada Bull., Geology and Mining Series No. 38, p. 148, 1943.

leasing operation in 1932, the property was idle until 1936 when Tungsten Metals Corp. was organized. This company built the present 75-ton mill in 1938, and has developed the Scheelite Chief, Silver Bell, Oriole, West Everit, and East Everit mines (fig. 2). Production from these mines in the period

Fig. 2. Index map of the Minerva district showing principal veins and faults.

1937-43 inclusive was 101,467 tons, yielding 77,889 units of WO_3 sold for approximately $1,615,275 (see table 1). Elsewhere in the district, the Hilltop,

Table 1. Production of tungsten ore and concentrates from mines of the Minerva district, Nev., 1916-43.

Tony, Canary Yellow, and Zigzag mines have yielded about 2,200 units, making a total district production of 82,000 units.

Field work by the Geological Survey

The writer, assisted by Donald Wyant, mapped most of the area during 3 months in the fall of 1940, and subsequently revised maps as development progressed in the mines. In 1942, Paul C. Bateman of the Survey assisted in underground mapping; in 1943, Konrad B. Krauskopf, aided by Robert F. Stopper, of the Survey, made a surface map of the Hilltop mine area.

Work by the Bureau of Mines

In the winter and spring of 1941, the United States Bureau of Mines core-drilled 34 holes totalling 6,932 feet on properties of Tungsten Metals Corp., and located the ore mined since then. Again, in the fall of 1943, the Bureau drilled 8 holes totalling 2,898 feet and located the westward continuation of the ore body in the Silver Bell mine. In each instance,

plans for the drilling were laid out jointly by the writer and the project engineer, E. W. Newman in 1941 and R. W. Geehan in 1943, as part of a cooperative program of the Geological Survey and Bureau of Mines.

Acknowledgments

Tungsten Metals Corp., through its staff consisting of Paul J. Sirkegian, W. L. Trent, A. J. O'Connell, and W. H. Dunham, furnished records, surveys, board and lodging, and helpful assistance. Hadley R. Bramel contributed assays and other information about the Canary Yellow and Zigzag claims, entered into many stimulating discussions, and was a source of information about other mines in the region.

GEOLOGY

Regional Setting

The Snake Range extends nearly 60 miles in a north-south direction and rises to over 13,000 feet in elevation. It is composed of (1) a great thickness of Paleozoic sedimentary rocks ranging from Cambrian through Carboniferous, (2) a central intrusive mass of late Mesozoic granitic rock exposed in Snake Creek and south of Osceola, and (3) a volcanic capping at the south end of the range in the Murphy Wash area. All the ore deposits known to the writer occur in the Cambrian sedimentary rocks or in the granitic intrusive, and none have yet been identified in the higher Paleozoic section, perhaps largely because of the distance of the upper rocks from the intrusive to which the mineralization is probably related. Gold and tungsten, with minor amounts of lead and silver, have been produced profitably in the range. The Minerva district, with its tungsten production, has first place in gross yield; the Osceola district with its gold and minor tungsten production has second place; and the Hub district, a former tungsten producer, third place.

Table 1. Production of tungsten ore and concentrate from mines of the Minerva district, Nev. 1916-43.

Year	Tungsten Metals Corp.[1]			Hilltop mine[2]		
	Tons of ore	Units of WO_3	Value	Tons of ore	Units of WO_3	Value
1916	191[3]	191[3]	$ 7,651[3]			
1918	1,846[4]	1,846[4]	55,377[4]			
1937	6,400[5]	6,036[5]	158,916[5]			
1938	14,955	12,858	206,039			
1939	19,617	9,396	146,216			
1940	14,750	10,617[6]	196,090			
1941	10,160	13,599[7]	226,128[7]	1,126	1,677	$36,800
1942	19,867	16,876	428,008	450	429	11,462
1943	15,718	8,507	253,878	-	-	-
	103,504	79,926	$1,678,303	1,576	2,106	$48,262

1/ Data from Tungsten Metals Corp. except where noted. Includes production from Nevada Scheelite Co. (1916) and Minerva Tungsten Co. (1918).

2/ Data from Shoshone Mining Co.

3/ Value from Nevada tax records, University of Nevada Bull., Geology and Mining Series No. 38, p. 148, 1943. Units estimated from value, assuming a price of $40 a unit. Tonnage based on recovery of 1.0 percent WO_3.

4/ Value from Nevada tax records, op. cit., p. 148. Units estimated from value, assuming a price of $30 a unit. Tonnage based on recovery of 1.0 percent WO_3.

5/ Units from records of Tungsten Metals Corp.; value and tonnage from Nevada tax records, op. cit., p. 148.

6/ Includes production from re-treatment of tailings.

7/ Includes production from re-treatment of tailings, also 4,521 units of WO_3 contained in 2,082 tons of slime tailings sold for $18,243, net.

The tungsten occurrences in the range are in veins or stockworks with quartz or calcite, or both, as gangue. No deposits of the contact-metamorphic type have been found. In general, either scheelite or huebnerite or both occur in those deposits with quartzite or granitic wall rocks, but only scheelite occurs in the stratigraphically higher deposits with limestone wall rock. Narrow pegmatitic veins with quartz, feldspar, beryl, and scheelite have been found in the granite west of the old Bonita tungsten mine on Snake Creek. Minerva is the only tungsten district that made appreciable production between 1918 and 1944. Perhaps six other districts in the range were worked profitably at higher prices in 1916-18.

The sedimentary rocks on the west side of the Snake Range, from Osceola south past Minerva to the mouth of Murphy Wash, from oldest to youngest are the Lower Cambrian Prospect Mountain quartzite and Pioche shale, a Middle Cambrian limestone perhaps 2,000 feet thick, a Middle or Upper Cambrian shale probably 300 to 1,000 feet thick, the Ordovician Pogonip limestone and Eureka quartzite, and an overlying limestone which is perhaps also Ordovician. The rocks exposed are successively younger from Osceola southward: the Pioche shale appears at the mouth of Pole Creek 6 miles north of Minerva; the Pogonip limestone and Eureka quartzite are exposed south and east of Minerva. The veins at Minerva lie in the upper part of the Middle Cambrian limestone, so only this part of the stratigraphic section was studied in detail. No attempt was made to measure thicknesses outside of the mapped area.

Sedimentary rocks

At Minerva, the section mapped consists of about 1,000 feet of limestone overlain by at least 300 feet of thin, platy limestone and shale. Faulting conceals the true thickness of the shale, which may be as much as 1,000 feet. The normal sequence above the shale is absent, for the shale is faulted against the middle part of the cherty Pogonip limestone of Ordovician age, probably many hundreds of feet above the base of the Pogonip. Below the Minerva section, massive, light- and dark-colored limestone beds with a total thickness estimated at 1,000 to 1,500 feet extend downward to the Pioche shale and Prospect Mountain quartzite. This part of the section is well exposed on Mt. Washington, 5 miles north of Minerva; the saddle between Mt. Washington and Mt. Lincoln is cut in the shale at the top of the Cambrian section at Minerva.

On the map of Tungsten Metals properties (fig. 3), the Cambrian limestone has been divided on the basis of lithology into 3 major units: the "Upper black limestone," "Upper white limestone," and "Lower black limestone." On the map of the Hilltop mine (fig. 4), the lowest of these units, the "Lower black limestone," has been divided into 4 subunits. Although it is

Fig. 3. Geologic map of a portion of the Minerva district.
Fig. 4. Surface map of the Hilltop mine, Minerva district.

possible to choose major units that maintain rather constant thicknesses over distances of miles, the small units mapped at Minerva are somewhat more variable. In the sequence of limestones that make up the Middle Cambrian, the units range from light to dark, massive to thin-bedded, dense to granular, not only down the dip but also along the strike of the beds. These lithologic variations are well illustrated by individual beds on the beautifully exposed west face of Mt. Washington, north of Minerva. For an example

from the Minerva district, the dense, massive unit mapped as "Upper white limestone" has a thickness of 80 feet at the Chief and Silver Bell mines, 180 feet in the east part of the Everit vein, 280 feet on the West Everit hill, and 180 feet at the Hilltop mine.

The following columnar section, starting with the youngest rocks, summarizes the lithologic units used in mapping in the Minerva district:

Cherty limestone	Thickness not determined, but certainly several thousands of feet. Part of the Ordovician Pogonip. In fault contact with underlying shale.
Shale	Thickness at least 300 feet, perhaps 1,000. Thin, platy limestone beds with shale partings in the lower portion, argillaceous shale above.
Upper black limestone	Thickness 300 feet. Thin-bedded to flaggy, dark-gray limestone, gradational contact upward. Abundant stylolites present in drill cores of Silver Bell area.
Upper white limestone	Thickness 75 feet at Chief mine, 180 feet at East Everit, 280 feet at West Everit, 180 feet at Hilltop. Massive, very fine-grained, light-gray limestone with pinkish cast. Contains a few thin, lenticular beds of dark-gray limestone. Cliff forming. Marked at top by a distinctive bed of thinly banded, cross-bedded limestone 2 to 4 feet thick, a bed that is present throughout the district and elsewhere in the range at this position and serves as a stratigraphic marker.
Lower black limestone	Thickness at least 300 feet. Dark-gray limestone with some lighter beds; mottled, numerous algal beds. Bedding indistinct to good. At the Chief mine, 180 feet below the top of this unit, is a 30-foot bed referred to as the "lower white limestone," lithologically similar to the "Upper white limestone." In the mapped area surrounding the Hilltop mine, rocks equivalent to the "Lower black limestone" have been further subdivided into the following distinctive units: "Middle gray limestone," 50 feet thick; "thin-bedded limestone," 40 feet thick; "lower gray limestone," 100 feet thick; "lower white limestone," over 50 feet thick, base not exposed.

Igneous rocks

Rhyolite is the only igneous rock exposed in the Minerva district. It occurs northwest of the Silver Bell mine in sills 2 to 20 feet thick near the base of the shale; elsewhere it forms dikes as much as 25 feet thick that follow east-dipping faults. The dikes are most abundant in a zone across the center of the district extending from the Silver Bell mine to the Hilltop mine. They were intruded after formation of the scheelite veins, for they cut through the veins at the portal of the 6,900-foot level in the East Everit mine and at the Tony prospect, and elsewhere occupy post-mineral faults that offset the veins. The silicification and iron-staining along some of the faults is probably related to the rhyolite, which may be allied to the flow rocks east of Murphy Was at the south end of the Snake Range.

Structure

The rocks and veins of the Minerva area are disrupted by numerous faults that follow at least five different systems. Nearly all of these faults, even the low-angle ones, are normal faults; that is, the hanging wall has dropped with respect to the footwall. The few that show reverse movement have relatively small displacements.

Most of the faults can be placed in one of the following groups, listed from oldest to youngest:

1. Faults now occupied by quartz veins that strike N. 70° W. to N. 70° E. and dip 40° to 70° N. Although the hanging wall appears to have moved downward 30 to 75 feet, the true displacement cannot be determined, and the apparent displacement cannot always be differentiated from post-mineral movement along the veins (group 4).

2. Faults that strike north, dip from 75° E. to 75° W., and have displacements up to 20 feet.

3. Faults that strike N. 15° W. to N. 30° E., dip 13° to 60° E., and have displacements up to hundreds of feet.

4. Faults that strike east, dip 45° to 60° N., and frequently follow vein segments. Displacements are up to 50 feet.

5. Faults that strike north and dip 45° to 70° W. Displacements are up to 200 feet. Faults of this group are abundant at the front of the range west of the Everit vein, and also on the Zigzag claim.

The quarts veins occupy the oldest fault structures, and have been offset by most of the others. A few steep faults that cut across the vein structures are also pre-mineral, but they have had only small displacements of probably not more than a few feet, and have only locally affected ore deposition. Most of the faults are post-mineral, demonstrated by the lack of quarts and scheelite in them, and by the disruption of formerly continuous ore shoots.

True displacements on all the faults except the oldest can usually be determined from the offsets of veins and stratigraphic units. It is essential to know the true displacement of veins, rather than the horizontal offset, to find continuations of ore shoots. The displacements on some of the larger faults, such as the Everit fault, change along the strike and dip because of the cumulative effect of subsidiary faults in the footwall.

Most of the faults are well exposed at the surface. The low-angle faults have topographic expression, for they repeat the massive, cliff-forming "Upper white limestone;" the faults lie at the tops of cliffs, and from a distance resemble bedding, which is much less apparent. All the

faults contain calcite veins or cemented breccia, from an inch to 6 feet or more in width. Some contain reddish-stained material, usually calcareous but sometimes siliceous; the siliceous material, which is very fine-grained and bears no resemblance to the quarts veins, is thought to be associated with the rhyolite.

Structure contours can be drawn with fair accuracy from the surface exposures of those faults that dip east at angles of 50° or less. The contours are curved, not straight, and in some instances appear to be "folded," with "fold axes" trending east. The Everit fault is a good example: it dips 13° E. where it offsets the Everit vein, and steepens to 45° within 500 feet north and south of the vein; the dip of the fault at the vein intersection persists for at least 500 feet downward into the East Everit mine. The curves in the faults probably represent the original fracture pattern, rather than subsequent folding, for the limestone beds are not similarly folded.

In the mapped areas, the bedding in the limestone strikes north to northwest and dips 12° to 45° SW. Folding within the different fault blocks is not pronounced, the attitudes within individual blocks being essentially similar. The exception to this generalization is outside the detailed map areas on the Zigzag and Calico claims, between the West Everit and Hilltop mines. On parts of these claims, and for half a mile northward, the beds have been folded and complexly faulted so that most of the beds dip to the east.

The contact between the "Upper black limestone" and overlying shale, in several exposures between the Chief and Everit mains, is marked by a red, silicified breccia 5 to 50 feet thick with limestone fragments up to 6

inches in size. One of the best exposures, north of the east limit of the Oriole vein, contains abundant fragments of vein quarts. Although this breccia is not yet adequately explained, it may represent an old bedding fault of unknown magnitude, perhaps one of the oldest faults in the district. The exposures of this contact are very poor except in these silicified areas.

ORE DEPOSITS

Extent and thickness of veins

Scheelite ore shoots occur in seven roughly parallel quarts veins occupying normal faults that strike east, dip 45° to 70° N., and are spaced at intervals of approximately half a mile. The Chief Extension, Scheelite Chief, Oriole, Everit, Lone Buck, and Canary Yellow veins are shown on figure 3, the Hilltop and Tony veins, which lie farther north, on figure 4.

The quartz veins range in width from a few inches to 30 feet, and in length from 1,000 to 4,000 feet. The quartz changes in thickness within short distances along strike or dip, and is in places distributed in a series of closely spaced, parallel fractures with horses of limestone. The vein outcrops are limited on the west by alluvium, and on the east by alluvium and shale through which the veins do not penetrate. No major veins have beenfound on the surface at stratigraphic horizons above the shale; it may be possible to follow the veins underground eastward beneath the shale capping.

The Chief vein has been traced for 550 feet west from the portal of the main adit, but none of the other veins have been explored beneath the alluvium. Frontal faults defining the range probably lie only a short dis-

tance west of the foothills; the possibility of discovering large segments of veins buried beneath the alluvium seems remote.

Mineralogy and grade of ore

The vins consist mainly of quarts and calcite with some scheelite and, in spots, traces of tetrahedrite, galena, silver haloids, powellite, and cuprodescloisite. The scheelite concentrates are reported to contain as much as 4 ounces of silver to the ton, but this represents a high concentration ratio. The scarcity of associated minerals is indicated by the purity of the concentrates, which contain only traces of phosphorus, sulfur, and arsenic, and very little copper and molybdenum.

The quarts in the veins is white or tinged with greenish-yellow, coarsely crystalline, and usually massive, although a few small vugs can occasionally be found. The carbonate in the veins and faults ranges in color from white through flesh-color to light reddish brown, suggesting several carbonate minerals, although calcite is dominant. The scheelite commonly occurs in coarse cleavages distributed through the quarts or alined along fractures in the quarts. In some parts of the veins, notably in the Oriole mine and Tony prospect, the scheelite is distributed in very fine grains.

