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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 1916-13, the major production has been since 1936. The average grade of ore has been nearly 1 per cent of WO_3, with a range from 0.5 per cent to 2.0 per cent 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 per cent 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, 15,300 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 per cent of WO_3 amount to 9000 tons of indicated ore containing 3600 units. Reserves at other properties in the district were estimated as 400 tons of indicated ore containing 400 units, and 1,660 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,[illegible]39 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 recources of Nevada: Nevada Newsletter Publishing Co., Reno, p. 254, 1923.

2/ Couch, E. 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 per cent 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 per cent 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 2,032 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 2,398 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 the 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 3000 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 those 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 individuals 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 Wash 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 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 those 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 per cent or more of WO_3 down to 0.3 per cent. 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 per cent 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 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. (1913), New Deal Leasing Co. (1940-41), Scheelite Leasing Co. (1941), and Viroot 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 1,035 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 E. 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 100-foot drift on the vein, and a raise to the surface 85 feet above (see fig. 21). The vein in the drift shows 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 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 veincroppings 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 Bramal 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 Path, 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 extens 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 veins 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	2,030
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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SIX SCHEELITE BEARING QUARTZ FISSURES OUTCROP ON THE PROPERTY

From North to South these fissures are:

CANERY YELLOW	1300 feet outcrop length	produced appx 1,000 tons
LONE BUCK	1200 feet outcrop length	no production
EVERITT	3000 feet explored length	produced appx 50,000 tons
ORIOLE	1800 feet outcrop length	produced appx 8,000 tons
CHIEF	3800 feet explored length	produced appx 90,000 tons
CHIEF EXTENSION	500 feet outcrop length	no production

A study of these fissures suggests the following areas of interest.

(1) Un-mined or unexplored fault blocks within the known ore shoots. There are several such blocks. Possibly the most attractive is the projection of the West Everitt fissure westward beyond the footwall of the West Everitt fault.

(2) Eastward projection of the Everitt and Chief fissures: The ore shoots are known to be faulted down beyond the last workings to the East in both of these fissures.

Five USGS holes on the Everitt located the fissure beyond the last workings to the east but, above the projected ore shoot. One of these holes encountered low grade ore in the fissure.

The Chief fissure has been stoped beyond the Silver Bell shaft to a fault believed to throw the ore shoot down 100 to 200 feet.

Another 1000 feet of each fissure can be explored by medium depth surface drill holes. (400 to 600 feet)

(3) Small, high grade, flat lying ore shoots: such as the one Stopper mined in a breccia zone near the hanging wall of the Everitt fissure. Stopper is reported to have mined 3500 tons of +3% ore from one stope near the portal of the East Everitt adit. There could be another similar ore shoot in the same area.

(4) Lower ore shoots in the fissures: Lemmon accurately describes the ore shoots "as limited in vertical extent, but with remarkable lateral continuity, which is disrupted by post-mineral faulting." These ore shoots have been confined to the Upper White limestone except that the Chief ore shoot raked upward into the Upper Black limestone to the East and remanents of an ore shoot in the Upper Black limestone where mined in the Everitt fissure.

Our drill hole M-3 cut 10 feet of 2.05% WO_3 at 435 feet in what appeared to be the Lyndon limestone. Thus; there is evidence of a lower ore shoot in the Everitt fissure. The hole was dry to the bottom.

I believe this potential is important. Portions of both the Chief and Everitt ore shoots were eroded away, therefore, lower ore shoots could be substantially larger. It is probable that before erosion the Everitt and Chief ore shoots each contained over 100,000 tons of +1% WO_3.

(5) Undeveloped fissures: There are four fissures outcropping in addition to the Chief and Everitt fissures. All four are mineralized in places and two (the Canery Yellow and the Oriole) have produced. With exception of the few small workings and a few USGS drill holes on the Oriole, exploration efforts have been limited to mapping and lamping the outcrops. There is a possibility of commercial ore shoots existing in these fissures also.

(6) Potential in the Wheeler limestone at depth. My father, R. G. Lee, has outlined this well, in his report.

(7) Low grade ore in the old stopes: Various estimates place this between 25,000 tons and 100,000 tons of 0.4% to 0.5% WO_3. Since the fissures lend themselves well to shrinkage mining methods, investigation of these low grade ore bodies should be considered at some point.

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White Pine County, Nevada
May 20, 1971

The Minerva District is located on the west slope of the Snake Range in eastern Nevada, at an elevation of 6200 feet.

Scheelite occurs in ore shoots in quartz veins. The wall rock is limestone from middle to lower Cambrian in age.

Quartz monzonite intrusives are exposed in the center and on the east slope of the Snake Range.

Production from the district to date is around 122,450 units of WO_3, at a value of $6,734,750 at current tungsten prices. Grade of ore produced has averaged nearly one per cent of WO_3.

The quartz veins strike east-west and dip 60° north. They are from a few feet to 30 feet wide, but the average width of the ore is about 5 feet.

There are six nearly parallel veins spaced more or less half a mile apart. Ninety per cent of the production is credited to the Scheelite Chief, Oriole and Everit veins.

Post mineral faulting off-set the quartz veins from a few feet to over 100 feet.

The veins have not been explored to any depth. Adit levels were driven in under the outcrop and this section has been mined.

The veins offer excellent potential for exploration.

MINERVA TUNGSTEN MINES
White Pine County, Nevada

INTRODUCTION

Tungsten associated with beryllium and fluorite are the predominent minerals of economic importance on the west slope of the Snake Range, White Pine County, in Eastern Nevada.

The Minerva Tungsten District has rewarded exploration efforts with tungsten ore in the form of scheelite during the first and second world wars, when the price of tungsten was attractive.

However, at the present time the projected consumption of this metal, due to its unique properties, will probably increase four fold during the next 15 years.

LOCATION

The Minerva Tungsten Mines are located in the vicinity of latitude 38° 48'N., longitude 114° 21' W., or what will be Sec. 21 and Sec. 28, T. 11N., R68E., Mount Diablo Base & Meridian, when surveyed.

The 20 acre mill site is located in Sec. 12, T 11 N., R. 67 E., or about 3 miles from the mines.

A paved road extends to the mill site and connects with U. S. highway 93, 15 miles to the west. The nearest town is Ely, which is 45 miles by paved highway. The elevation is 5800 feet at the mill site and6200 to 7000 feet at the mines.

CLIMATE

The climate is semiarid and is typical Great Basin desert climate. The average rainfall is about 10 to 12 inches a year. The temperature may range from 95°F. in the summer to as low as -15°F. for a few days during December and January. Usually, from the first of April to the middle of November the weather is pleasant and mild. Pinion pine and dwarf cedars with sagebrush comprise the growth around the mine area.

WATER & POWER

There is an ample supply of water at the mill site from a well about 50 feet deep. The water table is within 30 feet of the surface. At the mines the water is pumped from a well in the valley to tanks at the mine. The water table at the mines is probably about 600 feet under the present mine workings.

Mount Wheeler Power Co. just completed construction of a power line through the valley below the mines. A branch of this power line extends to the Minerva mill site. Mount Wheeler power indicated that they would extend the power line to the mines.

HISTORY

Silver ore was discovered in 1869 at the Indian Silver Mine, now a part of the Minerva Tungsten Mines. Silver production was meager, and by 1876 the area was abandoned. Scheelite was found in the veins in 1915 by C. E. Millick, A. G. Millick, and Jaspar M. Fox. Mining was started on a small scale in 1916. The Nevada Scheelite Co. operated the property in 1917; the Minerva Tungsten Co. in 1918. A 150 ton mill was completed in 1918 shortly before the collapse of the tungsten market after World War I. The mine was closed down and the mill sold. Except for small leasing operations in 1932, the property was idle until 1936 when Tungsten Metals Corp. was organized. This company built a 75 ton mill in 1938, and developed the Scheelite Chief, Silver Bell, Oriole, West Evrit, and East Everit mines from adit levels.

In 1947 Mr. Robert Stopper obtained a lease and option on the Minerva property. He constructed a small mill and started a small operation of selectively mining the better grade ore.

In 1952 Combined Metals Reduction Co. obtained a 25 year lease from Robert Stopper on about 90% of the property. A joint venture was formed with American Zinc Co. to operate the lease. However, when the W. S. Government quit purchasing tungsten in 1957, all operations were closed at the Minerva mine.