The grade of material mined in substantial quantities has ranged from 2.5 percent or more of WO_3 down to 0.3 percent. Local concentrations have contained as much as 10 or 20 percent of WO_3. All the ore milled by Tungsten Metals Corp. to the end of 1943 yielded an average of 0.76 units per ton, suggesting that the ore contained between 0.9 and 1.0 percent of WO_3.

Ore shoots

The tungsten ore occurs in shoots of limited vertical extent but with remarkable lateral continuity, which is disrupted by post-mineral faulting. The quartz veins are nearly barren outside of the shoots, which occupy only a small part of the veins. The ore shoots rake westward roughly parallel to the bedding in adjacent limestone, and frequently lie on the footwall side of the vein; the widest ore stoped is about 10 feet, although the vein in which the ore occurs may be 20 to 30 feet wide. In the smaller veins, ore shoots as narrow as 1 to 3 feet have been stoped.

Each of the main veins worked appears to have a single main ore shoot, although the Everit vein contains remnants of an upper ore shoot, and both it and the Chief vein may yet prove to contain lower shoots in portions that have never been prospected. In the East Everit mine, the main shoot was mined for 80 to 130 feet along the dip of the vein, and for a pitch length of 650 feet; extensions to the east have not yet been found, but an extension to the west is known to continue another 240 to 400 feet, possibly more. In the Chief mine, the ore shoot has been mined for 80 to 140 feet along the dip, and for a pitch length of 900 feet. Mine development may ultimately prove that the ore shoots before faulting were essentially continuous through most of the length of these veins. Little is known about the ore shoots in other veins of the district, for they have not been extensively explored.

The main ore bodies in the Chief, Everit, Canary Yellow, Zigzag, and Hilltop mines occur at about the same stratigraphic horizon in the "Upper white limestone." The upper stope in the West Everit mine, and the surface

stope in the East Everit mine east of the Everit fault, both lie higher stratigraphically in the "Upper black limestone." The ore shoot in the Silver Bell mine also lies at a higher horizon, but appears to rake downward to join the shoot in the Chief mine.

The walls of the veins are frozen to the limestone in most instances, and post-mineral surfaces of breakage lie within the veins. The wall rocks are unaltered regardless of the presence or absence of ore in the adjoining vein.

The occurrence of ore shoots and the brecciation in them show that theveins were formed by successive introductions of minerals, and that the ore bodies were probably deposited in more porous portions of the veins. The massiveness of the "Upper white limestone" appears responsible for conditions favorable to scheelite mineralization. Perhaps slight changes in dip of veins where they cross limestone beds of different competence permitted development of crushed zones within the quartz, zones formed by continuous shearing along the vein. If this explanation be true, then other ore shoots may be discovered at greater depths in the vein wherever similar conditions prevail.

MINES

The veins in the Minerva district known to contain tungsten ore are held by Tungsten Metals Corp., Calico Tungsten Co., or Shoshone Mining Co. Of the many claims in the district, only seven are patented, all part of the Tungsten Metals group. Companies formerly active on some of these properties include Nevada Scheelite Co. (1916-17) (not to be confused with a different company which has operated under this name at Rawhide, Nev.)[1], Minerva Tungsten Co. (1918), New Deal Leasing Co. (1940-41), Scheelite Leasing Co. (1941), and Virdot Development Co. (1941-42). These companies have all disbanded.

Tungsten Metals Corp.

Tungsten Metals Corp. owns the southern five of the seven known veins in the district. In addition to the seven patented claims (surveys 4485-A, 4486, and 4487) shown on the map (fig. 3), the group includes about 40 unpatented claims. Tungsten Metals Corp. also owns a 75-ton mill at Minerva. Custom ore from other properties has been accepted at this mill where all ore mined in the district since 1938 has been treated.

Scheelite Chief mine

The Scheelite Chief mine (see figs. 5 to 8) is in two major segments

Fig. 5. Map and vertical projection of the Scheelite Chief vein.
Fig. 6. Scheelite Chief mine, composite map.
Fig. 7. Scheelite Chief mine, vertical projection of west workings.
Fig. 8. Scheelite Chief mine, vertical projection of east workings.

of the Chief vein, separated by the Chief fault. Both segments are developed from the 6,316-foot level, an adit 1,530 feet long. The west segment has three upper adits now largely stoped, a shaft near the portal of the main adit, and two short lower levels from the shaft. The east segment has a winze 30 feet deep below stope 1, with a sublevel from the bottom west to the Chief fault.

The west segment has been stoped from the portal of the adit to the Chief fault. Two small blocks of ore probably still remain west of the fault that terminates the 6,246- and 6,276-foot levels. Of seven holes drilled beneath the alluvium, only one, 550 feet west of the mine, found ore. The ore shoot in the intervening area may have been eroded away.

The east segment has been stoped above the main level for a length of 260 feet, and the level has been extended another 340 feet beneath the shoot. The quartz vein below the shoot is narrower, ranging from half a foot to 4 feet, and contains sporadic traces of scheelite.

Silver Bell mine

The Silver Bell mine, (see figs. 9 and 10), in the east portion of the

Fig. 9. Silver Bell mine, composite map.
Fig. 10. Silver Bell mine, vertical projection.

Chief vein, is worked to the fourth level through a shaft 365 feet deep on the incline (238 feet vertically). A winze, 84 feet on the incline, connects the fourth level with a short fifth level at a point 300 feet west of the shaft. The total level workings, largely concentrated on the third and fourth levels, amount to nearly 1,200 feet of drifts and crosscuts. Ore was stoped above the third level for a length of 140 feet, a width of 3 to 5 feet, and a height of 60 feet along the dip. A faulted westward extension of this ore body was being worked from the fifth level in October 1944. Possible extensions eastward beyond the shaft have never been investigated either by drilling or drifting, and should be sought by extending the third level east through the various fault segments.

Oriole mine

The Oriole vein is the least developed of the major veins in the district. It is opened at the west end in the Oriole mine by two short adits at a vertical interval of 80 feet (see figs. 11 and 12). The ore stoped

Fig. 11. Oriole mine, composite map.
Fig. 12. Oriole mine, vertical projection.

consisted of very fine-grained scheelite in quartz, and averaged only 0.4 percent of WO_3. The width of ore ranged from $1\frac{1}{2}$ to 5 feet. The stopes mined are in offset segments of a single ore shoot, which could probably be readily followed eastward by extending the upper adit.

The outcrop of the vein is mostly barren except for some coarsely crystalline scheelite on the crest of the hill above the mine, and for

low-grade mineralization in the first segment east of Chief Canyon. The only exploration east of the mine is by three shallow drill holes in two fault segments east of the canyon. Although the vein is not as strong at the surface as the Chief or Everit veins, it shows impressive widths of quartz, and might be productive in the future.

West Everit mine

Workings in the West Everit mine consist of two adits, a sublevel above the upper adit, two stopes, and several connecting raises (see figs. 14 to 16).

Fig. 14. West Everit mine, composite map.
Fig. 15. West Everit mine, vertical projection.
Fig. 16. West Everit mine, section along 11,350 E.

An adit 50 feet long on the west face of the hill dates from 1917. Two small ore bodies have been mined, both of excellent grade: one on the crest of the hill, the other in the lower adit. Both ore bodies are in the hanging wall of the West Everit fault, and are but off by it. The upper ore shoot is a remnant, former extensions of which have been eroded away. The lower ore shoot, however, might have extensions below the West Everit fault. In spite of several hundred feet of exploratory work from the 6,800-foot level, the vein was not located. The work seems to have disproved the existence of any segments of appreciable size in the footwall of fault "A", which is parallel to the vein. The segment of vein exposed on the west side of the hill at 11,200 E., 9,400 N. is probably the same Everit vein and ore may be found in it below the 6,800-foot level.

The West Everit vein zone ranges in width from 5 to 50 feet, the vein branching into several parts with included layers of limestone. The maximum width of continuous quartz is 25 feet. Wherever drifts lie in the main

vein, the full width of quartz is not exposed; so scheelite ore bodies may be missed by failure to crosscut.

The only ore remaining in the mine is between the upper stope and the West Everit fault in a fault sliver estimated to contain 1,200 tons. The fault segments west of the mine are too little known to permit any inference as to quantity of ore. Because of extreme faulting, the vein westward beneath the alluvium probably does not justify underground exploration.

East Everit mine

The main development in the East Everit mine is from an adit 1,735 feet along at an elevation of 7,050 feet (see figs. 13 and 17-20). A raise

Fig. 13. Map and vertical projection of the Everit vein.
Fig. 17. East Everit mine, composite map.
Fig. 18. East Everit mine, vertical projection.
Fig. 19. East Everit mine, map of east extension.
Fig. 20. East Everit mine, section along [illegible] 14,674 E.

connects with the surface from a point 1,085 feet inside the portal. A shorter adit, 150 feet lower, is used for ore transfer, and also for development of another fault segment.

Two ore shoots have been mined, probably correlatives of the two in the West Everit mine. The upper ore shoot is eroded away except for a small segment stoped at the surface above the Everit fault. The lower shoot cropped out only west of the Everit fault, but has been stoped most extensively east of the fault. Although drill hole 8 and the westernmost stope in the mine (that from the 6,900-foot level) yielded ore containing only about 0.5 percent of WO_3, the ground has not been sufficiently tested to prove the absence of better ore. An adjoining segment of vein that crops out south of the portal of the 6,900-foot level is untested.

The portion of the vein intersected near the face of the 7,050-foot level (at 14,100 E.) contains low-grade scheelite-bearing material at that point, but has not been explored upward to the surface, which is masked by debris. Beyond the face, five holes drilled from the surface in 1943 found no ore, but proved that the ore horizon lies considerably lower in this fault block. The thickness of quartz and the presence of scheelite in this part of the vein are encouraging for the eventual discovery of an ore shoot at greater depth.

The small vein that lies 150 feet north of the Everit vein contains several exposures of narrow but high-grade scheelite ore. One outcrop (at 13,150 E.) was mined in an open cut. Drill hole 2 (at 13,240 E.) intersected 5 inches of vein that assayed 7.53 percent of WO_3. High-grade ore 8 inches wide has not been touched in an exposure at the east end of the vein (at 13,580 E.). The widths and tonnages available are unfavorable for company exploration, but the grade of ore might make portions of the vein attractive to a lessee.

Lone Buck vein

The Lone Buck vein, entirely unexplored, crops out for a length of 1,200 feet and ranges in width from a few inches to 4 feet. Two channel samples cut by the Bureau of Mines in 1941 indicate a block of ore (between 14,200 E. and 14,260 E.) 60 feet long, 1.8 feet wide, and averaging 1.74 percent of WO_3; indicated ore along the rake west to the nearest fault amounts to 220 tons. The vein shows little promise of productivity, for the only ore exposed is in this block, which is a small and inaccessible remnant of a shoot.

Calico Tungsten Co.

The Calico Tungsten Co., a partnership between Hadley R. Bramel and Stanley Feitler, owns three unpatented claims on a single vein; the Canary Yellow, Calico, and Zigzag claims. Exept for surface cuts, work has been concentrated at the Canary Yellow mine.

Canary Yellow mine

The Canary Yellow mine is developed by an 85-foot crosscut adit with a 110-foot drift on the vein, and a raise to the surface 85 feet above (see fig. 21). The vein in the drift shows 1 to 1½ feet of ore containing

Fig. 21. Canary Yellow mine, map and projection of workings.

more than 1 percent of WO_3 for a drift length of 60 feet. On the surface directly over the portal of the adit, Bramel and Feitler sampled the vein at 10-foot intervals for a length of 130 feet over widths of 1½ to 6 feet, and obtained assays ranging from 0.39 to 4.20 percent of WO_3, averaging more than 1.0 percent. From the raise, 37½ tons milled by Tungsten Metals Corp. yielded only 27 units of WO_3, an average of 0.72 unit per ton. Although the ore in the drift and raise is poorer than that at the surface, better ore may lie west of the workings if the surface body is part of a shoot that rakes westward. The ore in the drift may represent a lower shoot. With this interpretation, the upper shoot, with an average width of 2 feet, is estimated to contain 400 tons of indicated ore that will average more than 1.0 percent of WO_3; the lower shoot, 1½ feet wide and averaging 1.0 percent, may contain at least 600 tons of inferred ore if it continues 260 feet along the rake to the faults limiting this segment of vein. No estimate can be made of the possibilities of the vein eastward, for the vein is unexplored and ore is not exposed at the surface, although the vein croppings continue 1,000 feet east of the mine.

Zigzag and Calico claims

The Zigzag and Calico claims lie on the west end of the same vein as the Canary Yellow mine, but are separated from it by half a mile of alluvial cover. The vein on these claims, faulted even more than is normal to the district, is broken into fragments 20 to 200 feet long, some of which contain ore at the surface. The only workings are a few open cuts from which Bramel and Feitler mined 18 tons of ore that yielded 20 units of WO_3. The width of vein ranges from 1 to 4 feet. Inasmuch as ore at the surface has not been profitable to mine because of the small size of fault segments, it is doubtful if ore present in other segments but not exposed can be mined profitably unless the price of tungsten exceeds $30 a unit.

Shoshone Mining Co.

The Shoshone Mining Co., a partnership among A. J. O'Connell, W. L. Trent, J. E. Brinton, and Horace Bath, owns the Hilltop group of six unpatented claims known as the Hilltop, Tony, Tony No. 1, Tony No. 2, Tony No. 3, and Tony No. 4. The claims were operated in 1940-41 by the New Deal Leasing Co., in 1941 by the Scheelite Leasing Co., and in 1942 by the Virdot Development Co. The Tony prospect was operated by Tungsten Metals Corp. for a short time in 1940-41. Most of the production has come from the Hilltop mine, which yielded at least 2,106 units of WO_3.

Hilltop mine

The Hilltop mine is developed by a main adit at an elevation of 7,066 feet, by a short adit at 7,120 feet, and by several open cuts (see figs. 4, 22, and 23). The 7,066-foot level has about 650 feet of drifts

Fig. 4. Surface map of the Hilltop mine.
Fig. 22. Map and vertical projection of the Hilltop mine.
Fig. 23. Hilltop vein, map of main level with section.

and crosscuts, three stopes, and three raises to the surface. This level

is connected with an ore bin at the end of the road, 600 feet lower, by a single span, jib-back aerial tram 1,150 feet long.

The Hilltop vein is narrow, with surface widths of ½ to 3 feet. In the stope east of the crosscut adit, the vein flattened and widened to 8 feet of good ore between the level and the surface 35 feet above. Neither the drift level with 1½ feet of quartz nor the surface with 1 foot of quartz gave any indication of the intervening wide ore body. The stopes west of the adit were narrow, the ore being a foot or less in width although of high grade.

Hardly any ore remains in sight, although a few tons could still be underhanded beneath the level and stopes. The raise at the east end of the workings has some ore in the roof; so there may be ore in the 50 feet of unexplored ground up to the surface. The largest block of potential ore is in the vein segment beyond the west face of the 7,066-foot level, beneath the upper adit. All told, perhaps 1,000 tons of 1 to 2 percent ore might be found in these untested blocks with very little additional exploration.

Tony prospect

The Tony prospect is explored by a 225-foot adit, a raise to the surface, and several surface pits. The vein strikes north and dips east, and is in this repsect unique among the tungsten-bearing veins of the district. The vein outcrop extends for nearly 200 feet along the strike; continuations of the same vein-fault to the north and south contain no quartz or scheelite, although calcite filling, common to post-mineral faults of the district, is present. Scheelite mineralization for widths of 1 to 3 feet extends for about 100 feet on the surface, but no comparable mineralization

is present in the adit. The scheelite is extremely fine-grained. Only 32.5 units of WO_3 was recovered from 159 tons of ore milled in 1941, a yield of about 0.2 percent. No commercial ore is now exposed, and only a few tons that contain 0.2 to 0.5 percent are visible.

Two narrow veins on Tony No. 2 claim west of the section corner contain a few cyrstals of coarse scheelite, but the exposures are not encouraging enough to warrent exploration.

RESERVES

The mines of the Minerva district rarely have more than a few tons of measured ore, and seldom have more than a few thousand tons of indicated ore. As in many other tungsten mines, indicated, not measured, ore is mined. Consequently, an estimate of ore reserves must be primarily an interpretation of unexplored areas based on past experience. The writer believes that the total reached in the following tabulation is conservative, and less than the expectable future production of the district. Individual blocks inferred, however, may vary materially from the estimate given.

The structural complexity of the ore bodies necessitates considerable dead work in exploration. Development in the mines has never been far enough ahead to permit continuous milling at capacity. In the 6 years from 1938 to 1943, the tonnage produced annually ranged from 10,160 to 19,867 tons, and never approached the mill capacity of 27,000 tons. The added mining and milling cost involved in operating at capacity would be slight, and the net profit from such operation would be much greater.

Under operating conditions in 1943, the grade of ore mined (yield of 0.54 percent of WO_3) was the minimum that could be handled profitably at a market price of $30 a unit. Ore that would mill out at 0.75 percent (the

average yield from past production) presumably could have been worked at $21.00 a unit. The cost of production in both instances could be reduced substantially by operating the mines at capacity.

The district reserves are summarized by mines in table 2. The reserve figures are broken down into blocks within individual mines in table 3. The

Table 2. Summary by mines of ore reserves in the Minerva district.
Table 3. Reserves within mines of the Minerva district, distributed into ore blocks.

only measured ore is blocked out in the east workings of the Chief mine by a winze, sublevel, and raise. The indicated ore is in blocks that have been tested by drill holes or partially explored by drifts and raises. The inferred ore, which constitutes the bulk of the reserve, is inferred largely on geologic evidence as to continuity of ore shoots. Estimates of grade are based mainly on the yield from ore mined in the past.

In addition to the estimates enumerated, it is expected that future prospecting will discover other ore bodies in the Oriole vein, unexplored for 2,600 feet east of the Oriole mine, and in the Chief vein, which extends at least 400 feet east of the Silver Bell shaft. Although these areas have not yet been tested by drilling or underground workings, they probably contain ore bodies similar to those mined elsewhere in the veins, where production has amounted to about 23 tons per foot of vein explored along the strike. This additional tonnage might be on the order of 70,000 tons averaging 0.8 percent of WO_3.

Table 2. Summary, by mines, of ore reserves in the Minerva district. December 1, 1943.

Ore commercial under present conditions

Grade 0.5 percent WO_3 or higher

	Measurable		Indicated		Inferred*		Inferred **	
	Tons	Units	Tons	Units	Tons	Units	Tons	Units
Scheelite Chief***	1,200	900	6,200	4,590	17,000	12,000		
Silver Bell***			4,540	4,540	18,300	15,975		
East Everit			4,400	2,200	2,400	1,920	15,000	11,100
West Everit					1,200	1,200		
Lone Buck			220	375				
Canary Yellow			400	400	600	600		
Hilltop								
	1,200	900	15,760	12,105	40,500	32,695	15,000	11,100

Ore marginal under present conditions

Grade less than 0.5 percent WO_3

	Indicated	
	Tons	Units
East Everit	5,200	2,080
Oriole	3,800	1,520
	9,000	3,600

* Inferred with reasonable assurance on basis of nearby workings.
** Inferred by geologic reasoning, unconfirmed by workings in the immediate vicinity.
*** Reserves partially depleted between December 1, 1943 (the date of this estimate) and May 1945. Most of the ore mined in this period was from the Silver Bell mine, some from the Scheelite Chief mine.

Table 3. Reserves within mines of the Minerva district, distributed into ore blocks. December 1, 1943. *

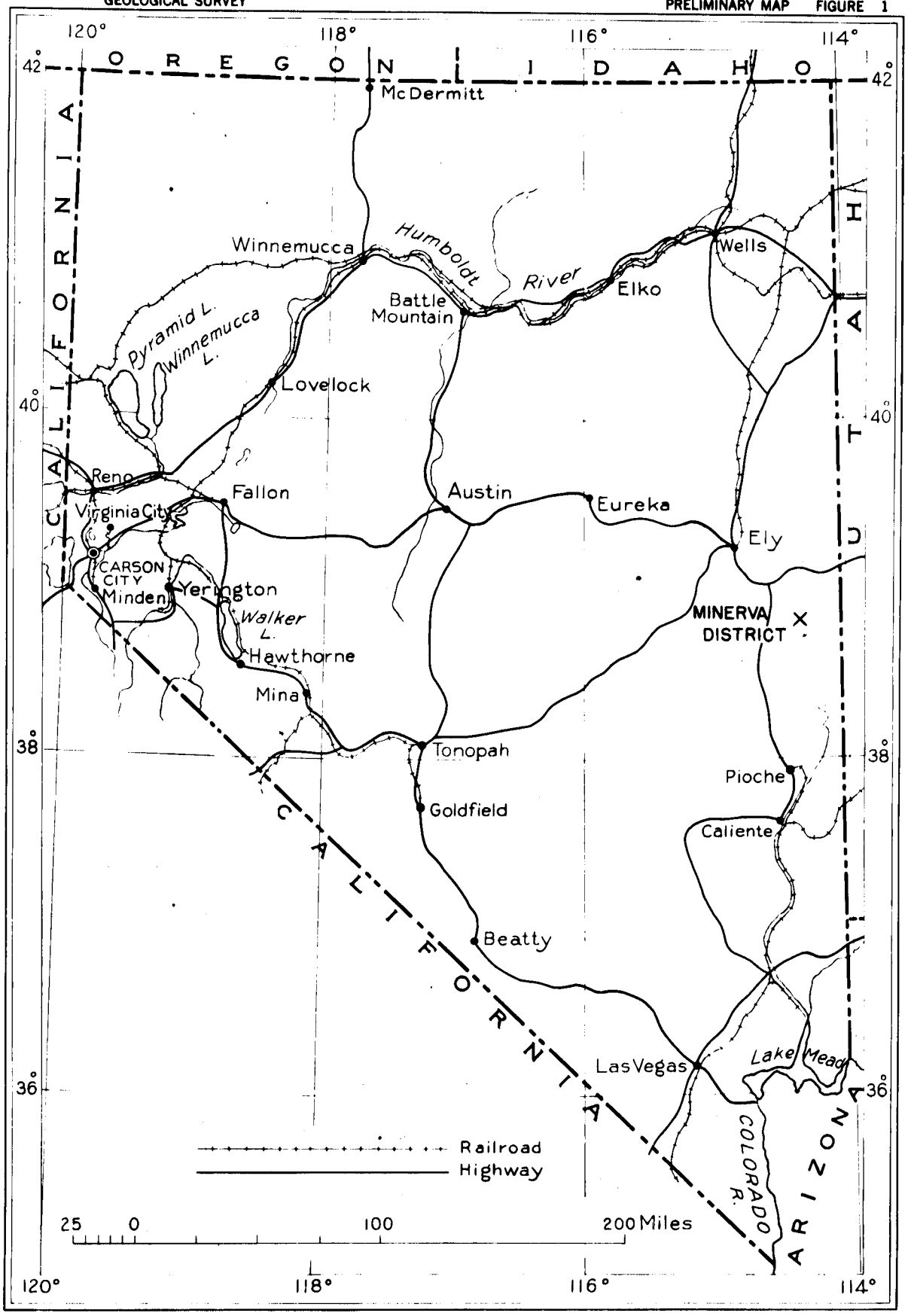
Location		Width in feet	Measurable ore			Indicated ore			Inferred ore		
Mine	Block		Tons	% WO_3	Units WO_3	Tons	% WO_3	Units WO_3	Tons	% WO_3	Units WO_3
Scheelite Chief*	C-6	3	..	..	..	1,200	0.7	840	..	..	..
	C-7	3	..	..	..	..	..	..	700	0.8	560
	C-8	2.5	..	..	..	..	..	..	300	0.8	240
	C-9	4	1,200	0.75	900	..	..	..	..	..	..
	C-10	3-7	..	..	..	5,000	0.75	3,750	..	..	..
	C-11	5	..	..	..	..	..	..	16,000	0.7	11,200
			1,200		900	6,200		4,590	17,000		12,000
Silver Bell*	C-1	6.5	..	..	..	3,500	1.0	3,500	..	..	..
	C-2	4	..	..	..	1,040	1.0	1,040	..	..	..
	C-3	6.5	..	..	..	..	..	..	9,000	1.0	9,000
	C-4	5	..	..	..	..	..	..	9,300	0.75	6,975
						4,540		4,540	18,300		15,975
Oriole	C-1	2.5	..	..	..	1,000	0.4	400	..	..	..
	C-2	2.5	..	..	..	2,800	0.4	1,120	..	..	..
						3,800		1,520			
West Everit	E-7	3	..	..	..	..	..	..	1,200	1.0	1,200
East Everit	E-1	5	..	..	..	..	..	..	3,000	0.5	1,500**
	E-2	5	..	..	..	4,400	0.5	2,200	..	..	..
	E-3	5	..	..	..	1,800	0.4	720	..	..	..
	E-4	5	..	..	..	3,400	0.4	1,360	..	..	..
	E-5	5	..	..	..	..	..	..	2,400	0.8	1,920
	E-6	5	..	..	..	..	..	..	12,000	0.8	9,600**
						9,600		4,280	17,400		13,020
Lone Buck		1.8	..	..	..	220	1.74	375	..	..	..
Canary Yellow		2.0	..	..	..	400	1.0	400	..	..	..
		1.5	..	..	..	..	..	..	600	1.0	600
Hilltop		1.5	..	..	..	..	..	..	1,000	1.0	1,000

** Inferred by geologic reasoning, unconfirmed by workings in the immediate vicinity.

* Reserves partially depleted between December 1, 1943 (the date of this estimate) and May 1945. Most of the ore mined in this period was from the Silver Bell mine, some from the Scheelite Chief mine.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP FIGURE 1



INDEX MAP OF NEVADA SHOWING LOCATION OF THE MINERVA DISTRICT

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UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey
Washington

TUNGSTEN DEPOSITS IN THE MINERVA DISTRICT, WHITE PINE COUNTY, NEVADA

By Dwight M. Lemmon

February 1944

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TUNGSTEN DEPOSITS IN THE MINERVA DISTRICT, WHITE PINE COUNTY, NEVADA

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ABSTRACT

The Minerva district is on the west slope of the Snake Range in eastern Nevada, near the Utah border. Scheelite occurs in ore shoots in quartz veins that cut through limestone of Middle Cambrian age. The only igneous rocks exposed in the area are dikes and sills of rhyolite, younger than the tungsten deposits. Of the seven veins known, five have been productive, and two of these are responsible for most of the district yield. Since the discovery of tungsten in 1915 until 1944, the district yielded 82,000 units of WO_3, sold for approximately $1,726,565. Except for about $63,000 worth produced in 1916-18, the major production has been since 1936. The average grade of ore has been nearly 1 percent of WO_3, with a range from 0.5 percent to 2.0 percent or more. The quartz veins are as much as 30 feet in width, but the maximum width of ore has been only 10 feet, and the average nearer to 5 feet.

The veins, which strike east and dip north, are offset by many post-mineral normal faults with displacements as great as 400 feet. These faults disrupt ore shoots that were formerly continuous for pitch lengths of 900 feet or more.

On properties of Tungsten Metals Corp., reserves with 0.5 percent or more of WO_3 were estimated in collaboration with the Bureau of Mines on December 1, 1943, at 1,200 tons of measured ore containing 900 units of WO_3, 15,320 tons of indicated ore containing 11,705 units, and 53,900 tons of inferred ore containing 42,195 units. Reserves with a grade less than 0.5 percent of WO_3 amount to 9,000 tons of indicated ore containing 3,600 units. Reserves at other properties in the district were estimated at 400 tons of indicated ore containing 400 units, and 1,600 tons of inferred ore containing 1,600 units. In these estimates, no account is taken of entirely untested portions of veins that may be found, by future exploration, to contain additional tonnages perhaps equal to the total cited.

INTRODUCTION

Location

The Minerva district is near the Utah border in White Pine County, Nev., 45 miles southeast of Ely, which is on the standard gauge Nevada Northern Railroad (fig. 1). Minerva, the mill and townsite of Tungsten Metals Corp., at an elevation of 5,800 feet, is 1 mile south of Shoshone Post Office in Spring Valley, and is reached by a level dirt road extending 15 miles from surfaced U. S. Highway 93. The mines, in the lower portion of the Snake Range at elevations of 6,300 to 7,500 feet, are 2 to 5 miles from the mill.

History and production

Although silver ore was discovered in 1869 at the Indian Silver mine, now included in the east portion of the Scheelite Chief vein, operations here and at Bromide Flat, east of the Hilltop vein, were not extensive; silver production was meagre, and the district was abandoned by 1876.1/ Scheelite was found in the veins in 1915 by C. E. Millick, A. G. Millick, and Jasper M. Fox, and mined on a small scale in 1916. The Nevada Scheelite Co. held the property in 1917, the Minerva Tungsten Co. in 1918. A 150-ton mill, located below the Chief mine, was completed in 1918 shortly before collapse of the tungsten market. Production for this period is unknown to the writer, but is believed to be less than $100,000 worth of concentrate valued at the high prices then prevailing; Nevada bullion tax records show production only in 1916, amounting to $7,651.2/ Except for a small-scale leasing operation in 1932, the property was idle until 1936 when Tungsten Metals Corp. was organized. This company built the present 75-ton mill in 1938, and has developed the Scheelite Chief, Silver Bell, Oriole, West Everit, and East Everit mines (fig. 2). Production from these mines in the period 1937-43 inclusive was 101,467 tons, yielding 77,889 units of WO_3 sold for approximately $1,615,275 (see table 1). Elsewhere in the district, the Hilltop, Tony, Canary Yellow, and Zigzag mines have yielded about 2,200 units, making a total district production of 82,000 units.

Fig. 1. Index map of Nevada showing location of the Minerva district.

Fig. 2. Index map of the Minerva district showing principal veins and faults.

Table 1. Production of tungsten ore and concentrates from mines of the Minerva district, Nev., 1916-43.

1/ Lincoln, F. C., Mining districts and mineral resources of Nevada: Nevada Newsletter Publishing Co., Reno, p. 254, 1923.

2/ Couch, B. F., and Carpenter, J. A., Nevada's metal and mineral production: University of Nevada Bull., Geology and Mining Series No. 38, p. 148, 1943.

Table 1. Production of tungsten ore and concentrate from mines of the Minerva district, Nev. 1916-43.

Year	Tungsten Metals Corp.[1]			Hilltop mine[2]		
	Tons of ore	Units of WO_3	Value	Tons of ore	Units of WO_3	Value
1916	191[3]	191[3]	$7,651[3]			
1918	1,846[4]	1,846[4]	55,377[4]			
1937	6,400[5]	6,036[5]	158,916[5]			
1938	14,955	12,858	206,039			
1939	19,617	9,396	146,216			
1940	14,750	10,617[6]	196,090			
1941	10,160	13,599[7]	226,128[7]	1,126	1,677	$36,800
1942	19,867	16,876	428,008	450	429	11,462
1943	15,718	8,507	253,878	-	-	-
	103,504	79,926	$1,678,303	1,576	2,106	$48,262

1/ Data from Tungsten Metals Corp. except where noted. Includes production from Nevada Scheelite Co. (1916) and Minerva Tungsten Co. (1918).

2/ Data from Shoshone Mining Co.

3/ Value from Nevada tax records, University of Nevada Bull., Geology and Mining Series No. 38, p. 148, 1943. Units estimated from value, assuming a price of $40 a unit. Tonnage based on recovery of 1.0 percent WO_3.

4/ Value from Nevada tax records, op. cit., p. 148. Units estimated from value, assuming a price of $30 a unit. Tonnage based on recovery of 1.0 percent WO_3.

5/ Units from records of Tungsten Metals Corp.; value and tonnage from Nevada tax records, op. cit., p. 148.

6/ Includes production from re-treatment of tailings.

7/ Includes production from re-treatment of tailings, also 4,521 units of WO_3 contained in 2,082 tons of slime tailings sold for $18,243, net.