Reginald G. Lee and sons obtained a lease and option on the Minerva mines and mill site in 1968, and have pursued a small exploration program with their own funds to this date, with some success of finding ore.

PAST PRODUCTION

Table I.

Production of tungsten ore and concentrate from Minerva Tungsten 1916—1957.

Year	Tons of Ore	Concentrate Units WO_3	Value based on present price of $55.00 per unit
1916	191	191	$ 10,505
1918	1,846	1,846	101,530
1938	14,955	12,858	707,190
1939	19,617	9,396	516,780
1940	14,750	10,617	583,935
1941	10,160	13,599	747,945
1942	19,867	16,876	928,180
1943	15,718	8,507	467,885
1944	13,500	8,640	475,200
1945	7,000	5,020	276,100
1947 to 1957	24,567	34,900	1,919,500
totals	142,171	122,450	$6,734,750

The production figures from 1916 to and including 1943 are quoted from a report by D. M. Lemmon of U. S. G. S., 1944, Tungsten Deposits in the Minerva District, White Pine County, Nevada.

Production figures for 1944 and 1945 are from net proceeds tax paid, on records at court house in Ely, Nevada.

Production figures for years 1947 to 1957 are from the records of Combined Metals Reduction Co. and net proceed tax paid by Stopper, except for the year 1955 and 1956 of Stopper's production which was obtained from oral communication with Stopper's associates.

MINING CLAIMS

The Minerva Property consists of 7 patented lode claims, 1 patented 5 acre mill site, 69 unpatented lode claims, one 60 acre placer claim and 20 acres of deeded land used for the mill site.

All the patented and unpatented claims are contiguous

and cover the mineralized area known at this time. Please refer to Plate II.

GEOLOGY

Regional Setting

The Snake Range extends nearly 60 miles in a north-south direction and rises to over 13,000 feet in elevation at Mount Wheeler, about 12 miles north of Minerva. It is composed of great thickness of Paleozoic sedimentary rocks ranging from Cambrian through Carboniferous, and a central intrusive mass of late Mesozoic granitic rock exposed in Snake Creek and south of Osceola; and a volcanic capping at the south end of the range in the Murphy Wash area.

A low angle thrust fault is exposed on the west slope of the range, east of Minerva. North-south striking normal faults are predominant throughout the range.

Gold and Tungsten, with minor amounts of lead and silver, have been produced profitably in the Snake Range. The Minerva District with its Tungsten production has first place in gross yield; the Osceola District with gold and minor tungsten production has second place. At this writing the Mount Wheeler Mines Co. is developing a promising deposit of beryllium, tungsten, and flourite in a limestone bed in the Pioche Shale, a member of the lower Cambrian formations.

The sedimentary rocks exposed on the west slope of the Snake Range, from Osceola south are successively younger. From the oldest to youngest are the Lower Cambrian Prospect Mountain Quartzite and Pioche Shale, a Middle Cambrian Limestone up to 2000 feet thick, an Upper Cambrian Shale 300 to 1,000 feet thick, the Ordovician Pogonip Limestone and Eureka Quartzite are exposed near the south end of the range.

Ore Deposits and Related Geology of the Minerva District

Scheelite ore shoots occur in six roughly parallel quartz veins occupying normal faults that strike east-west and

dip from 50° to 70° to the north. The veins are separated by a distance of a few hundred feet to 3,000 feet. From north to south they are the Canary Yellow, Lone Buck, Everit, Oriole, Scheelite Chief, and the Chief Extension veins. The Everit, Oriole and Scheelite Chief are the strongest and widest veins, and are very persistent along their strike. They can be seen on the surface from the alluvium on the west to the shale and alluvium on the east, a distance of 1,000 to 4,000 feet.

The veins consist mainly of quartz and some calcite. Scheelite mineralization occurs in certain sections of the veins; and in spots, traces of tetrahedrite, galena, silver haloids, and powellite. The scarcity of associated minerals is indicated by the purity of scheelite concentrate, which contains only traces of phosphorus, sulphur, and arsenic, and very little copper and molybdenum.

The quartz in the veins is white, coarsely crystalline, and is usually massive. The scheelite commonly occurs in coarse cleavages and is distributed through the quartz or aligned along fractures in the quartz. In the Oriole vein the scheelite is distributed in very fine grains. The grade of ore extracted as shown in Table I contained about 1.0% WO_3, figuring a mill recovery of 75% to 85%.

The wall rock is limestone and at the surface is of middle Cambrian age. Using the U. S. G. S. map units of the Wheeler Peak and Garrison Quadrangles, Map I-579. The units in sequence above the Pioche Shale at Minerva are: Unit A about 400 feet, Unit B about 600 feet, Unit C about 200 feet (lower black), Unit D about 200 feet (upper white), and Unit E about 300 feet (upper black).

Due to faulting, Units C, D and E are exposed at the surface in the Minerva District. However, it is believed that the various limestone units have little, if any, selective control of scheelite deposition in the veins except that one limestone bed may be more susceptible to fracturing than another. The limestone beds dip to the west at an angle of 20°.

Faulting

The quartz veins occupy the oldest structures, and have been offset by most of the others. A few steep dipping faults

that cut across the vein structures are pre-mineral. Most of the faults are well exposed at the surface and have been mapped in the immediate area of the tungsten mines, as shown on the surface geology map, Plate IV.

Nearly all of the faults have normal displacement from a few feet up to more than a hundred feet. The early faults now occupied by the quartz veins have displacements of approximately 60 feet, although this will vary some from one vein to another.

Mines and Exploration

At the Everit, Oriole, and Scheelite Chief Mines; mining was started on the outcrops, and from adit level driven in under the outcrops. The ore of suitable grade was stoped and milled. The ground stands well and the only timber required was for chutes, manways, and working stations in the stopes. Most of the ore was mined out above these levels. The tunnels and stopes are still open and accessible.

No efforts have been made to sink shafts or drill to depth.

The U. S. Bureau of Mines drilled a number of diamond drill holes in 1942. This program was designed for the war effort to find ore that could be mined during the immediate term. They found several ore shoots that were mined in 1943 and 1944.

One reason for not pursuing deeper exploration work was probably the drilling equipment available at that time, which was mostly churn drills. Also, no electric power was available for shaft operation.

In 1968 Reginald G. Lee and Sons drilled a rotary drill hole at the West Everit on the projection of the Everit vein. The vein was cut at 430 feet deep. It was 5 feet wide and assayed 2.05% WO_3. The second drill hole was started but was lost at 130 feet in depth., about 100 feet from the target.

Targets for Exploration

The Scheelite Chief, Everit and Oriole veins are excellent exploration targets from the present mine workings to the Wheeler limestone bed, a vertical section of about 1200 feet.

The Wheeler limestone bed is a good host rock, and is the ore bearing bed that is being developed at Mount Wheeler Mine, about 5 miles north of Minerva, as mentioned before in this report.

In the Pioche area, about 70 miles south of Minerva, the Combined Metals bed, which is the equivalent of the Wheeler bed, has been very productive.

The vein section below the present mine workings to the Wheeler bed should be expected to be as productive, if not better, than the mine workings above the adit levels. Plates VI,VII, and VIII show the section along the Scheelite Chief, Everit and Oriole veins. Plate V shows a section across the veins.

The quartz monzonite intrusive which is believed to be the central core of the Snake Range, with its western flank of sediments not yet eroded sufficiently to expose it, but is probably not too distant from Minerva. It is believed that the quartz monzonite intrusive is the source of the mineralizing solutions that deposited the scheelite in the quartz veins at Minerva.

It is possible that the quartz tungsten veins and perhaps favorable limestone beds will increase in tungsten value as greater depth is attained and the distance to the contact zone with the intrusive becomes less.

Ore Reserves and Possibilities of Finding Ore

There is very little developed ore that will fall under the category of measured ore. The following table set forth

indicated and inferred ore.

Table II

Indicated Ore *			Inferred Ore **		
Tons	Grade %WO_3	Units WO_3	Tons	Grade %WO_3	Units WO_3
15,600	0.48	7,500	43,000	0.77	33,000

* Indicated ore is on basis of reasonable assurance from workings nearby.

** Inferred ore is totally on basis of geologic reasoning.

Page 3

Table I sets forth all ore milled. Table II shows possible ore yet to be confirmed above adit levels in the Scheelite Chief, Oriole, and Everit Mines. The total of Table I and Table II in round figures is 200,000 tons.

Drifting on the veins along their strikes has amounted to 22 tons of ore per foot of vein explored.