Field work by the Geological Survey

The writer, assisted by Donald Wyant, mapped most of the area during 3 months in the fall of 1940, and subsequently revised maps as development progressed in the mines. In 1942, Paul C. Bateman of the Survey assisted in underground mapping; in 1943, Konrad B. Krauskopf, aided by Robert F. Stopper, of the Survey, made a surface map of the Hilltop mine area.

Work by the Bureau of Mines

In the winter and spring of 1941, the United States Bureau of Mines core-drilled 34 holes totalling 6,932 feet on properties of Tungsten Metals Corp., and located the ore mined since then. Again, in the fall of 1943, the Bureau drilled 8 holes totalling 2,898 feet and located the westward continuation of the ore body in the Silver Bell mine. In each instance, plans for the drilling were laid out jointly by the writer and the project engineer, E. W. Newman in 1941 and R. W. Geehan in 1943, as part of a cooperative program of the Geological Survey and Bureau of Mines.

Acknowledgments

Tungsten Metals Corp., through its staff consisting of Paul J. Sirkegian, W. L. Trent, A. J. O'Connell, and W. H. Dunham, furnished records, surveys, board and lodging, and helpful assistance. Hadley R. Bramel contributed assays and other information about the Canary Yellow and Zigzag claims, entered into many stimulating discussions, and was a source of information about other mines in the region.

GEOLOGY

Regional setting

The Snake Range extends nearly 60 miles in a north-south direction and rises to over 13,000 feet in elevation. It is composed of (1) a great thickness of Paleozoic sedimentary rocks ranging from Cambrian through Carboniferous, (2) a central intrusive mass of late Mesozoic granitic rock exposed in Snake Creek and south of Osceola, and (3) a volcanic capping at the south end of the range in the Murphy Wash area. All the ore deposits known to the writer occur in the Cambrian sedimentary rocks or in the granitic intrusive, and none have yet been identified in the higher Paleozoic section, perhaps largely because of the distance of the upper rocks from the intrusive to which the mineralization is probably related. Gold and tungsten, with minor amounts of lead and silver, have been produced profitably in the range. The Minerva district with its tungsten production has first place in gross yield; the Osceola district with its gold and minor tungsten production has second place; and the Hub district, a former tungsten producer, third place.

The tungsten occurrences in the range are in veins or stockworks with quartz or calcite, or both, as gangue. No deposits of the contact-metamorphic type have been found. In general, either scheelite or

huebnerite or both occur in those deposits with quartzite or granitic wall rocks, but only scheelite occurs in the stratigraphically higher deposits with limestone wall rock. Narrow pegmatitic veins with quartz, feldspar, beryl, and scheelite have been found in the granite west of the old Bonita tungsten mine on Snake Creek. Minerva is the only tungsten district that made appreciable production between 1918 and 1944. Perhaps six other districts in the range were worked profitably at higher prices in 1916-18.

The sedimentary rocks on the west side of the Snake Range, from Osceola south past Minerva to the mouth of Murphy Wash, from oldest to youngest are the Lower Cambrian Prospect Mountain quartzite and Pioche shale, a Middle Cambrian limestone perhaps 2,000 feet thick, a Middle or Upper Cambrian shale probably 300 to 1,000 feet thick, the Ordovician Pogonip limestone and Eureka quartzite, and an overlying limestone which is perhaps also Ordovician. The rocks exposed are successively younger from Osceola southward: the Pioche shale appears at the mouth of Pole Creek 6 miles north of Minerva; the Pogonip limestone and Eureka quartzite are exposed south and east of Minerva. The veins at Minerva lie in the upper part of the Middle Cambrian limestone, so only this part of the stratigraphic section was studied in detail. No attempt was made to measure thicknesses outside of the mapped area.

Sedimentary rocks

At Minerva, the section mapped consists of about 1,000 feet of limestone overlain by at least 300 feet of thin, platy limestone and shale. Faulting conceals the true thickness of the shale, which may be as much as 1,000 feet. The normal sequence above the shale is absent, for the shale is faulted against the middle part of the cherty Pogonip limestone of Ordovician age, probably many hundreds of feet above the base of the Pogonip. Below the Minerva section, massive, light- and dark-colored limestone beds with a total thickness estimated at 1,000 to 1,500 feet extend downward to the Pioche shale and Prospect Mountain quartzite. This part of the section is well exposed on Mt. Washington, 5 miles north of Minerva; the saddle between Mt. Washington and Mt. Lincoln is cut in the shale at the top of the Cambrian section at Minerva.

On the map of Tungsten Metals properties (fig. 3), the Cambrian limestone has been divided on the basis of lithology into 3 major units: the "Upper black limestone," "Upper white limestone," and "Lower black limestone." On the map of the Hilltop mine (fig. 4), the lowest of these units, the "Lower black limestone," has been divided into 4 subunits. Although it is possible to choose major units that maintain rather constant thicknesses over distances of miles, the small units mapped at Minerva are somewhat more variable. In the sequence of limestones that

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Fig. 3. Geologic map of a portion of the Minerva district.

Fig. 4. Surface map of the Hilltop mine, Minerva district.

---

make up the Middle Cambrian, the units range from light to dark, massive to thin-bedded, dense to granular, not only down the dip but also along the strike of the beds. These lithologic variations are well illustrated by individual beds on the beautifully exposed west face of Mt. Washington, north of Minerva. For an example from the Minerva district, the dense, massive unit mapped as "Upper white limestone" has a thickness of 80 feet at the Chief and Silver Bell mines, 180 feet in the east part of the Everit vein, 280 feet on the West Everit hill, and 180 feet at the Hilltop mine.

The following columnar section, starting with the youngest rocks, summarizes the lithologic units used in mapping the Minerva district:

Cherty limestone	Thickness not determined, but certainly several thousands of feet. Part of the Ordovician Pogonip. In fault contact with underlying shale.
Shale	Thickness at least 300 feet, perhaps 1,000. Thin, platy limestone beds with shale partings in the lower portion, argillaceous shale above.
Upper black limestone	Thickness 300 feet. Thin-bedded to flaggy, dark-gray limestone, gradational contact upward. Abundant stylolites present in drill cores of Silver Bell area.
Upper white limestone	Thickness 75 feet at Chief mine, 180 feet at East Everit, 280 feet at West Everit, 180 feet at Hilltop. Massive, very fine-grained, light-gray limestone with pinkish cast. Contains a few thin, lenticular beds of dark-gray limestone. Cliff forming. Marked at top by a distinctive bed of thinly banded, cross-bedded limestone 2 to 4 feet thick, a bed that is present throughout the district and elsewhere in the range at this position and serves as a stratigraphic marker.
Lower black limestone	Thickness at least 300 feet. Dark-gray limestone with some lighter beds; mottled, numerous algal beds. Bedding indistinct to good. At the Chief mine, 180 feet below the top of this unit, is a 30-foot bed referred to as the "lower white limestone," lithologically similar to the "Upper white limestone." In the mapped area surrounding the Hilltop mine, rocks equivalent to the "Lower black limestone" have been further subdivided into the following distinctive units: "middle gray limestone," 50 feet thick; "thin-bedded limestone," 40 feet thick; "lower gray limestone," 100 feet thick; "lower white limestone," over 50 feet thick, base not exposed.

Igneous rocks

Rhyolite is the only igneous rock exposed in the Minerva district. It occurs northwest of the Silver Bell mine in sills 2 to 20 feet thick near the base of the shale; elsewhere it forms dikes as much as 25 feet thick that follow east-dipping faults. The dikes are most abundant in a zone across the center of the district extending from the Silver Bell mine to the Hilltop mine. They were intruded after formation of the scheelite veins, for they cut through the veins at the portal of the 6,900-foot level in the East Everit mine and at the Tony prospect, and elsewhere occupy post-mineral faults that offset the veins. The silicification and ironstaining along some of the faults is probably related to the rhyolite, which may be allied to the flow rocks east of Murphy Washat the south end of the Snake Range.

Structure

The rocks and veins of the Minerva area are disrupted by numerous faults that follow at least five different systems. Nearly all of these faults, even the low-angle ones, are normal faults; that is, the hanging wall has dropped with respect to the footwall. The few that show reverse movement have relatively small displacements.

Most of the faults can be placed in one of the following groups, listed from oldest to youngest:

1. Faults now occupied by quartz veins that strike N. 70° W. to N. 70° E. and dip 40° to 70° N. Although the hanging wall appears to have moved downward 30 to 75 feet, the true displacement cannot be determined, and the apparent displacement cannot always be differentiated from post-mineral movement along the veins (group 4).

2. Faults that strike north, dip from 75° E. to 75° W., and have displacements up to 20 feet.

3. Faults that strike N, 15° W. to N. 30° E., dip 13° to 60° E., and have displacements up to hundreds of feet.

4. Faults that strike east, dip 45° to 60° N., and frequently follow vein segments. Displacements are up to 50 feet.

5. Faults that strike north and dip 45° to 70° W. Displacements are up to 200 feet. Faults of this group are abundant at the front of the range west of the Everit vein, and also on the Zigzag claim.

The quartz veins occupy the oldest fault structures, and have been offset by most of the others. A few steep faults that cut across the vein structures are also pre-mineral, but they have had only small displacements

of probably not more than a few feet, and have only locally affected ore deposition. Most of the faults are post-mineral, demonstrated by the lack of quartz and scheelite in them, and by the disruption of formerly continuous ore shoots.

True displacements on all the faults except the oldest can usually be determined from the offsets of veins and stratigraphic units. It is essential to know the true displacement of veins, rather than the horizontal offset, to find continuations of ore shoots. The displacements on some of the larger faults, such as the Everit fault, change along the strike and dip because of the cumulative effect of subsidiary faults in the footwall.

Most of the faults are well exposed at the surface. The low-angle faults have topographic expression, for they repeat the massive, cliff-forming "Upper white limestone;" the faults lie at the tops of cliffs, and from a distance resemble bedding, which is much less apparent. All the faults contain calcite veins or cemented breccia, from an inch to 6 feet or more in width. Some contain reddish-stained material, usually calcareous but sometimes siliceous; the siliceous material, which is very fine-grained and bears no resemblance to the quartz veins, is thought to be associated with the rhyolite.

Structure contours can be drawn with fair accuracy from the surface exposures of those faults that dip east at angles of 50° or less. The contours are curved, not straight, and in some instances appear to be "folded," with "fold axes" trending east. The Everit fault is a good example: it dips 13° E. where it offsets the Everit vein, and steepens to 45° within 500 feet north and south of the vein; the dip of the fault at the vein intersection persists for at least 500 feet downward into the East Everit mine. The curves in the faults probably represent the original fracture pattern, rather than subsequent folding, for the limestone beds are not similarly folded.

In the mapped areas, the bedding in the limestone strikes north to northwest and dips 12° to 45° SW. Folding within the different fault blocks is not pronounced, the attitudes within individual blocks being essentially similar. The exception to this generalization is outside the detailed map areas on the Zigzag and Calico claims, between the West Everit and Hilltop mines. On parts of these claims, and for half a mile northward, the beds have been folded and complexly faulted so that most of the beds dip to the east.

The contact between the "Upper black limestone" and overlying shale, in several exposures between the Chief and Everit veins, is marked by a red, silicified breccia 5 to 50 feet thick with limestone fragments up to 6 inches in size. One of the best exposures, north of the east limit of the Oriole vein, contains abundant fragments of vein quartz. Although this breccia is not yet adequately explained, it may represent an old bedding fault of unknown magnitude, perhaps one of the oldest faults in the district. The exposures of this contact are very poor except in these silicified areas.

ORE DEPOSITS

Extent and thickness of veins

Scheelite ore shoots occur in seven roughly parallel quartz veins occupying normal faults that strike east, dip 45° to 70° N., and are spaced at intervals of approximately half a mile. The Chief Extension, Scheelite Chief, Oriole, Everit, Lone Buck, and Canary Yellow veins are shown on figure 3, the Hilltop and Tony veins, which lie farther north, on figure 4.

The quartz veins range in width from a few inches to 30 feet, and in length from 1,000 to 4,000 feet. The quartz changes in thickness within short distances along strike or dip, and is in places distributed in a series of closely spaced, parallel fractures with horses of limestone. The vein outcrops are limited on the west by alluvium, and on the east by alluvium and shale through which the veins do not penetrate. No major veins have been found on the surface at stratigraphic horizons above the shale; it may be possible to follow the veins underground eastward beneath the shale capping.

The Chief vein has been traced for 550 feet west from the portal of the main adit, but none of the other veins have been explored beneath the alluvium. Frontal faults defining the range probably lie only a short distance west of the foothills; the possibility of discovering large segments of veins buried beneath the alluvium seems remote.

Mineralogy and grade of ore

The veins consist mainly of quartz and calcite with some scheelite and, in spots, traces of tetrahedrite, galena, silver haloids, powellite, and cuprodescloisite. The scheelite concentrates are reported to contain as much as 4 ounces of silver to the ton, but this represents a high concentration ratio. The scarcity of associated minerals is indicated by the purity of the concentrates, which contain only traces of phosphorus, sulfur, and arsenic, and very little copper and molybdenum.

The quartz in the veins is white or tinged with greenish-yellow, coarsely crystalline, and usually massive, although a few small vugs can occasionally be found. The carbonate in the veins and faults ranges in color from white through flesh-color to light reddish brown, suggesting several carbonate minerals, although calcite is dominant. The scheelite commonly occurs in coarse cleavages distributed through the quartz or alined along fractures in the quartz. In some parts of the veins, notably in the Oriole mine and Tony prospect, the scheelite is distributed in very fine grains.

The grade of material mined in substantial quantities has ranged from 2.5 percent or more of WO_3 down to 0.3 percent. Local concentrations have contained as much as 10 or 20 percent of WO_3. All the ore milled by Tungsten Metals Corp. to the end of 1943 yielded an average of 0.76 units per ton, suggesting that the ore contained between 0.9 and 1.0 percent of WO_3.

Ore shoots

The tungsten ore occurs in shoots of limited vertical extent but with remarkable lateral continuity, which is disrupted by post-mineral faulting. The quartz veins are nearly barren outside of the shoots, which occupy only a small part of the veins. The ore shoots rake westward roughly parallel to the bedding in adjacent limestone, and frequently lie on the footwall side of the vein; the widest ore stopped is about 10 feet, although the vein in which the ore occurs may be 20 to 30 feet wide. In the smaller veins, ore shoots as narrow as 1 to 3 feet have been stoped.

Each of the main veins worked appears to have a single main ore shoot, although the Everit vein contains remnants of an upper ore shoot, and both it and the Chief vein may yet prove to contain lower shoots in portions that have never been prospected. In the East Everit mine, the main shoot was mined for 80 to 130 feet along the dip of the vein, and for a pitch length of 650 feet; extensions to the east have not yet been found, but an extension to the west is known to continue another 240 to 400 feet, possibly more. In the Chief mine, the ore shoot has been mined for 80 to 140 feet along the dip, and for a pitch length of 900 feet. Mine development may ultimately prove that the ore shoots before faulting were essentially continuous through most of the length of these veins. Little is known about the ore shoots in other veins of the district, for they have not been extensively explored.

The main ore bodies in the Chief, Everit, Canary Yellow, Zigzag, and Hilltop mines occur at about the same stratigraphic horizon in the "Upper white limestone." The upper stope in the West Everit mine, and the surface stope in the East Everit mine east of the Everit fault, both lie higher stratigraphically in the "Upper black limestone." The ore shoot in the Silver Bell mine also lies at a higher horizon, but appears to rake downward to join the shoot in the Chief mine.

The walls of the veins are frozen to the limestone in most instances, and post-mineral surfaces of breakage lie within the veins. The wall rocks are unaltered regardless of the presence or absence of ore in the adjoining vein.

The occurrence of ore shoots and the brecciation in them show that the veins were formed by successive introductions of minerals, and that the ore bodies were probably deposited in more porous portions of the veins. The massiveness of the "Upper white limestone" appears responsible for conditions favorable to scheelite mineralization. Perhaps slight changes in dip of veins where they cross limestone beds of different competence permitted development of crushed zones within the quartz, zones formed by continuous shearing along the vein. If this explanation be true, then other ore shoots may be discovered at greater depths in the vein wherever similar conditions prevail.

MINES

The veins in the Minerva district known to contain tungsten ore are held by Tungsten Metals Corp., Calico Tungsten Co., or Shoshone Mining Co. Of the many claims in the district, only seven are patented, all part of the Tungsten Metals group. Companies formerly active on some of these properties include Nevada Scheelite Co. (1916-17) (not to be confused with a different company which has operated under this name at Rawhide, Nev.), Minerva Tungsten Co. (1918), New Deal Leasing Co. (1940-41), Scheelite Leasing Co. (1941), and Virdot Development Co. (1941-42). These companies have all disbanded.

Tungsten Metals Corp.

Tungsten Metals Corp. owns the southern five of the seven known veins in the district. In addition to the seven patented claims (surveys 4485-A, 4486, and 4487) shown on the map (fig. 3), the group includes about 40 unpatented claims. Tungsten Metals Corp. also owns a 75-ton mill at Minerva. Custom ore from other properties has been accepted at this mill where all ore mined in the district since 1938 has been treated.

Scheelite Chief mine

The Scheelite Chief mine (see figs. 5 to 8) is in two major segments of the Chief vein, separated by the Chief fault. Both segments are developed from the 6,316-foot level, an adit 1,530 feet long. The west segment has three upper adits now largely stoped, a shaft near the portal of the main adit, and two short lower levels from the shaft. The east segment has a winze 30 feet deep below stope 1, with a sublevel from the bottom west to the Chief fault.

The west segment has been stoped from the portal of the adit to the Chief fault. Two small blocks of ore probably still remain west of the fault that terminates the 6,246- and 6,276-foot levels. Of seven holes drilled beneath the alluvium, only one, 550 feet west of the mine, found ore. The ore shoot in the intervening area may have been eroded away.

The east segment has been stoped above the main level for a length of 260 feet, and the level has been extended another 340 feet beneath the shoot. The quartz vein below the shoot is narrower, ranging from half a foot to 4 feet, and contains sporadic traces of scheelite.

Fig. 5. Map and vertical projection of the Scheelite Chief vein.

Fig. 6. Scheelite Chief mine, composite map.

Fig. 7. Scheelite Chief mine, vertical projection of west workings.

Fig. 8. Scheelite Chief mine, vertical projection of east workings.

Silver Bell mine

The Silver Bell mine (see figs. 9 and 10), in the east portion of the Chief vein, is worked to the fourth level through a shaft 365 feet deep on the incline (238 feet vertically). A winze, 84 feet on the incline, connects the fourth level with a short fifth level at a point 300 feet west of the shaft. The total level workings, largely concentrated on the third and fourth levels, amount to nearly 1,200 feet of drifts and crosscuts. Ore was stoped above the third level for a length of 140 feet, a width of 3 to 5 feet, and a height of 60 feet along the dip. A faulted westward extension of this ore body was being worked from the fifth level in October 1944. Possible extensions eastward beyond the shaft have never been investigated either by drilling or drifting, and should be sought by extending the third level east through the various fault segments.

Oriole mine

The Oriole vein is the least developed of the major veins in the district. It is opened at the west end in the Oriole mine by two short adits at a vertical interval of 80 feet (see figs. 11 and 12). The ore stoped consisted of very fine-grained scheelite in quartz, and averaged only 0.4 percent of WO_3. The width of ore ranged from 1-1/2 to 5 feet. The stopes mined are in offset segments of a single ore shoot, which could probably be readily followed eastward by extending the upper adit.

The outcrop of the vein is mostly barren except for some coarsely crystalline scheelite on the crest of the hill above the mine, and for low-grade mineralization in the first segment east of Chief Canyon. The only exploration east of the mine is by three shallow drill holes in two fault segments east of the canyon. Although the vein is not as strong at the surface as the Chief or Everit veins, it shows impressive widths of quartz, and might be productive in the future.

West Everit mine

Workings in the West Everit mine consist of two adits, a sublevel above the upper adit, two stopes, and several connecting raises (see figs. 14 to 16).

Fig. 9. Silver Bell mine, composite map.

Fig. 10. Silver Bell mine, vertical projection.

Fig. 11. Oriole mine, composite map.

Fig. 12. Oriole mine, vertical projection.

Fig. 14. West Everit mine, composite map.

Fig. 15. West Everit mine, vertical projection.

Fig. 16. West Everit mine, section along 11,350 E.

An adit 50 feet long on the west face of the hill dates from 1917. Two small ore bodies have been mined, both of excellent grade: one on the crest of the hill, the other in the lower adit. Both ore bodies are in the hanging wall of the West Everit fault, and are cut off by it. The upper ore shoot is a remnant, former extensions of which have been eroded away. The lower ore shoot, however, might have extensions below the West Everit fault. In spite of several hundred feet of exploratory work from the 6,800-foot level, the vein was not located. The work seems to have disproved the existence of any segment of appreciable size in the footwall of fault "A", which is parallel to the vein. The segment of vein exposed on the west side of the hill at 11,200 E., 9,400 N. is probably the same Everit vein and ore may be found in it below the 6,800-foot level.

The West Everit vein zone ranges in width from 5 to 50 feet, the vein branching into several parts with included layers of limestone. The maximum width of continuous quartz is 25 feet. Wherever drifts lie in the main vein, the full width of quartz is not exposed; so scheelite ore bodies may be missed by failure to crosscut.

The only ore remaining in the mine is between the upper stope and the West Everit fault in a fault sliver estimated to contain 1,200 tons. The fault segments west of the mine are too little known to permit any inference as to quantity of ore. Because of extreme faulting, the vein westward beneath the alluvium probably does not justify underground exploration.

East Everit mine

The main development in the East Everit mine is from an adit 1,735 feet long at an elevation of 7,050 feet (see figs. 13 and 17-20). A raise connects with the surface from a point 1,085 feet inside the portal. A shorter adit, 150 feet lower, is used for ore transfer, and also for development of another fault segment.

Two ore shoots have been mined, probably correlatives of the two in the West Everit mine. The upper ore shoot is eroded away except for a small segment stoped at the surface above the Everit fault. The lower shoot cropped out only west of the Everit fault, but has been stoped most extensively east of the fault. Although drill hole 8 and the westernmost stope in the mine (that from the 6,900-foot level) yielded ore containing only about 0.5 percent of WO_3, the ground has not been sufficiently tested to prove the absence of better ore. An adjoining segment of vein that crops out south of the portal of the 6,900-foot level is untested.

Fig. 13. Map and vertical projection of the Everit vein.
Fig. 17. East Everit mine, composite map.
Fig. 18. East Everit mine, vertical projection.
Fig. 19. East Everit mine, map of east extension.
Fig. 20. East Everit mine, section along 14,674 E.

The portion of the vein intersected near the face of the 7,050-foot level (at 14,100 E.) contains low-grade scheelite-bearing material at that point, but has not been explored upward to the surface, which is masked by debris. Beyond the face, five holes drilled from the surface in 1943 found no ore, but proved that the ore horizon lies considerably lower in this fault block. The thickness of quartz and the presence of scheelite in this part of the vein are encouraging for the eventual discovery of an ore shoot at greater depth.

The small vein that lies 150 feet north of the Everit vein contains several exposures of narrow but high-grade scheelite ore. One outcrop (at 13,150 E.) was mined in an open cut. Drill hole 2 (at 13,240 E.) intersected 5 inches of vein that assayed 7.53 percent of WO_3. High-grade ore 8 inches wide has not been touched in an exposure at the east end of the vein (at 13,580 E.). The widths and tonnages available are unfavorable for company exploration, but the grade of ore might make portions of the vein attractive to a lessee.

Lone Buck vein

The Lone Buck vein, entirely unexplored, crops out for a length of 1,200 feet and ranges in width from a few inches to 4 feet. Two channel samples cut by the Bureau of Mines in 1941 indicate a block of ore (between 14,200 E. and 14,260 E.) 60 feet long, 1.8 feet wide, and averaging 1.74 percent of WO_3; indicated ore along the rake west to the nearest fault amounts to 220 tons. The vein shows little promise of productivity, for the only ore exposed is in this block, which is a small and inaccessible remnant of a shoot.

Calico Tungsten Co.

The Calico Tungsten Co., a partnership between Hadley R. Bramel and Stanley Feitler, owns three unpatented claims on a single vein; the Canary Yellow, Calico, and Zigzag claims. Except for surface cuts, work has been concentrated at the Canary Yellow mine.

Canary Yellow mine

The Canary Yellow mine is developed by an 85-foot crosscut adit with a 110-foot drift on the vein, and a raise to the surface 85 feet above (see fig. 21). The vein in the drift shows 1 to 1-1/2 feet of ore containing more than 1 percent of WO_3 for a drift length of 60 feet. On the surface directly over the portal of the adit, Bramel and Feitler sampled the vein at 10-foot intervals for a length of 130 feet over widths of 1-1/2 to 6 feet, and obtained assays ranging from 0.39 to 4.20 percent of WO_3, averaging more than 1.0 percent. From the raise, 37-1/2 tons milled by Tungsten Metals Corp. yielded only 27 units of WO_3, an average of 0.72 unit per ton.

Fig. 21. Canary Yellow mine, map and projection of workings.

Although the ore in the drift and raise is poorer than that at the surface, better ore may lie west of the workings if the surface body is part of a shoot that rakes westward. The ore in the drift may may represent a lower shoot. With this interpretation, the upper shoot, with an average width of 2 feet, is estimated to contain 400 tons of indicated ore that will average more than 1.0 percent of WO_3; the lower shoot, 1-1/2 feet wide and averaging 1.0 percent, may contain at least 600 tons of inferred ore if it continues 260 feet along the rake to the faults limiting this segment of vein. No estimate can be made of the possibilities of the vein eastward, for the vein is unexplored and ore is not exposed at the surface, although the vein croppings continue 1,000 feet east of the mine.

Zigzag and Calico claims

The Zigzag and Calico claims lie on the west end of the same vein as the Canary Yellow mine, but are separated from it by half a mile of alluvial cover. The vein on these claims, faulted even more than is normal to the district, is broken into fragments 20 to 200 feet long, some of which contain ore at the surface. The only workings are a few open cuts from which Bramel and Feitler mined 18 tons of ore that yielded 20 units of WO_3. The width of vein ranges from 1 to 4 feet. Inasmuch as ore at the surface has not been profitable to mine because of the small size of fault segments, it is doubtful if ore present in other segments but not exposed can be mined profitably unless the price of tungsten exceeds $30 a unit.

Shoshone Mining Co.

The Shoshone Mining Co., a partnership among A. J. O'Connell, W. L. Trent, J. E. Brinton, and Horace Bath, owns the Hilltop group of six unpatented claims known as the Hilltop, Tony, Tony No. 1, Tony No. 2, Tony No. 3, and Tony No. 4. The claims were operated in 1940-41 by the New Deal Leasing Co., in 1941 by the Scheelite Leasing Co., and in 1942 by the Virdot Development Co. The Tony prospect was operated by Tungsten Metals Corp. for a short time in 1940-41. Most of the production has come from the Hilltop mine, which yielded at least 2,106 units of WO_3.

Hilltop mine

The Hilltop mine is developed by a main adit at an elevation of 7,066 feet, by a short adit at 7,120 feet, and by several open cuts (see figs. 4, 22, and 23). The 7,066-foot level has about 650 feet of drifts and crosscuts, three stopes, and three raises to the surface. This level is connected with an ore bin at the end of the road, 600 feet lower, by a single span, jig-back aerial tram 1,150 feet long.

Fig. 4. Surface map of the Hilltop mine.

Fig. 22. Map and vertical projection of the Hilltop mine.

Fig. 23. Hilltop vein, map of main level with section.

The Hilltop vein is narrow, with surface widths of 1/2 to 3 feet. In the stope east of the crosscut adit, the vein flattened and widened to 8 feet of good ore between the level and the surface 35 feet above. Neither the drift level with 1-1/2 feet of quartz nor the surface with 1 foot of quartz gave any indication of the intervening wide ore body. The stopes west of the adit were narrow, the ore being a foot or less in width although of high grade.

Hardly any ore remains in sight, although a few tons could still be underhanded beneath the level and stopes. The raise at the east end of the workings has some ore in the roof; so there may be ore in the 50 feet of unexplored ground up to the surface. The largest block of potential ore is in the vein segment beyond the west face of the 7,066-foot level, beneath the upper adit. All told, perhaps 1,000 tons of 1 to 2 percent ore might be found in these untested blocks with very little additional exploration.

Tony prospect

The Tony prospect is explored by a 225-foot adit, a raise to the surface, and several surface pits. The vein strikes north and dips east, and is in this respect unique among the tungsten-bearing veins of the district. The vein outcrop extends for nearly 200 feet along the strike; continuations of the same vein-fault to the north and south contain no quartz or scheelite, although calcite filling, common to post-mineral faults of the district, is present. Scheelite mineralization for widths of 1 to 3 feet extends for about 100 feet on the surface, but no comparable mineralization is present in the adit. The scheelite is extremely fine-grained. Only 32.5 units of WO_3 was recovered from 159 tons of ore milled in 1941, a yield of about 0.2 percent. No commercial ore is now exposed, and only a few tons that contain 0.2 to 0.5 percent are visible.

Two narrow veins on Tony No. 2 claim west of the section corner contain a few crystals of coarse scheelite, but the exposures are not encouraging enough to warrant exploration.

RESERVES

The mines of the Minerva district rarely have more than a few tons of measured ore, and seldom have more than a few thousand tons of indicated ore. As in many other tungsten mines, indicated, not measured, ore is mined. Consequently, an estimate of ore reserves must be primarily an interpretation of unexplored areas based on past experience. The writer believes that the total reached in the following tabulation is conservative, and less than the expectable future production of the district. Individual blocks inferred, however, may vary materially from the estimate given.

The structural complexity of the ore bodies necessitates considerable dead work in exploration. Development in the mines has never been far enough ahead to permit continuous milling at capacity. In the 6 years from 1938 to 1943, the tonnage produced annually ranged from 10,160 to 19,867, and

never approached the mill capacity of 27,000 tons. The added mining and milling cost involved in operating at capacity would be slight, and the net profit from such operation would be much greater.

Under operating conditions in 1943, the grade of ore mined (yield of 0.54 percent of WO_3) was the minimum that could be handled profitably at a market price of $30 a unit. Ore that would mill out at 0.75 percent (the average yield from past production) presumably could have been worked at $21.00 a unit. The cost of production in both instances could be reduced substantially by operating the mines at capacity.

The district reserves are summarized by mines in table 2. The reserve figures are broken down into blocks within individual mines in table 3. The only measured ore is blocked out in the east workings of the Chief mine by a winze, sublevel, and raise. The indicated ore is in blocks that have been tested by drill holes or partially explored by drifts and raises. The inferred ore, which constitutes the bulk of the reserve, is inferred largely on geologic evidence as to continuity of ore shoots. Estimates of grade are based mainly on the yield from ore mined in the past.

In addition to the estimates enumerated, it is expected that future prospecting will discover other ore bodies in the Oriole vein, unexplored for 2,600 feet east of the Oriole mine, and in the Chief vein, which extends at least 400 feet east of the Silver Bell shaft. Although these areas have not yet been tested by drilling or underground workings, they probably contain ore bodies similar to those mined elsewhere in the veins, where production has amounted to about 23 tons per foot of vein explored along the strike. This additional tonnage might be on the order of 70,000 tons averaging 0.8 percent of WO_3.

Table 2. Summary by mines of ore reserves in the Minerva district.

Table 3. Reserves within mines of the Minerva district, distributed into ore blocks.

Table 2. Summary, by mines, of ore reserves in the Minerva district. December 1, 1943.