The total development footage, drifts, crosscuts, and raises is around 10,000 feet with a ratio of 14.2 tons of ore mined per foot development.

Stoping has amounted to 287,000 square feet on the vein wall of a total of 1,440,000 square feet of vein wall available between the adit levels and the surface. Then, 287,000 square feet divided by 1,440,000 square feet gives a ratio of 19.9% of the veins have been mined and milled.

From Table I, total ore milled is 142,171 tons. Using 12.5 cubic feet per ton and the average mining width of 6 feet; multiplying 287,000 by 6 and dividing by 12.5, gives 138,800 tons which checks fairly well with table I of 142,171.

It is believed that the veins will extend in depth to the Prospect Mountain Quartzite which is a reasonable

assumption, due to the fact that the veins can be traced on the surface up to 4,000 feet along their strike length, (the Scheelite Chief and Silver Bell vein, 4,000 feet-- The Oriole vein, 1800 feet -- The Everit vein, 3,000 feet) which indicates that they should extend downward at least one half of this length or 2,000 feet. The Prospect Mountain quartzite is estimated to be about 1,200 feet deep.

Taking the known strike length of the veins and the estimated depth to the quartzite;there is then 10,460,000 square feet of veins under the adit levels to the Prospect Mountain Quartzite. Applying the per cent of stope area above the adit levels to the area under the adit levels and the quartzite, or 10,460,000 square feet multiplied by 0.199 equaling 2,081,540 square feet of expected stoping area. 2,081,540 multiplied by the least expected width of 5 feet and divided by 12.5 cubic feet per ton indicates 833,000 tons. Expecting the same grade of ore and units recovered in milling as shown in Table I, there would be 720,545 units of WO_3, and at the present price of $55.00 per unit, the gross value would be $39,630,000.

The Wheeler Limestone bed is about 40 feet above the quartzite. The intersection of the veins with the Wheeler bed will be the deepest and perhaps the largest and most profitable target.

PROPOSED EXPLORATION

Stage I

Since 19.9% of the veins developed and mined have been in ore, and if the same ratio of ore to waste holds true below the adit levels, then one out of every five drill holes drilled should be in ore, assuming wide spacing and considerable variation in depth.

Geologic projection of structure, veins, and certain limestone beds and spotting the drill holes accordingly will reduce the number of drill holes in waste.

Suggested drill hole sites and depths in Stage I are as follows:

Scheelite Chief	N 5,500	E 10,700	500'
Scheelite Chief	N 5,900	E 9,900	1200'
Oriole	N 6,300	E 12,200	600'
Oriole	N 7,300	E 10,200	400'
Oriole	N 6,400	E 12,800	600'
West Everit	N 9,825	E 11,020	600'
West Everit	N 9,600	E 11,775	450'
West Everit	N 9,650	E 10,950	250'
East Everit	N 9,550	E 10,950	850'
East Everit	N 9,250	E 12,350	500'
Silver Bell	N 4,000	E 14,100	350'
Silver Bell	N 4,000	E 14,400	350'
Chief Extension	N 4,500	E 10,200	300'
Total	13 drill holes		6950'

Using one rig on two shifts at 50 feet per shift would complete Stage I in 70 days or about three months. No water is expected in the first 600 feet of depth. Rotary drilling with a tri-cone bit supplemented by a down-hole drilling hammer where ground is hard should result in a reasonable cost per foot of drill hole. It would not be possible to drill angle holes with a rotary rig, whereas a diamond drill rig can be mounted at any angle.

It is estimated that the average cost (including drill sites, roads, and incidentals) will be $8.00 per foot with a rotary rig and $ 10.50 per foot using a diamond drill rig.

Stage II

The amount of drilling under Stage II will be dependent on the information gained from Stage I. A minimum expectation from Stage I is 4 holes drilled in ore out of the total of 13 drilled.

Near the area of a drill hole drilled in ore, additional drill holes will be required to confirm the size of the ore block. At least three additional drill holes under Stage II for each ore hole drilled under Stage I.

The average depth of drill holes under Stage I is 535 feet. For Stage II, expecting 4 ore holes from Stage I, and 3 supplementary drill holes for each, there would be a total of 12 drill holes @ 535 feet or 6400 feet of drilling. At $8.00 a foot, this would cost $51,000 for Stage II.

Stage III - Mine Development

Shafts must be sunk, drifts, and raises driven to develop the ore blocks for mining.

A 500 foot vertical shaft, 1000 feet of drifting and 100 feet of raises will be required to put the first ore block into production for each vein. Development of other ore blocks on the same vein will be less expensive.

500 feet of shaft, 2 compartment @ $150 -----	$ 75,000
1000 feet of drifting @ $50 ----------	50,000
100 feet of raises @ $50 ----------	5,000
Total	$130,000

Recap of Stages I, II, and III

Stage I ---------	$ 69,400
Stage II -------	51,000
Stage III ------	130,000
Total	$250,400

Expected Production

Expected production from each of the three main veins is 100 tons per day. Average grade and mill recovery at 0.865 units per ton would give 86.5 units WO_3 per day from 1 developed vein under Stage III. 86.5 units @ $55.00 a unit would generate a gross income of $4,860 per day.

It will be possible to acquire the Minerva property under a lease and purchase option or as a purchase. Terms are open to negotiations with responsible parties.

It is felt that the Minerva property is an excellent speculative investment for people interested in tungsten and related minerals.

Respectfully yours,

May 28, 1971

Reginald G. Lee
Professional Mining Engineer

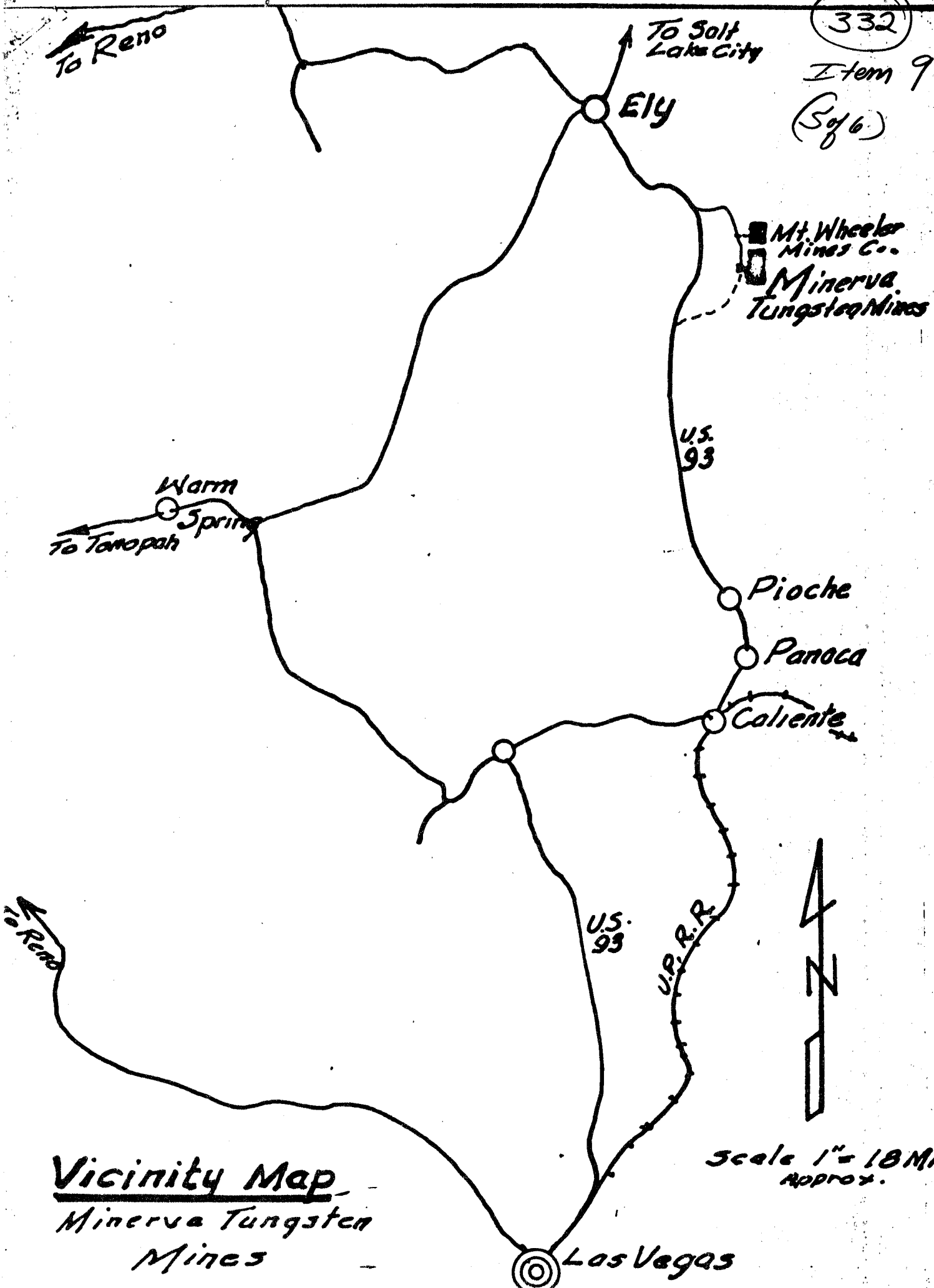
Publications:

1. Lemmon, Dwight M., U. S. G. S. February, 1944
Tungsten Deposits in the Minerva District,
White Pine County, Nevada

2. Couch, B. F. and Carpenter, J. A.
Nevada Metal and Mineral Production:
University of Nevada Bulletins,
Geology and Mining Services No. 38
Page 148, 1943

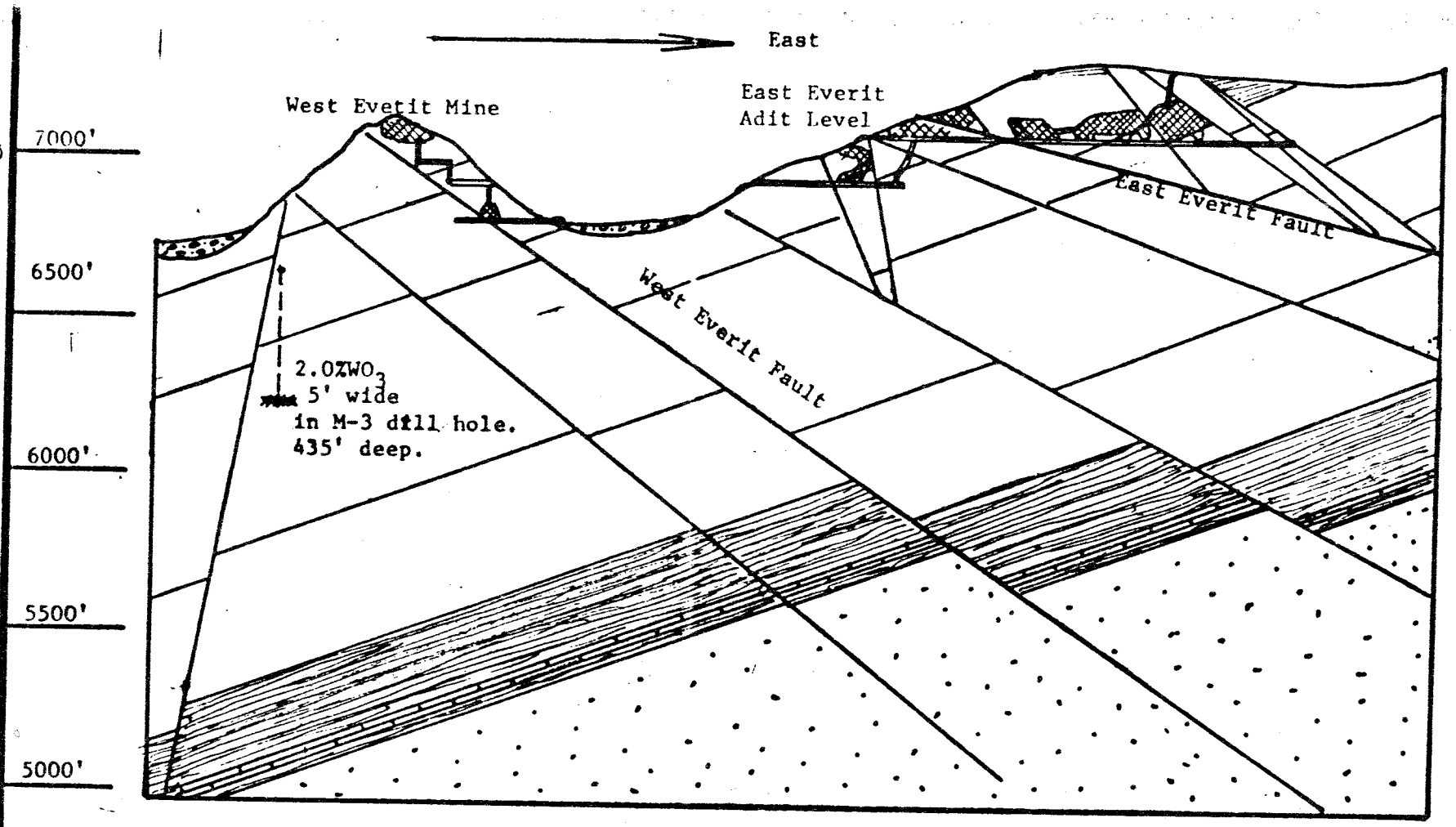
3. Lincoln, F. C., Mining Districts and Minerals Resources of Nevada:
Nevada Newsletter Publishing Co.,
Reno, Nevada. P. 254 -- 1923

Item 9
(5 of 6)



Vicinity Map

Minerva Tungsten Mines



Upper Shale

Unit E (upper Black)

Unit D (upper white)

Unit C (lower black)

Unit B

Unit A

Pioche Shale and Wheeler Ls.

Prospect Mountain Quartzt.

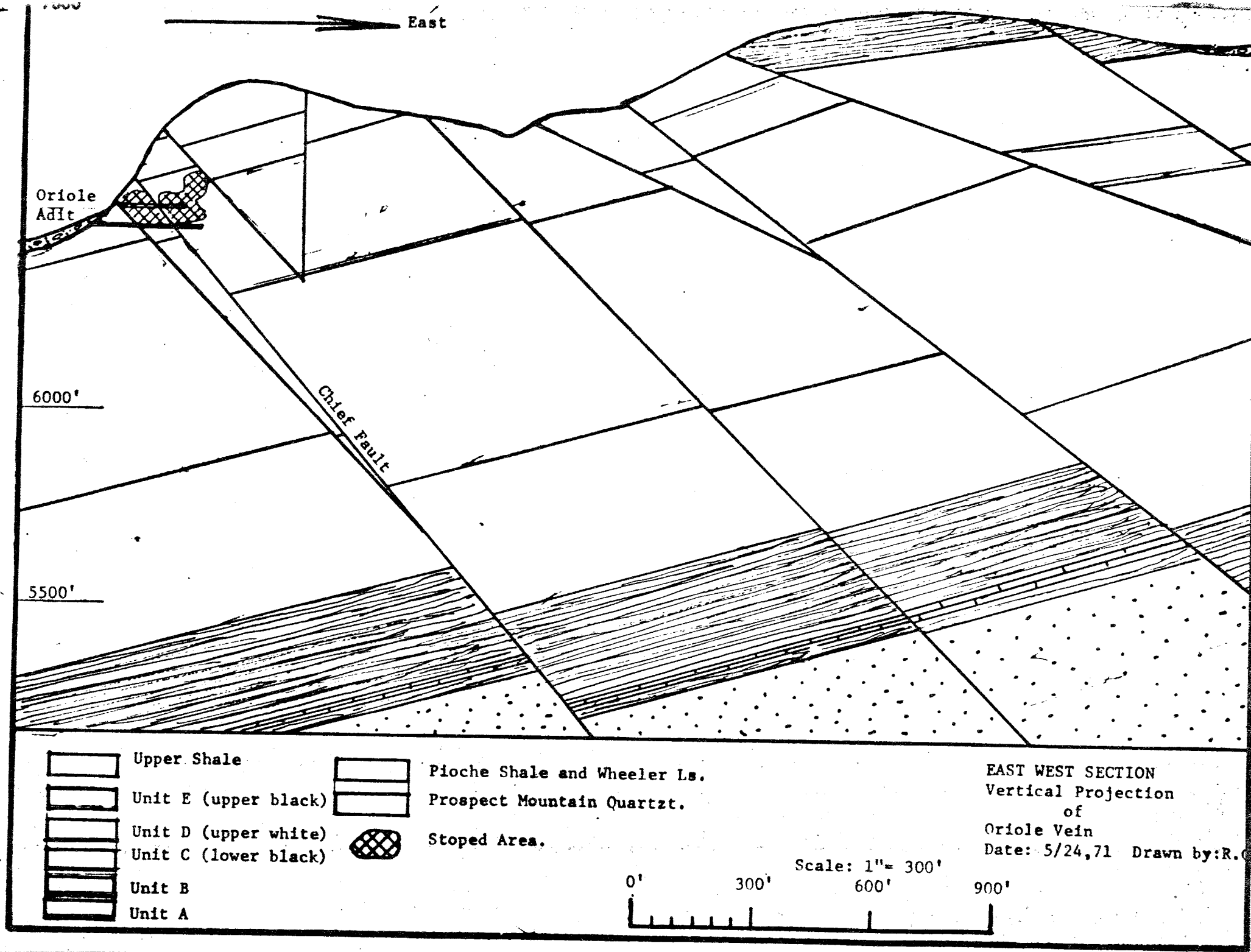
Stoped Area

0' 500' 1000' 1500'

Scale: 1"= 500'

EAST WEST SECTION
Vertical Projection
of
The Everit Vein

Date: 5/24-1971
Drawn by: R.G.L.