Ore commercial under present conditions

Grade 0.5 percent WO_3 or higher

	Measurable		Indicated		Inferred*		Inferred**	
	Tons	Units	Tons	Units	Tons	Units	Tons	Units
Scheelite Chief***	1,200	900	6,200	4,590	17,000	12,000		
Silver Bell***			4,540	4,540	18,300	15,975		
East Everit			4,400	2,200	2,400	1,920	15,000	11,100
West Everit					1,200	1,200		
Lone Buck			200	375				
Canary Yellow			400	400	600	600		
Hilltop					1,000	1,000		
	1,200	900	15,760	12,105	40,500	32,695	15,000	11,100

Ore marginal under present conditions

Grade less than 0.5 percent WO_3

	Indicated	
	Tons	Units
East Everit	5,200	2,080
Oriole	3,800	1,520
	9,000	3,600

* Inferred with reasonable assurance on basis of nearby workings.
** Inferred by geologic reasoning, unconfirmed by workings in the immediate vicinity.
*** Reserves partially depleted between December 1, 1943 (the date of this estimate) and May 1945. Most of the ore mined in this period was from the Silver Bell mine, some from the Scheelite Chief mine.

Table 3. Reserves within mines of the Minerva district, distributed into ore blocks. December 1, 1943. *

Location		Width	Measurable ore			Indicated ore			Inferred ore		
Mine	Block	in feet	Tons	% WO_3	Units WO_3	Tons	% WO_3	Units WO_3	Tons	% WO_3	Units WO_3
Scheelite Chief*	C-6	3	..	..	..	1,200	0.7	840	..	..	..
	C-7	3	..	..	..	..	..	..	700	0.8	560
	C-8	2.5	..	..	..	..	..	..	300	0.8	240
	C-9	4	1,200	0.75	900	..	..	..	..	..	..
	C-10	3-7	..	..	..	5,000	0.75	3,750	..	..	..
	C-11	5	..	..	..	..	..	..	16,000	0.7	11,200
			1,200		900	6,000		4,590	17,000		12,000
Silver Bell*	C-1	6.5	..	..	..	3,500	1.0	3,500	..	..	..
	C-2	4	..	..	..	1,040	1.0	1,040	..	..	..
	C-3	6.5	..	..	..	..	..	..	9,000	1.0	9,000
	C-4	5	..	..	..	..	..	..	9,300	0.75	6,975
						4,540		4,540	18,300		15,975
Oriole	O-1	2.5	..	..	..	1,000	0.4	400	..	..	..
	O-2	2.5	..	..	..	2,800	0.4	1,120	..	..	..
						3,800		1,520			
West Everit	E-7	3	..	..	..	..	..	..	1,200	1.0	1,200
East Everit	E-1	5	..	..	..	..	..	..	3,000	0.5	1,500**
	E-2	5	..	..	..	4,400	0.5	2,200	..	..	..
	E-3	5	..	..	..	1,800	0.4	720	..	..	..
	E-4	5	..	..	..	3,400	0.4	1,360	..	..	..
	E-5	5	..	..	..	..	..	..	2,400	0.8	1,920
	E-6	5	..	..	..	..	..	..	12,000	0.8	9,600**
						9,600		4,280	17,400		13,020
Lone Buck		1.8	..	..	..	220	1.74	375	..	..	..
Canary Yellow		2.0	..	..	..	400	1.0	400	..	..	..
		1.5	..	..	..	..	..	..	600	1.0	600
Hilltop		1.5	..	..	..	..	..	..	1,000	1.0	1,000

* Reserves partially depleted between December 1, 1943 (the date of this estimate) and May 1945. Most of the ore mined in this period was from the Silver Bell mine, some from the Scheelite Chief mine.

** Inferred by geologic reasoning, unconfirmed by workings in the immediate vicinity.

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Item 19

Docket DMA 2138, (Tungsten) Hilltop Mine,

Minerva Mining District

White Pine County, Nevada

GEOLOGY

The rock in the area is limestone of Cambrian age that is gently tilted west and is displaced by faults of several systems. [1] The oldest faults are occupied by scheelite-bearing quartz veins.

[1] Lemmon, D. M., Tungsten Deposits in the Minerva District, White Pine County, Nevada: Open File Report, Strategic Minerals Investigations, 1944.

The limestone in the mine area has been subdivided by Lemmon into different units. Listed in order of youngest to oldest they are:

Upper white limestone (Cuw)	180 feet
Lower black limestone	
Middle gray limestone (Cmg)	50 feet
Thin-bedded limestone (Ctb)	40 feet
Lower gray limestone	100 feet
Lower white limestone	over 50 feet

The upper white limestone is cliff-forming unit; it is fine-grained, massive, light gray with a pinkish cast, and contains a few thin, lenticular beds of dark gray limestone. In general, the lower black limestone is dark gray, mottled, and indistinctly to well bedded. In the mine area, the middle gray unit is massive and forms steep cliffs. All the beds strike north and dip

5°-22° W. in the mine area. The workings of the Hilltop Mine are in the upper white and middle gray units (fig. 3).

Faults that cut the limestone are nearly all normal and have displacements of as much as 75 feet. They strike northeast, north, or northwest, and most of them dip steeply eastward. The fault occupied by the Hilltop quartz vein strikes northeast and dips 45°-75° NW. The displacement of the limestone on this fault is estimated to be less than 20 feet.

ORE DEPOSITS

The tungsten ore body that has been mined is a quartz vein along a fault that strikes northeast and dips 45°-75° NW. The ore shoot is about 160 feet long, as much as 8 feet wide, and has been mined to a depth of 40 feet (fig. 3).

The ore mineral is scheelite; it occurs finely disseminated throughout the quartz vein, and, to a slight extent, in the limestone wall rock adjacent to the vein. The average grade of approximately 3,000 tons of ore mined was about 1.23 percent WO_3.

The ore body pinches and swells along the strike and down the dip and ranges from a few inches to 8 feet wide. On the surface the average width of the vein is 1 foot, and along the drift it is 1 1/2 feet. It has been offset by many normal faults having displacements of as much as 75 feet (fig. 2).

The ore shoot appears to be locallized at a brecciated zone in the vein. Lemmon (1945, p. 10) considered that the massiveness of the upper white limestone influenced brecciation, and thus zones favorable to scheelite deposition were formed. In the Hilltop mine, the vein has been productive only in this unit. Scheelite also occurs in the vein in the middle gray unit (samples No.

3 and 4, fig. 4), but the width of the ore found thus far has been too narrow to be mined profitably.

ORE RESERVES

There are no reserves of measured or indicated ore in the Hilltop Mine. About 200 tons of ore containing about 1.0 percent WO_3 may be inferred above the level in the offset segment of the vein at the west end of the mine. This block is 40 feet long, 1.5 feet wide, and extends 40 feet down the dip below the upper level (fig. 3).

A small additional tonnage may be found in the upper white limestone below the level. As the middle gray limestone is also massive, it is possible that the vein may be productive in it. If this is true, the ore shoot may continue to an average depth of about 50 feet vertically below the level, and the maximum reserves that may be inferred are about 1100 tons of ore averaging about 1.0 percent WO_3, contained in the block 160 feet long, 1.5 feet wide and extending 57 feet down the dip of the vein.

PROPOSED EXPLORATION

The applicant has proposed to explore the downward continuation of the ore shoot by driving a crosscut 225 feet north from the face of the cliff 130 feet below the workings to intersect the vein, to drift along the vein 100 feet in each direction, and to raise 130 feet to the existing level. This work would provide a haulage way as well as explore the deposit. The applicant also proposes to construct 1/2 mile of road to gain access to the portal of the proposed crosscut. He estimated that the total cost of the project would be $31,000.

This program does not appear to be sound, as all but about 57 feet of the 130 feet of new depth is believed to be in an unfavorable limestone unit, and the chances of making a significant discovery in this unit are considered to be small.

The tungsten branch suggested in a letter to the applicant (Holderer, 10/22/51) that he submit a counter proposal designed to explore the west and east blocks (faulted continuations of the ore shoot in the favorable limestone unit).

The applicant in a reply (letter of 10/28/51) stated that there was no change of formation between the existing level and the site of the proposed crosscut, and that recent work has disclosed new data regarding the stratigraphy. He requested a DMA examination of the property. As a result, the Coordinating Committee requested the Field Team, Region III (letter of Lyon, 11/13/51) to examine the property with particular emphasis on determining whether the additional work done may have changed the picture.

The examining engineer and geologists carefully checked the Hilltop mine and determined that there has been no new work done since Lemmon mapped the mine in 1943; they confirm that the lithologic change shown on Lemmon's maps is present.

A representative of the applicant was present at the time of examination and was informed of these facts. He also agreed that Lemmon's map showed the true picture of the stratigraphy. He did not concur in the opinion that the lower member was unfavorable for tungsten deposition, but was unable to offer any evidence to the contrary. He stated that his company would not be in-

terested in performing work in the west and east blocks in the favorable unit because the tonnage to be expected is small.

SUMMARY AND CONCLUSIONS

The tungsten deposit at the Hilltop Mine is in a quartz vein that cuts limestone of Cambrian age. The ore is composed of finely disseminated scheelite in quartz; 3000 tons of ore was shipped which averaged about 1.23 percent WO_3.

The ore shoot is 160 feet long, up to 8 feet wide, and was mined down dip for about 40 feet. The ore shoot, where mined, is confined to a limestone unit that extends only a few feet below the present workings. Ore of good grade but narrow width occurs in a gray limestone (underlying the favorable unit) which extends to about 50 feet below the workings.

There are no measured or indicated ore reserves in the Hilltop Mine. The inferred reserves are 200 tons of ore containing 1.0 percent WO_3 above the existing level, and about 1100 tons containing 1.0 percent WO_3 below the level.

It is concluded that although ore may be found in the favorable white limestone near the existing level, the chance of making a significant discovery at depth is poor. The cost of exploring the upper level is too high to be justified by the small inferred ore reserve tonnage. It is recommended, therefore, that the application be denied.

U. S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DEFENSE MINERALS ADMINISTRATION
DOCKET NO. 2138

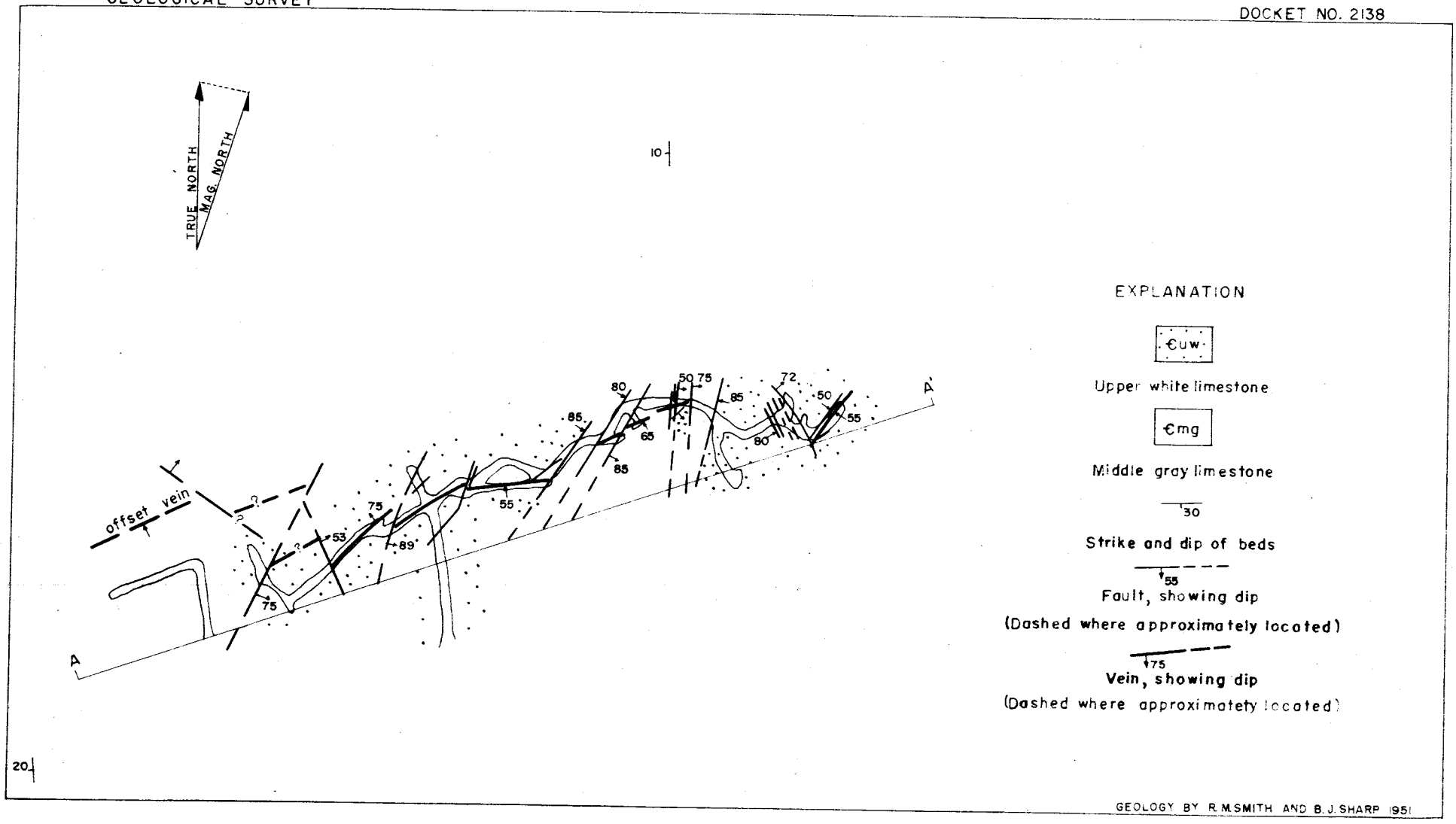

FIG. 2

GEOLOGIC MAP OF HILLTOP MINE
MINERVA MINING DISTRICT
WHITE PINE COUNTY, NEVADA

0 100 200 FEET
Scale

U. S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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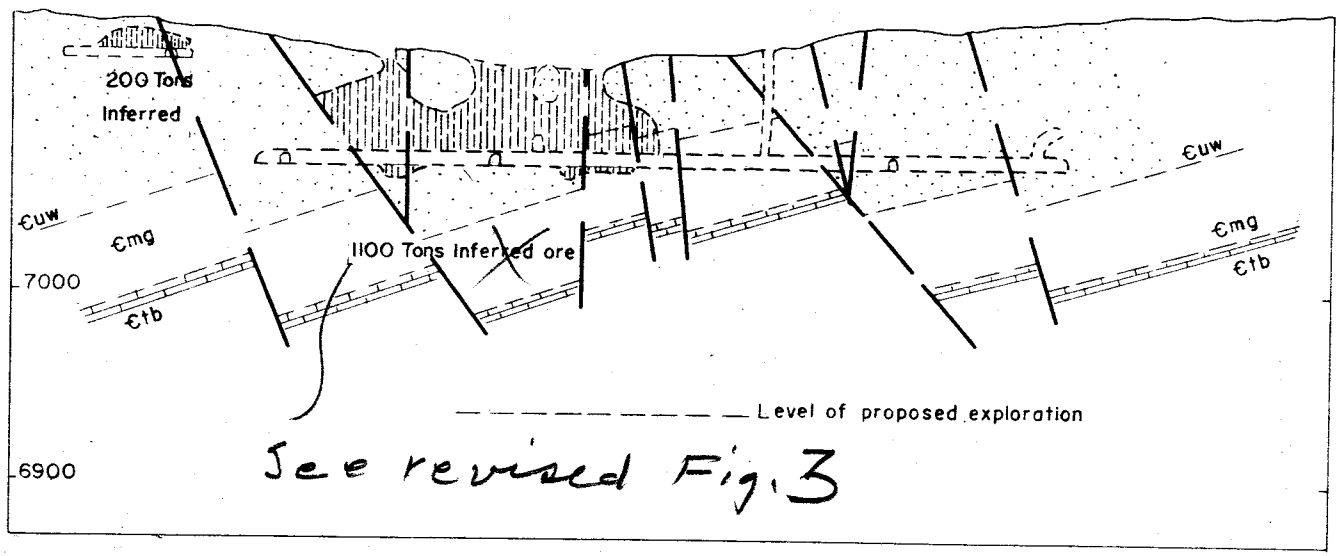
DOCKET NO. 2138



EXPLANATION

€uw
Upper white limestone

€mg
Middle gray limestone

€tb
Thin-bedded limestone

Contact
(Approximately located)

Fault
(Approximately located)

Stopes
(Projected)