East
Oriole
Adit
6000'
5500'
Chief Fault
Upper Shale
Unit E (upper black)
Unit D (upper white)
Unit C (lower black)
Unit B
Unit A
Pioche Shale and Wheeler Ls.
Prospect Mountain Quartzt.
Stoped Area.
EAST WEST SECTION
Vertical Projection
of
Oriole Vein
Date: 5/24,71 Drawn by:R.
Scale: 1"= 300'
0'
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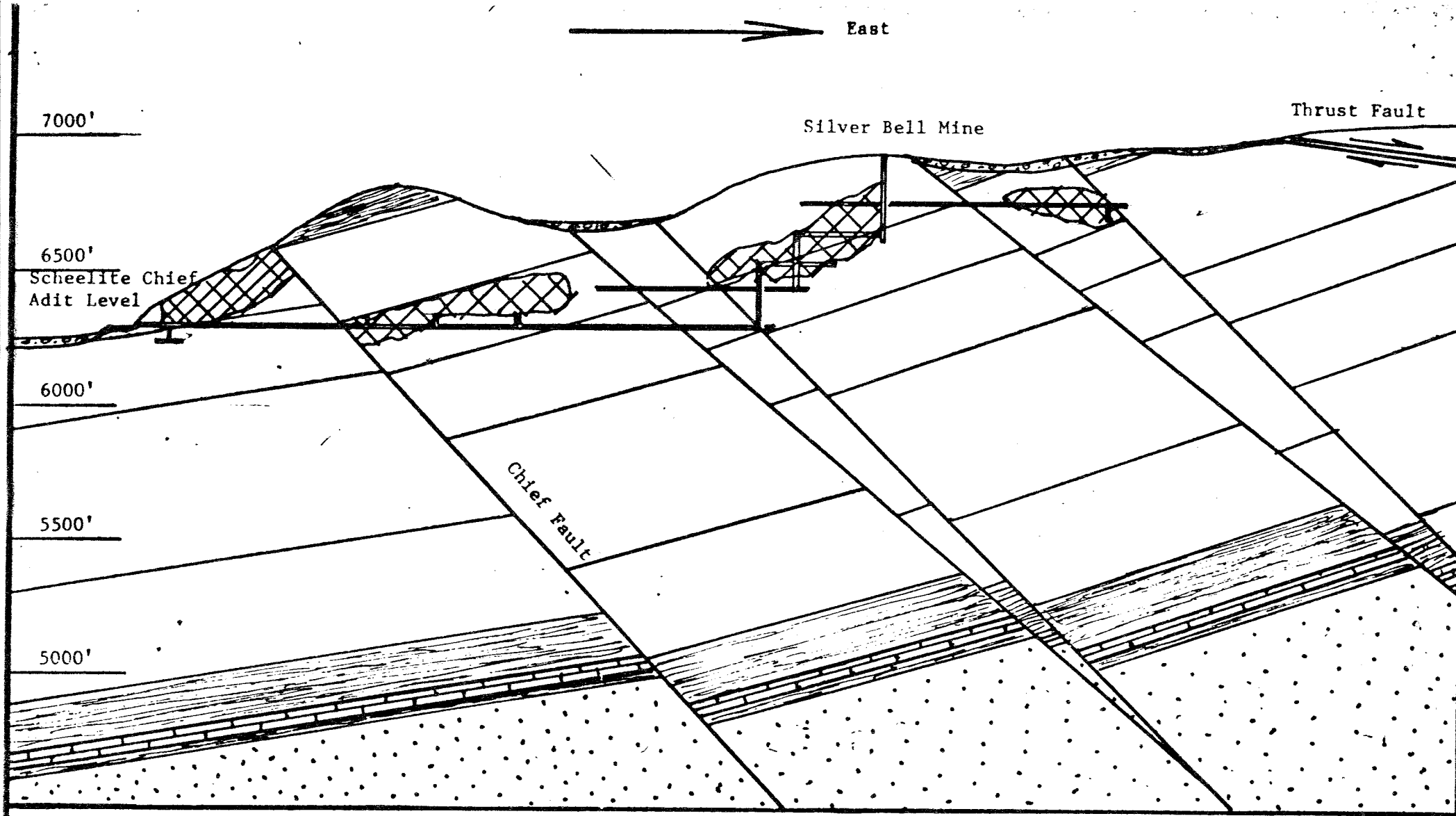
600'
900'



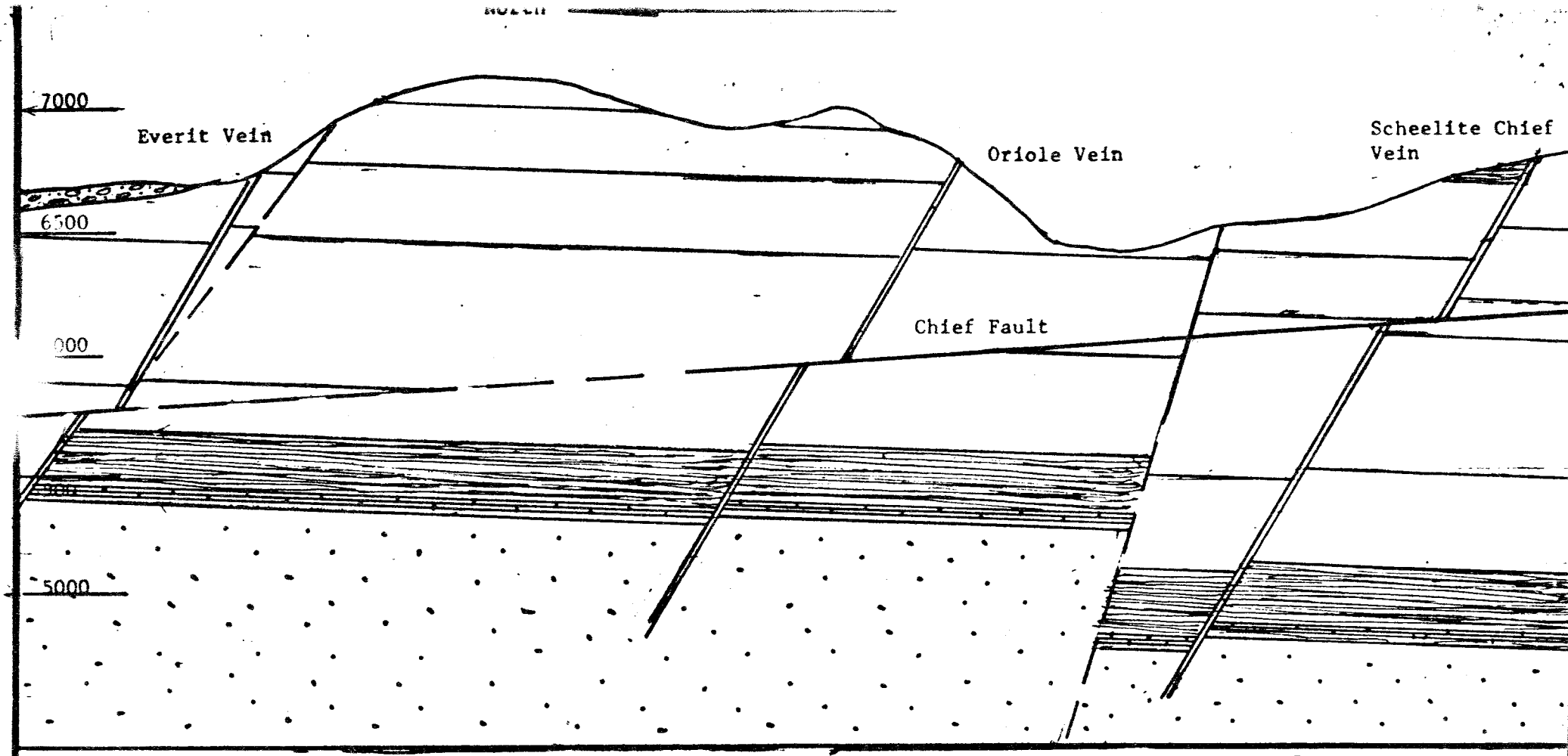
Upper Shale
Unit E (upper black)
Unit D (upper white)
Unit C (lower black)
Unit B
Unit A
Pioche Shale and Wheeler Ls.