GEOLOGY BY R. M. SMITH AND B. J. SHARP 1951

FIG. 3

SECTION ALONG LINE A-A'
HILLTOP MINE, MINERVA MINING DISTRICT
WHITE PINE COUNTY, NEVADA

0 100 200 FEET
Scale

U. S. DEPARTMENT OF THE INTERIOR
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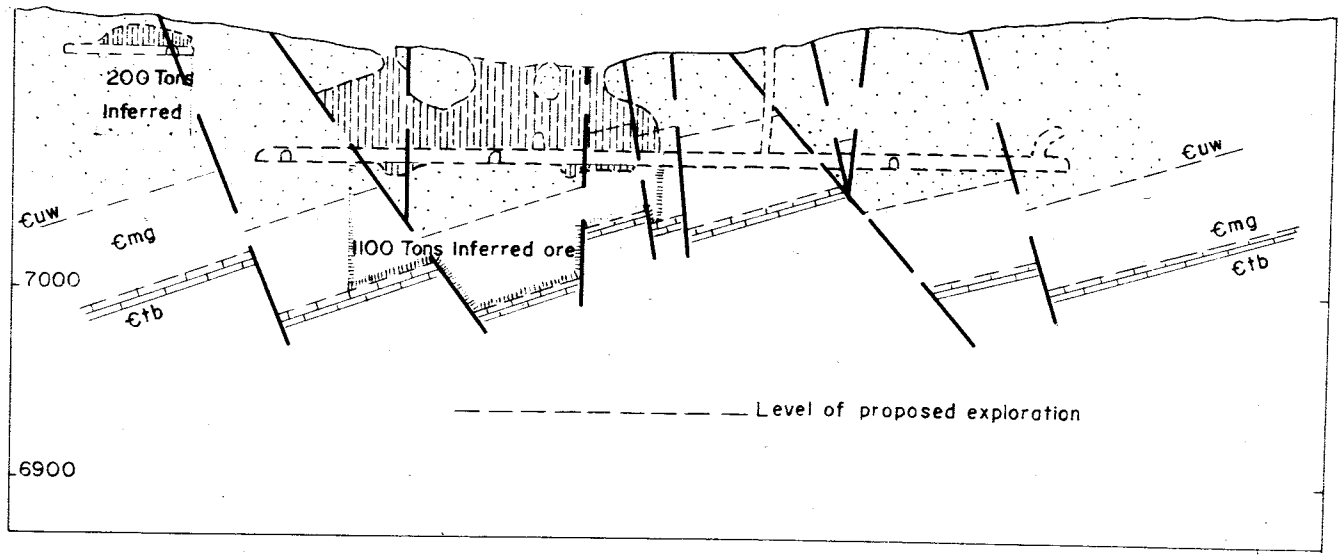

EXPLANATION

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SECTION ALONG LINE A-A'
HILLTOP MINE, MINERVA MINING DISTRICT
WHITE PINE COUNTY, NEVADA

0 100 200 FEET
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SHOSHONE (MINERVA, LEXINGTON)

Lincoln, F. C., Mining Districts and Mineral Resources of Nevada, Reno, 1923 pp 254-5

"The Shoshone district is situated southeast of Shoshone post office on the west flank of the Snake Range in southeast White Pine County. Ely, on the Nevada Northern Railroad is 55 miles northwest. The Snake district adjoins the Shoshone district on the east. The east section of the Shoshone district was organized in the early days as the Lexington district but no mines of importance were discovered there.

"In 1869, an Indian showed the Indian silver mine to white miners and the Shoshone district was organized. Some rich chloride ore was found but the mines did not prove profitable and the district was abandoned about 1876. The St. Lawrence mine produced in 1916. Tungsten ore was discovered in the district in 1915 and mined in 1916. In 1918, the Minerva Tungsten Corporation was incorporated and equipped with a 150-ton concentrating mill.

"At the Indian Mine, a vein in limestone carries silver chlorides. At the Minerva mine, scheelite occurs in a quartz vein in limestone from 9 feet to 50 feet in width and dipping at 55°.

MR 1915 "Scheelite in quartz veins was found at several places between the Minerva district, 30 miles south of Osceola, and....some and probably most of the veins were prospected for gold and silver years ago, but scheelite was not then recognized. Scheelite was found in the dumps from some of the old workings."

MR 1916 "Scheelite was mined from various veins in the Minerva district near Shoshone post office, 13 miles south of Tungsten."

MR 1930 (?) "C. B. Jacobs produced some scheelite in the Osceola district 45 miles east of Ely" (Might be Osceola or Sacramento Pass)

MR 1934 (?) "The Moulton-Vogelaas Syndicate (Ely) sank a shallow shaft

SHOSHONE (MINERVA, LEXINGTON) Cont.

on its scheelite property on the west side of the Snake Range 40 miles southeast of Ely but made no concentrates." (Might be Osceola or Sacramento Pass)

MR 1937 "The Tungsten Metals Corporation at Ely in White Pine County produced scheelite from two mines and was the largest of several other small operators that contributed to the Nevada total in 1937."

MR 1938 "The Tungsten Metals Corporation at Ely, White Pine County, produced from three mines and was the largest of several other small operators that contributed to the Nevada total in 1938."

Nevada Mining Press, October, 1939, p. 7. "An initial divident was paid recently by the Nevada Tungsten Company, operating near the border of the Osceola placer district in eastern White Pine County with the distribution in cash to its shareholders of 25% of its $25,000 authorized capitalization. A modern mill was provided less than a year ago on the property.

"Manager of the enterprise is Paul Sirkegian, consulting geologist for the Consolidated Coppermines Corporation at Kimberly, Associated with him in control is J. B. Haffner, Manager, for the Consolidated Coppermines Corporation, and it is reported that members of the Reno legal firm of Thatcher and Woodburn are also financially interested in the undertaking." (Relation between Tungsten Metals Corporation and Nevada Tungsten Company?)

Do, p. 5 Tungsten properties in White Pine County:

Dirty Shirt Mine	Tungstonia District	J. Benj. Parker in chg.	Idle
Nevada Tungsten Co.	Osceola	Paul Sirkegian	Milling
Pony Express Mine	Snake Range	Leroy Leach	Idle
Tungsten Metals Corp.	Shoshone	Travis P. Lane	"
Tungsten Mines, Inc.	Regan	C. B. Reynolds	"

Mining Press, 4/15/39. Tungsten Metals Corporation, operating 47 miles southeast of Ely. "This mill is under the supervision of W. L. Trent, who reports an average of 75 tons of ore is handled per day with this set-up.

SHOSHONE (MINERVA, LEXINGTON) Cont.

E. and M. J., November, 1939, p. 68 "Tungsten Metals Corporation, operating a scheelite mine and mill in the Shoshone district eastern White Pine County, since starting its mill late in September, 1936, has treated about 75,000 tons of ore from its mine and has produced more than 600 tons of 70% tungsten concentrate, employing a force of 40 men. It is now second to the Nevada-Massachusetts Company, in Nevada, in production of Tungsten. Paul J. Sirkegian, Chief Geologist for the Consolidated Coppermies Corporation at Kimberly is president and manager; W. L. Trent is mill superintendent, and Horace B. Bath is secretary, with main offices at Ely." (Mining Press, November, 1939, p. 1, essentially same as this.)

Nevada Mining Press, December, 1939, p. 6. "An official report, just issued at Ely, says that the Tungsten Metals Corporation is enlarging its 100-ton flotation and gravity concentration mill to handle 150 tons daily.

"Another 100-KW power unit is being installed, secondary grinding ball mills and a secondary crusher, one more bankof flotation cells and cells for some of the silver oxides. This equipment will give maximum recovery and allows a large additional tonnage of low grade ore to be milled.

"Company operations have been continuous since their inception 3 years ago and will be continued during the present construction work... Holdings are located in White Pine County near Shoshone and were formerly controlled by the old Minerva Tungsten Corporation.

"Around 40 men have been employed steadily and this crew will be increased to 65 when full operations are started with the new equipment. The operating staff includes Harold Dunham, Mine Foreman, Wm. Trent, Mill Superintendent, and A. O'Connel, Chief Clerk and Purchasing Agent, Horace Bath is Secretary-Treasurer."

E. and M. J., Vol. 141, March 1940, p. 64. "Equipment added recently

SHOSHONE (MINERVA, LEXINGTON) Cont.

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4340 0017

(32) JJemm

WHITE PINE COUNTY
Shoshone (Minerva, Lexington) W,Ag. 55 miles SE Ely
Limestone, veins

1932

Recommendation for the installation of government custom tungsten mills, by F.W. Horton, Aug 13, 1942 Loc: Shoshone, Nevada. Tungsten files 1207

The ores of the district are quite similar in composition, differing primarily in the size of the included scheelite. The gangue in most of the ores consists almost wholly of quartz, calcite and silicified limestone. three major parallel veins varying from 1 to 15 feet wide and about 2,000 feet apart traverse massive Cambrian limestone. the veins consist of quartz and calcite and carry scheelite in definite ore shoots which rake westerly at about 30 degrees from the horizontal. the best ore shoots as determined by the USBM have 32,475 tons having a theoretical assay value of 0.72% WO_3 and containing over 465,000 pounds of WO_3.

1. Map of the southeastern portion of White Pine Co showing the location of tungsten deposits. Scale: 1" to 4 miles. (plotted on index map)

4340 0017

(332)
Item 19

SHOSHONE (MINERVA, LEXINGTON)

Lincoln, F. C., Mining Districts and Mineral Resources of Nevada, Reno, 1923 pp 254-5

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4840 0017

Minerva district

Shoshone

(332)

Item 19

The Minerva district is near the Utah border in White Pine County, Nevada, 45 miles southeast of Ely. Minerva, the former millsite of Tungsten Metals Corporation, at an altitude of about 5,850 feet in sec. 7, T. 11 N., R. 68 E. and sec. 12, T. 11 N.,

R. 67 E., Shoshone quadrangle, is 1 mile south of Shoshone post office in Spring Valley, and is reached by a level dirt road extending 16 miles southeast from U. S. Highway 93. The mines are 2 to 5 miles from the millsite, in the lower portion of the Snake Range at altitudes of 6,300 to 7,400 feet, in secs. 16, 21, and 28, T. 11 N., R. 68 E.

History and production

Although silver ore was discovered in 1869 at the Indian Silver mine, now included in the east portion of the Scheelite Chief vein, operations here and at Bromide Flat, east of the Hilltop vein, were not extensive; silver production was meagre, and the district was abandoned by 1876. Scheelite was found in the veins in 1915 by C. E. Millick, A. G. Millick, and Jasper M. Fox, and mined on a small scale in 1916. The Nevada Scheelite Co. held the property in 1917, the Minerva Tungsten Co. in 1918. A 150-ton mill, located below the Chief mine, was completed in 1918 shortly before collapse

of the tungsten market. Production for this period is believed to be less than $100,000 worth of concentrate valued at the high prices then prevailing; Nevada bullion tax records show production only in 1916, amounting to $7,651. Except for a small-scale leasing operation in 1932, the property was idle until 1936 when Tungsten Metals Corporation was organized. This company built a 75-ton mill in 1938, and developed the Scheelite Chief, Silver Bell, Oriole, West Everit, and East Everit mines. In 1945, the mines were closed and all mining and milling equipment was sold. Production in the period 1937-45 was 89,303 units of WO_3 from 120,780 tons of ore treated. In 1941-42, about 2,200 units were produced from the Hilltop, Tony, Canary Yellow, and Zigzag mines, the ore being concentrated in the mill of the Tungsten Metals Corporation. The total district production to the end of 1945 was about 95,540 units of WO_3 sold for approximately $2,000,000. In 1947, the Minerva Scheelite Mining Co., managed

by R. F. Stopper, held a lease on the properties of Tungsten Metals Corporation and was preparing for small-scale operation.

In 1941, the U. S. Bureau of Mines core-drilled 34 holes with a combined length of 6,932 feet on properties of Tungsten Metals Corporation and located the ore mined in 1941-43. In 1943, the Bureau of Mines drilled 8 holes totalling 2,698 feet and located the westward continuation of the ore body in the Silver Bell mine.

Geology

The rocks exposed in the Minerva district include Middle Cambrian limestone, at least 1,000 feet thick, capped by Middle Cambrian platy limestone and shale (fig. 183). The rocks are tilted 12° - 45° SW.,

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Fig. 183. Geologic map of the Minerva district, White Pine County, Nevada.

---

and are complexly faulted. The earliest faults strike N. 70° W. to N. 70° E. and dip 40° to 70° N., and are occupied by quarts veins. The hanging wall appears to have moved 30 to 75 feet downward, but

the true displacement cannot be determined, and the apparent displacement cannot always be differentiated from post-mineral movement along the veins (fig. 183-A). The veins are cut by a multitude

---

Fig. 183-A. Geologic sections through veins of the Minerva district, White Pine County, Nevada.

---

of normal faults with dips that range from 18° to vertical and with displacements of a few feet to many hundred feet. These later faults can be differentiated into 4 groups on the basis of relative age and of attitude.

True displacements on all the faults except the oldest can usually be determined from the offsets of veins and stratigraphic units. It is essential to know the true displacement of veins, rather than the horizontal offset, to find continuations of ore shoots.

Rhyolite is the only igneous rock exposed in the Minerva district. It occurs northwest of the Silver Bell mine in sills 2 to

20 feet thick near the base of the shale; elsewhere it forms dikes as much as 25 feet thick that follow east-dipping faults. The dikes are most abundant in a zone across the center of the district extending from the Silver Bell mine to the Hilltop mine. They were intruded after formation of the scheelite veins, for they cut through the veins at the portal of the 6,900-foot level in the East Everit mine and at the Tony prospect, and elsewhere occupy post-mineral faults that offset the veins.

Scheelite ore shoots occur in seven roughly parallel quartz veins occupying normal faults that strike east, dip 65° to 70° N., and are spaced at intervals of approximately half a mile. The quartz veins range in width from a few inches to 30 feet, and in length from 1,000 to 4,000 feet. The quartz changes in thickness within short distances along strike or dip, and is in places distributed in a series of closely spaced, parallel fractures with horses of limestone. The vein outcrops are limited on the west by alluvium, and

on the east by alluvium and shale through which the veins do not penetrate. No major veins have been found on the surface at stratigraphic horizons above the shale; it may be possible to follow the veins underground eastward beneath the shale capping.

The Chief vein has been traced for 550 feet west from the portal of the main adit, but none of the other veins have been explored beneath the alluvium. Frontal faults defining the range probably lie only a short distance west of the foothills; the possibility of discovering large segments of veins buried beneath the alluvium seems remote.

The veins consist mainly of quarts and calcite with some scheelite and, in spots, traces of tetrahedrite, galena, silver haloids, powellite, and cuprodescloisite. The scheelite concentrates are reported to contain as much as 4 ounces of silver to the ton, but this represents a high concentration ratio. The scarcity of associated minerals is indicated by the purity of the concentrates, which con-

tain only traces of phosphorus, sulfur, and arsenic, and very little copper or molybdenum.

The quarts in the veins is white or tinged with greenish-yellow, coarsely crystalline, and usually massive, although a few small vugs can occasionally be found. The carbonate in the veins and faults ranges in color from white through flesh-color to light reddish brown, suggesting several carbonate minerals, although calcite is dominant. The scheelite commonly occurs in coarse cleavages distributed through the quarts or aligned along fractures in the quarts. In some parts of the veins, notably in the Oriole mine and Tony prospect, the scheelite is distributed in very fine grains.

The grade of [illegible] material mined in substantial quantities has ranged from 2.6 percent or more of WO_3 down to 0.3 percent. Local concentrations have contained as much as 10 or 20 percent of WO_3. All the ore milled by Tungsten Metals Corporation to the end of 1943 yielded an average of 0.76 units per ton, suggesting that the

ore contained between 0.9 and 1.0 percent of WO_3.

The tungsten ore occurs in shoots of limited vertical extent but with remarkable lateral continuity, which is disrupted by post-mineral faulting. The quartz veins are nearly barren outside of the shoots, which occupy only a small part of the veins. The ore shoots rake westward roughly parallel to the bedding in adjacent limestone, and frequently lie on the footwall side of the vein; the widest ore stoped is about 10 feet, although the vein in which the ore occurs may be 20 to 30 feet wide. In the smaller veins, ore shoots as narrow as 1 to 3 feet have been stoped.