Prospect Mountain Quartzt.
Stoped area

0' 500' 1000' 1500'
Scale: 1" = 500'

EAST WEST SECTION
Vertical Projection
of
Scheelite Chief and
Silver Bell Veins

Date 5/24 -71
Drawn by: R.G.L.



Upper Shale
Unit E (upper black)
Unit D (upper white)
Unit C (lower black)
Unit B
Unit A
Pioche Shale and Wheeler Ls.
Prospect Mountain Quartzt.
Vein
Fault

VERTICAL NORTH SOUTH SECTION

Along Coordinate Line
11,050 feet East.

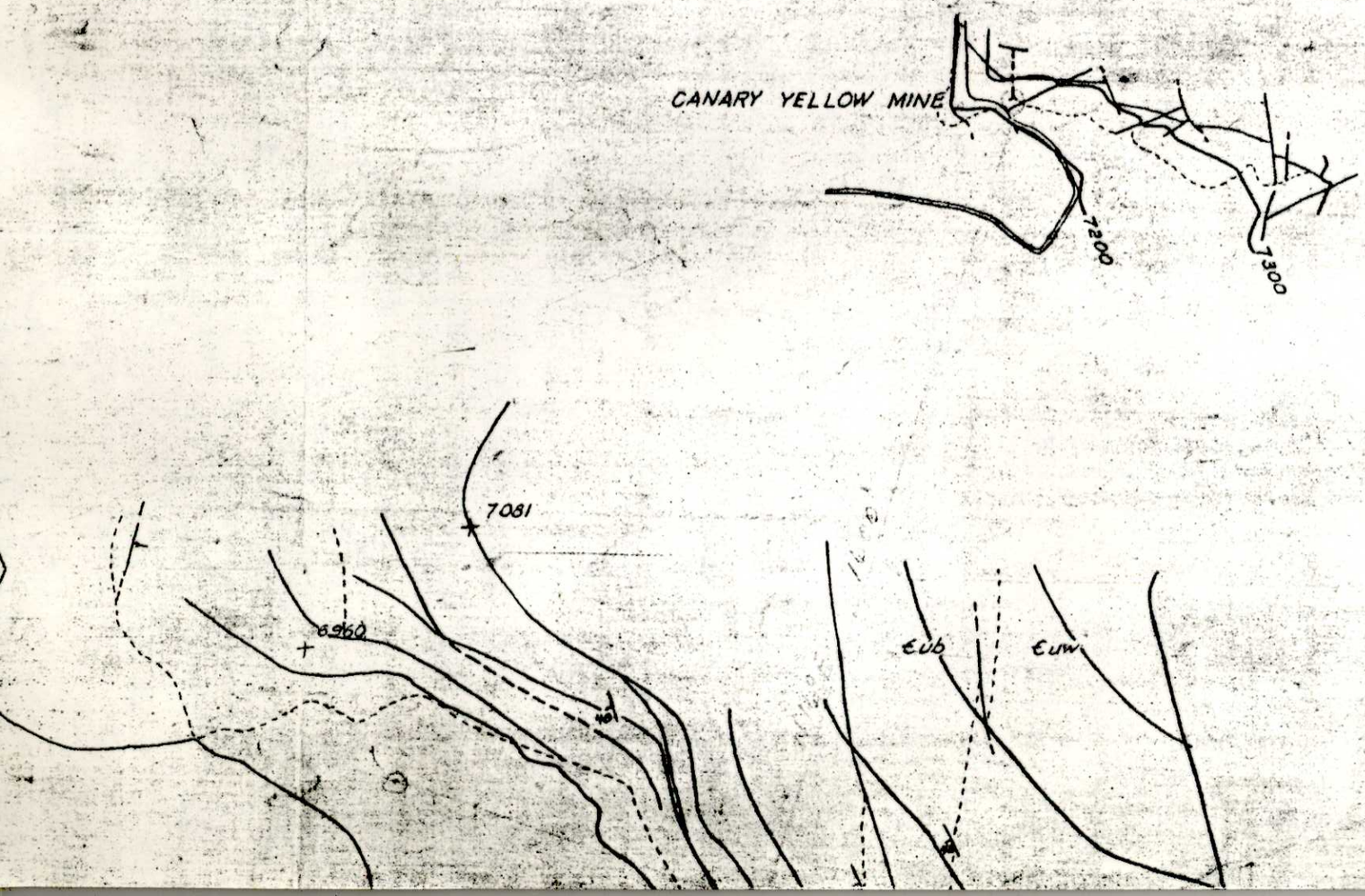
Date: 5/23-71
Drawn by: R.G.L.

0 600' 1200' 1800' 2400'

Scale: 1"= 600'

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP FIGURE 3

150022E



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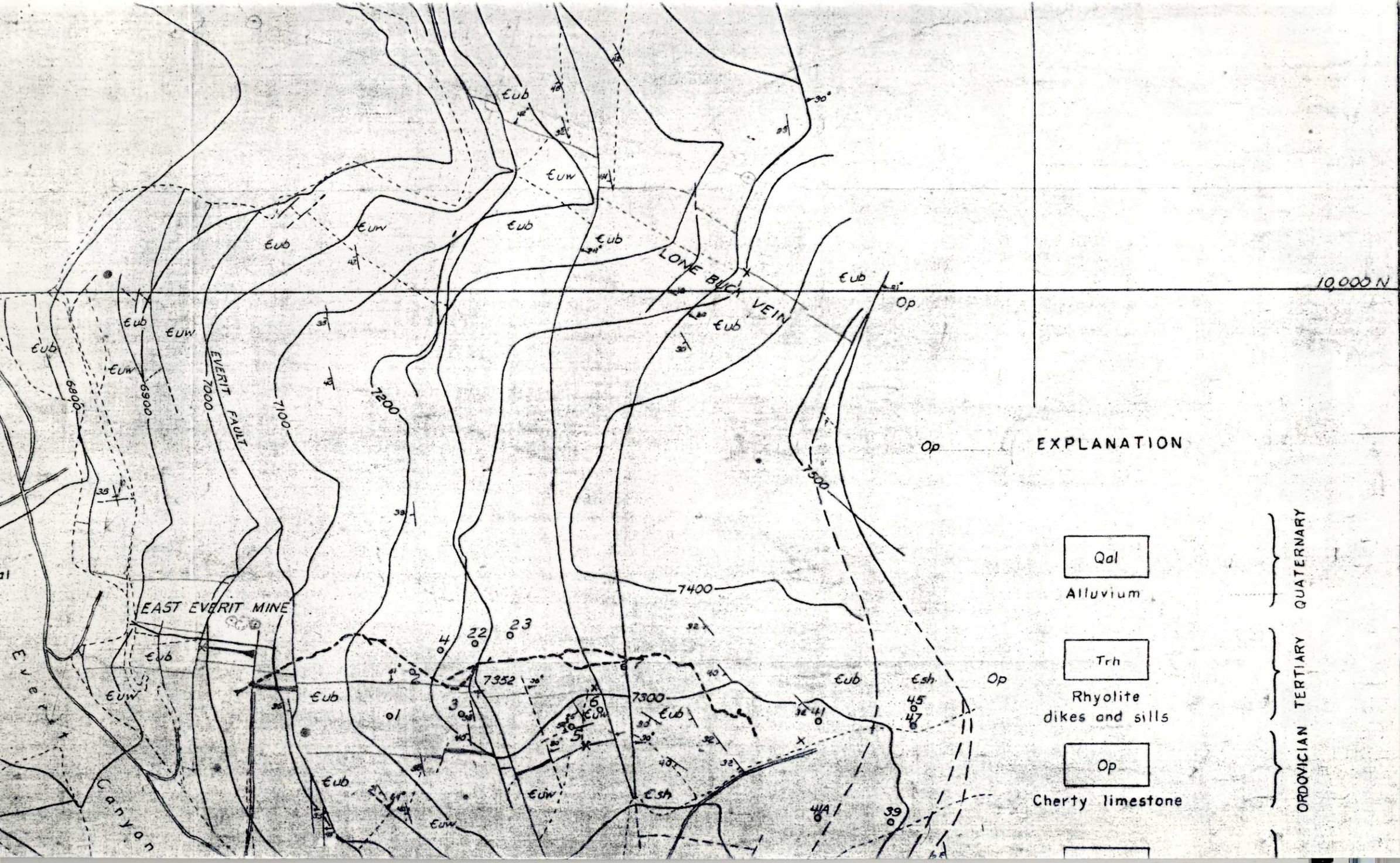
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EAST EVERIT MINE
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Cherty limestone
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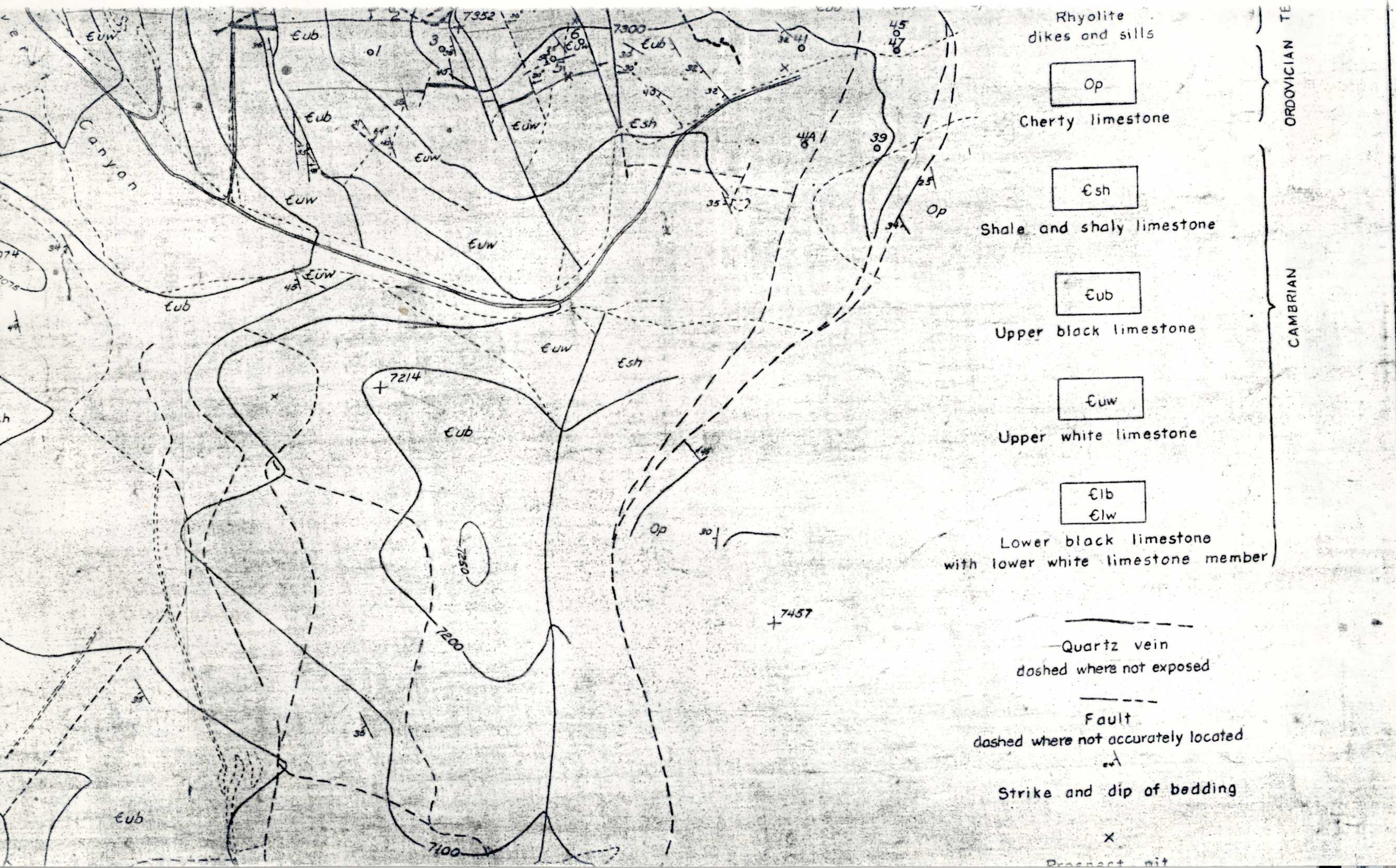
Rhyolite
dikes and sills
Qal
Alluvium
EXPLANATION
ORDOVICIAN TERTIARY QUATERNARY
Canyon


Rhyolite
dikes and sills
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ORDOVICIAN
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Upper white limestone
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Lower black limestone
with lower white limestone member
Quartz vein
dashed where not exposed
Fault
dashed where not accurately located
Strike and dip of bedding
Prospect pit
Canyon
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7100
7457
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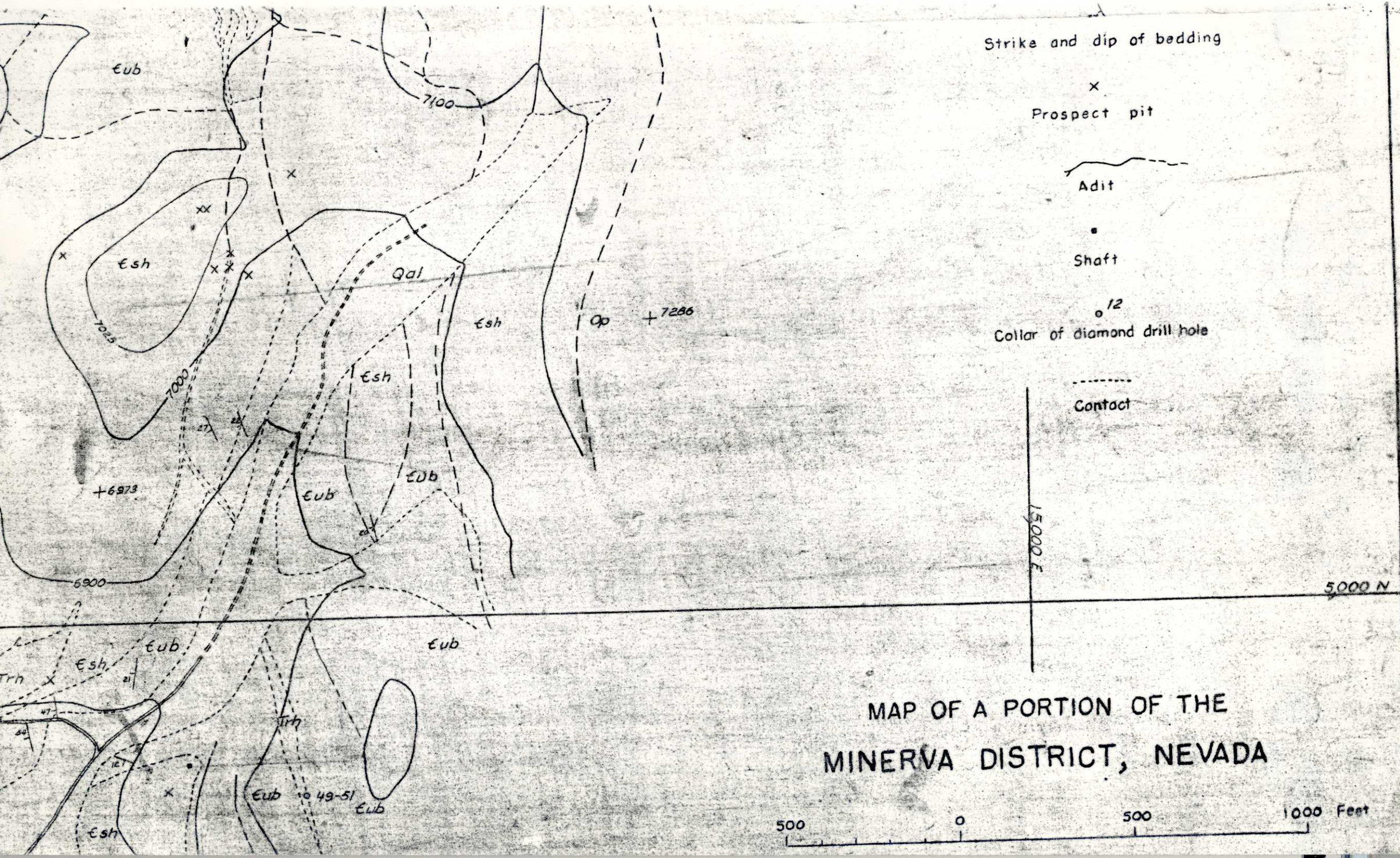
€uw
€sh
Op