Each of the main veins worked appears to have a single main ore shoot, although the Everit vein contains remnants of an upper ore shoot, and both it and the Chief vein may yet prove to contain lower shoots in portions that have never been prospected. In the East Everit mine, the main shoot was mined for 80 to 130 feet along the dip of the vein, and for a pitch length of 650 feet; extensions to the east

have not yet been found, but an extension to the west is known to continue another 240 to 400 feet, possibly more. In the Chief mine, the ore shoot has been mined for 80 to 140 feet along the dip, and for a pitch length of 900 feet. Mine development may ultimately prove that the ore shoots before faulting were essentially continuous through most of the length of these veins. Little is known about the ore shoots in other veins of the district, for they have not been extensively explored.

The main ore bodies in the Chief, Everit, Canary Yellow, Zigzag, and Hilltop mines occur ab about the same stratigraphic horizon in the "Upper white limestone," which is a massive, cliff-forming, fine-grained, light-gray limestone 75 to 280 feet thick. The upper stope in the West Everit mine, and the surface stope in the East Everit mine east of the Everit fault, both lie higher stratigraphically in the "Upper black limestone." The ore shoot in the Silver Bell mine also lies at a higher horizon, but appears to rake down-

ward to join the shoot in the Chief mine.

The walls of the veins are frozen to the limestone in most instances, and post-mineral surfaces of breakage lie within the veins. The wall rocks are unaltered regardless of the presence or absence of ore in the adjoining vein.

The occurrence of ore shoots and the brecciation in them show that the veins were formed by successive introductions of minerals, and that the ore bodies were probably deposited in more porous portions of the veins. The massiveness of the "Upper white limestone" appears responsible for conditions favorable to scheelite mineralization. Perhaps slight changes in dip of veins where they cross limestone beds of different competence permitted development of crushed zones within the quartz, zones formed by continuous shearing along the vein. If this explanation be true, then other ore shoots may be discovered at greater depths in the vein wherever similar conditions prevail.

Mines

The southern six of the nine known veins in the district are owned by Tungsten Metals Corporation, and are named, in order from south to north, the Chief Extension, Chief, Oriole, Everit, North Everit, and Lone Buck. The Canary Yellow vein was worked 1940-42 by the Calico Tungsten Co., a partnership between Hadley R. Bramel and Stanley Peitler. The Hilltop and Tony veins were owned by the Shoshone Mining Co. until the claims were allowed to lapse in 1945. The claims were worked in 1940-41 by the New Deal Leasing Co., in 1941 by the Scheelite Leasing Co., and in 1942 by the Virdot Development Co.

The Chief and Everit veins provided the bulk of the district output to 1947. Some ore was also taken from the Oriole, Hilltop, and Canary Yellow veins. The Chief Extension, North Everit, and Tony veins are narrow, and give little hope of ore bodies.

The best prospects for future production in the district are the Chief vein, in undeveloped blocks between the Chief and Silver

Bell mines and east of the Silver Bell; the Everit vein east of the East Everit mine; and the Oriole vein. In 1944, reserves of indicated and inferred ore were estimated to be 69,000 tons containing 54,000 units of WO_3. In this estimate, no account was taken of entirely untested portions of veins that may be found, by future exploration, to contain additional tonnages perhaps equal to the total cited.

Scheelite Chief

The Scheelite Chief mine (fig. 184) is in two major segments

Fig. 184. Map and projection of the Scheelite Chief and Silver Bell mines, Minerva district, White Pine County, Nevada.

of the Chief vein, separated by the Chief fault. Both segments are developed from the 6,316-foot level, an adit 1,530 feet long. The west segment has three upper adits now largely stoped, a shaft near the portal of the main adit, and two short lower levels from the shaft.

The east segment has a winze 30 feet deep below stope 1, with a sub-level from the bottom west to the Chief fault.

The west segment was stoped from the portal of the adit to the Chief fault. Two small blocks of ore probably still remain west of the fault that terminates the 6,246- and 6,276-foot levels. Of seven holes drilled beneath the alluvium, only one, 550 feet west of the mine, found ore. The ore shoot in the intervening area may have been eroded away.

The east segment was stoped above the main level for a length of 260 feet, and the level was extended another 340 feet beneath the shoot. The quartz vein below the shoot is narrower, ranging from half a foot to 4 feet, and contains sporadic traces of scheelite.

Silver Bell

The Silver Bell mine (fig. 184), in the east portion of the Chief vein, was worked to the fourth level through a shaft 365 feet deep on the incline (238 feet vertically). A winze, 84 feet on the in-

cline, connects the fourth level with a short fifth level at a point 300 feet west of the shaft. The total level workings, largely concentrated on the third and fourth levels, amounts to nearly 1,200 feet of drifts and crosscuts. Ore was stoped above the third level for a length of 140 feet, a width of 3 to 5 feet, and a height of 60 feet along the dip. A faulted westward extension of this ore body was worked from the fifth level. Possible extensions eastward beyond the shaft have never been investigated either by drilling or drifting, and should be sought by extending the third level east through the various fault segments.

Oriole

The Oriole vein is the least developed of the major veins in the district. It is opened at the west end in the Oriole mine by two short adits at a vertical interval of 80 feet (fig. 185). The

Fig. 185. Map and projection of the Oriole mine, Minerva district, White Pine County, Nevada.

ore stoped consisted of very fine-grained scheelite in quartz, and averaged only 0.4 percent of WO_3. The width of ore ranged from 1.5 to 5 feet. The stopes mined are in offset segments of a single ore shoot, which could probably be readily followed eastward by extending the upper adit.

The outcrop of the vein is mostly barren except for some coarsely crystalline scheelite on the crest of the hill above the mine, and for low-grade mineralization in the first segment east of Chief Canyon. The only exploration east of the mine is by three shallow drill holes in two fault segments east of the canyon. Although the vein is not as strong at the surface as the Chief or Everit veins, it shows impressive widths of quartz, and might be productive in the future.

West Everit

Workings in the West Everit mine consist of two adits, a sub-

level above the upper adit, two stopes, and several connecting raises (fig. 186). An adit 50 feet long on the west face of the hill dates

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Fig. 186. Map and projection of the Everit vein, Minerva district, White Pine County, Nevada.

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from 1917. Two small ore bodies have been mined, both of excellent grade; one on the crest of the hill, the other in the lower adit. Both ore bodies are in the hanging wall of the West Everit fault, and are cut off by it. The upper ore shoot is a remnant, former extensions of which have been eroded away. The lower ore shoot, however, might have extensions below the West Everit fault. In spite of several hundred feet of exploratory work from the 6,800-foot level, the vein was not located. The work seems to have disproved the existence of any segment of appreciable size in the footwall of fault "A", which is parallel to the vein. The segment of vein exposed on the west side of the hill at 11,200 E., 9,400 N. is probably the same

Everit vein and ore may be found in it below the 6,800-foot level.

The West Everit vein zone ranges in width from 5 to 50 feet, the vein branching into several parts with included layers of limestone. The maximum width of continuous quartz is 25 feet. Wherever drifts lie in the main vein, the full width of quartz is not exposed; so scheelite ore bodies may be missed by failure to crosscut.

The only ore remaining in the mine is between the upper stope and the West Everit fault in a fault sliver estimated to contain 1,200 tons. The fault segments west of the mine are too little known to permit any inference as to quantity of ore. Because of extreme faulting, the vein westward beneath the alluvium probably does not justify underground exploration.

East Everit

The main development in the East Everit mine is from an adit 1,755 feet long at an elevation of 7,050 feet (fig. 186). A raise connects with the surface from a point 1,085 feet inside the portal.

A shorter adit, 160 feet lower, is used for ore transfer, and also for development of another fault segment.

Two ore shoots have been mined, probably correlatives of the two in the West Everit mine. The upper ore shoot is eroded away except for a small segment stoped at the surface above the Everit fault. The lower shoot cropped out only west of the Everit fault, but has been stoped most extensively east of the fault. Although drill hole 8 and the westernmost stope in the mine (that from the 6,900-foot level) yielded ore containing only about 0.6 percent of WO_3, the ground has not been sufficiently tested to prove the absence of better ore. An adjoining segment of vein that crops out south of the portal of the 6,900-foot level is untested.

The portion of the vein intersected near the face of the 7,050-foot level (at 14,100 E.) contains low-grade scheelite-bearing material at that point, but has not been explored upward to the surface, which is masked by debris. Beyond the face, five holes drilled from

the surface in 1948 found no ore, but proved that the ore horizon lies considerably lower in this fault block. The thickness of quarts and the presence of scheelite in this part of the vein are encouraging for the eventual discovery of an ore shoot at greater depth.

The North Everit vein, [illegible] about 150 feet north of the Everit vein, contains several exposures of narrow but high-grade scheelite ore. One outcrop (at 13,150 E.) was mined in an open cut. Drill hole 2 (at 13,240 E.) intersected 5 inches of vein that assayed 7.53 percent of WO_3. High-grade ore 8 inches wide has not been touched in an exposure at the east end of the vein (at 13,580 E.). The widths and tonnages available are unfavorable for company exploration, but the grade of ore might make portions of the vein attractive to a lessee.

Lone Buck

The Lone Buck vein, entirely unexplored, crops out for a length

of 1,200 feet and ranges in width from a few inches to 4 feet. Two channel samples cut by the Bureau of Mines in 1941 indicate a block of ore (between 14,200 E. and 14,260 E.) 60 feet long, 1.8 feet wide, and averaging 1.74 percent of WO_3; indicated ore along the rake west to the nearest fault amounts to 220 tons. The vein shows little promise of productivity, for the only ore exposed is in this block, which is a small and inaccessible remnant of a shoot.

Canary Yellow

The Canary Yellow mine is developed by an 85-foot crosscut adit with a 110-foot drift on the vein, and a raise to the surface 85 feet above (fig. 187). The vein in the drift shows 1 to 1.6 feet of ore

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Fig. 187. Map and projection of the Canary Yellow mine, Minerva district, White Pine County, Nevada.

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containing more than 1 percent of WO_3 for a drift length of 60 feet. On the surface directly over the portal of the adit, Bramel and Feitler sampled the vein at 10-foot intervals for a length of 130

feet over widths of 1.5 to 6 feet, and obtained assays ranging from 0.39 to 4.20 percent of WO_3, averaging more than 1.0 percent. From the raise, 37.5 tons milled by Tungsten Metals Corporation yielded only 27 units of WO_3, an average of 0.72 unit per ton. Although the ore in the drift and raise is poorer than that at the surface, better ore may lie west of the workings if the surface body is part of a shoot that rakes westward. The ore in the drift may represent a lower shoot. With this interpretation, the upper shoot, with an average width of 2 feet, is estimated t o contain 400 tons of indicated ore that will average more than 1.0 percent of WO_3; the lower shoot, 1.5 feet wide and averaging 1.0 percent, may contain at least 600 tons of inferred ore if it continues 260 feet along the rake to the faults limiting this segment of vein. No estimate can be made of the possibilities of the vein eastward, for the vein is unexplored and ore is not exposed at the surface, although the vein croppings continue 1,000 feet east of the mine.

Zigzag and Calico

The Zigzag and Calico claims lie on the west end of the same vein as the Canary Yellow mine, but are separated from it by half a mile of alluvial cover. The vein on these claims, faulted even more than is normal to the district, is broken into fragments 20 to 200 feet long, some of which contain ore at the surface. The only workings are a few open cuts from which Bramel and Feitler mined 18 tons of ore that yielded 20 units of WO_3. The width of vein ranges from 1 to 4 feet.

Hilltop

The Hilltop mine is developed by a main adit at an elevation of 7,066 feet, by a short adit at 7,120 feet, and by several open cuts (fig. 188). The 7,066-foot level has about 650 feet of drifts and

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Fig. 188. Map and projection of the Hilltop mine, Minerva district, White Pine County, Nevada.

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crosscuts, three stopes, and three raises to the surface. This level

was formerly connected with an ore bin at the end of the road, 600 feet lower, by a single span, jig-back aerial tram 1,150 feet long.

The Hilltop vein is narrow, with surface widths of 0.5 foot to 3 feet. In the stope east of the crosscut adit, the vein flattened and widened to 8 feet of good ore between the level and the surface 35 feet above. Neither the drift level with 1.5 feet of quartz nor the surface with 1 foot of quartz gave any indication of the intervening wide ore body. The stopes west of the adit were narrow, the ore being a foot or less in width although of high grade.

Hardly any ore remains in sight, although a few tons could still be underhanded beneath the level and stopes. The raise at the east end of the workings has some ore in the roof; so there may be ore in the 50 feet of unexplored ground up to the surface. The largest block of potential ore is in the vein segment beyond the west face of the 7,066-foot level, beneath the upper adit. All told, perhaps 1,000 tons of 1 to 2 percent ore might be found in these un-

tested blocks with very little additional exploration.

Tony

The Tony prospect is explored by a 225-foot adit, a raise to the surface, and several surface pits. The vein strikes north and dips east, and is in this respect unique among the tungsten-bearing veins of the district. The vein outcrop extends for nearly 200 feet along the strike; continuations of the same vein-fault to the north and south contain no quartz or scheelite, although calcite filling, common to post-mineral faults of the district, is present. Scheelite mineralization for widths of 1 to 3 feet extends for about 100 feet on the surface, but no comparable mineralization is present in the adit. The scheelite is extremely fine-grained. Only 32.6 units of WO_3 was recovered from 159 tons of ore milled in 1941, a yield of about 0.2 percent. No commercial ore is now exposed, and only a few tons that contain 0.2 to 0.6 percent are visible.

Two narrow veins on Tony No. 2 claim contain a few crystals of

coarse scheelite, but the exposures are not encouraging enough to warrant exploration.

WHITE PINE COUNTY
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SHOSHONE

ENGINEERING & MINING JOURNAL
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E&MJ, vol. 152, no. 9, p. 133, September 1951. (Also quoted in EMJ, vol. 153, no. 4, p. 145, April, 1952)
Ten tons of ore per day are being produced at underground operations of Scheelite Chief mine in White Pine County, which is owned by the Minerva Scheelite M Mining Co. Ore is concentrated at a 25-ton mill. Robert Stopper, Ely, has charge of t the work

E&MJ, vol. 152, no. 10, p. 131, October 1951
... Mining is by the open-stope-and pillar method; miners are also drifting on the ore body.

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MINING WORLD
ENGINEERING & MINING JOURNAL

Mining World, vol. 4, no. 2, p. 36, Feb. 1942.

Tungsten Metals Corp. is treating 100 tons daily of tailing and ore at the property about 45 miles southeast of Ely, Nevada it is reported. William B. Trent is mill superintendent and Harold Dunham is mine manager.

Mining World, vol. 1, no. 6, p. 27, Dec. 1939.
Tungsten Metals Corp. which has operated continuously since Sept. 1936 in the Shoshone district, 50 miles southeast of Ely, has shipped a total of more than 600 tons of 70% tungsten concentrate during that period, mining in all about 75,000 tons of scheelite ore, and employing at all times a working force of more than 40 men in the mine and mill. The production record ranks it second to Nevada- Massachusetts in tungsten production.

Engineering & Mining Journal, vol. 146, no. 7, pp. 125-126, July 1945.
The property of the Tungsten Metals Corp., with scheelite mine and 100-ton cencentrator at Shoshone, has been closed and equipment sold after nine years operation with high-grade tungsten concentrate receipts exceeding $3,000,000.

WHITE PINE COUNTY
~~MINERVA~~ DISTRICT
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NEWMAN, E. W., GEEHAN, ROBERT W., AND TRENGOVE, RUSSELL R., 1950, Investigation of Tungsten Metals Corp. deposits (Minerva mining district), White Pine County, Nevada: U. S. BUR. Mines, Rept. Inves. 4648, 12 pp.

The tungsten ore deposits in the Minerva district, Nevada, occur as shoots in quartz veins occupying faults in Cambrian limestone. Production from 1936 to 1945 was over 110,000 tons of ore or 83,000 units of WO_3.