Strike and dip of bedding
Prospect pit
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Shaft
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Collar of diamond drill hole
Contact
15,000 E
5,000 N
MAP OF A PORTION OF THE
MINERVA DISTRICT, NEVADA
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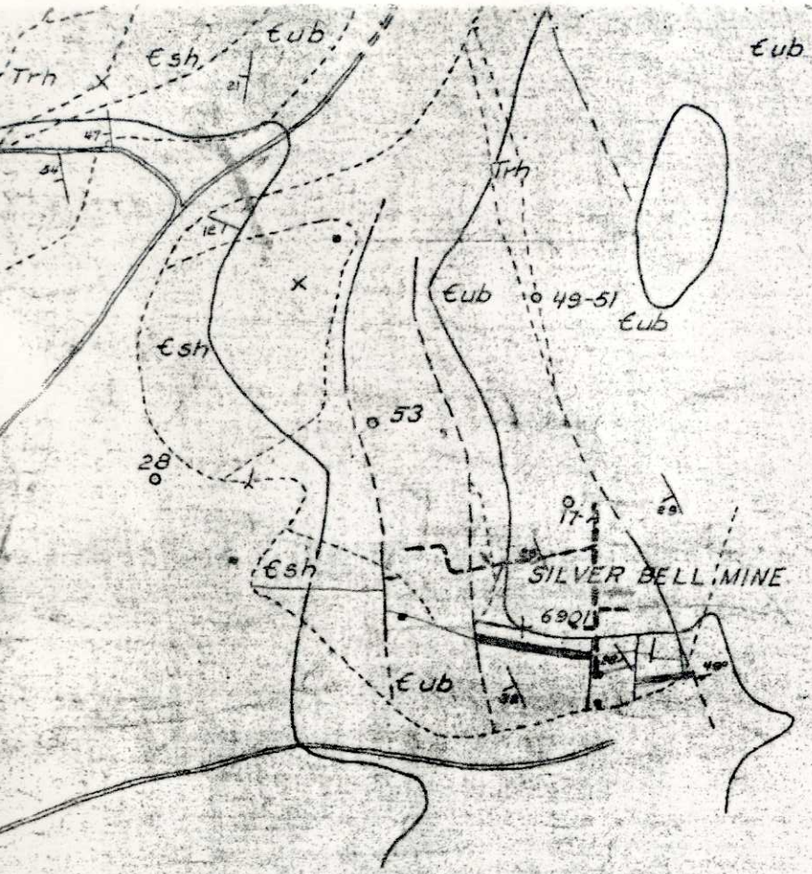

MAP OF A PORTION OF THE MINERVA DISTRICT, NEVADA

500 0 500 1000 Feet

N

17° 45'

Geology and topography by Dwight M. Lemmon and Donald Wyant

Assumed sea level datum

1940

Revised 1943

E MINERVA DISTRICT, WHITE PINE COUNTY, NEVADA

TUNGSTEN DEPOSITS IN THE MINERVA DISTRICT, WHITE PINE COUNTY

TRACING — U.S. GEOLOGICAL SURVEY MAP
"TUNGSTEN DEPOSITS, MINERVA DISTRICT, WHITE PINE COUNTY, NEVADA"

SCALE 1" = 300'

D- 1194


REVISIONS
REFERENCES
C-1099
D-1199
ORIOLE MINE
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6244
6300
6400
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6600
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7043
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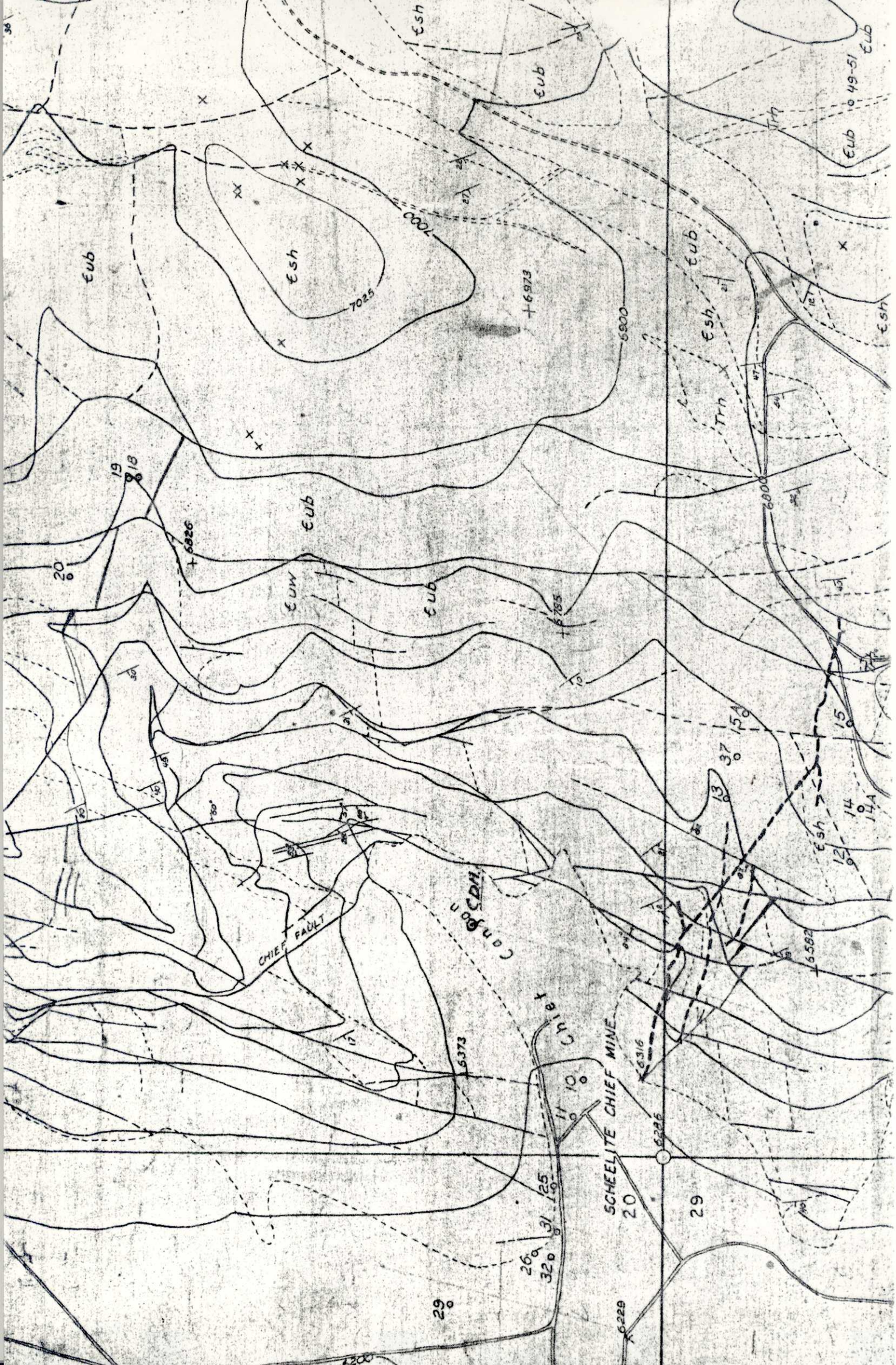

WORK	DRAWN		COMBINED METALS REDUCTION CO.
	TRACED R.H Goode	11-2-51	PIOCHE, NEVADA
	CHECKED		
	APPROVED		

TRACING — U.S.
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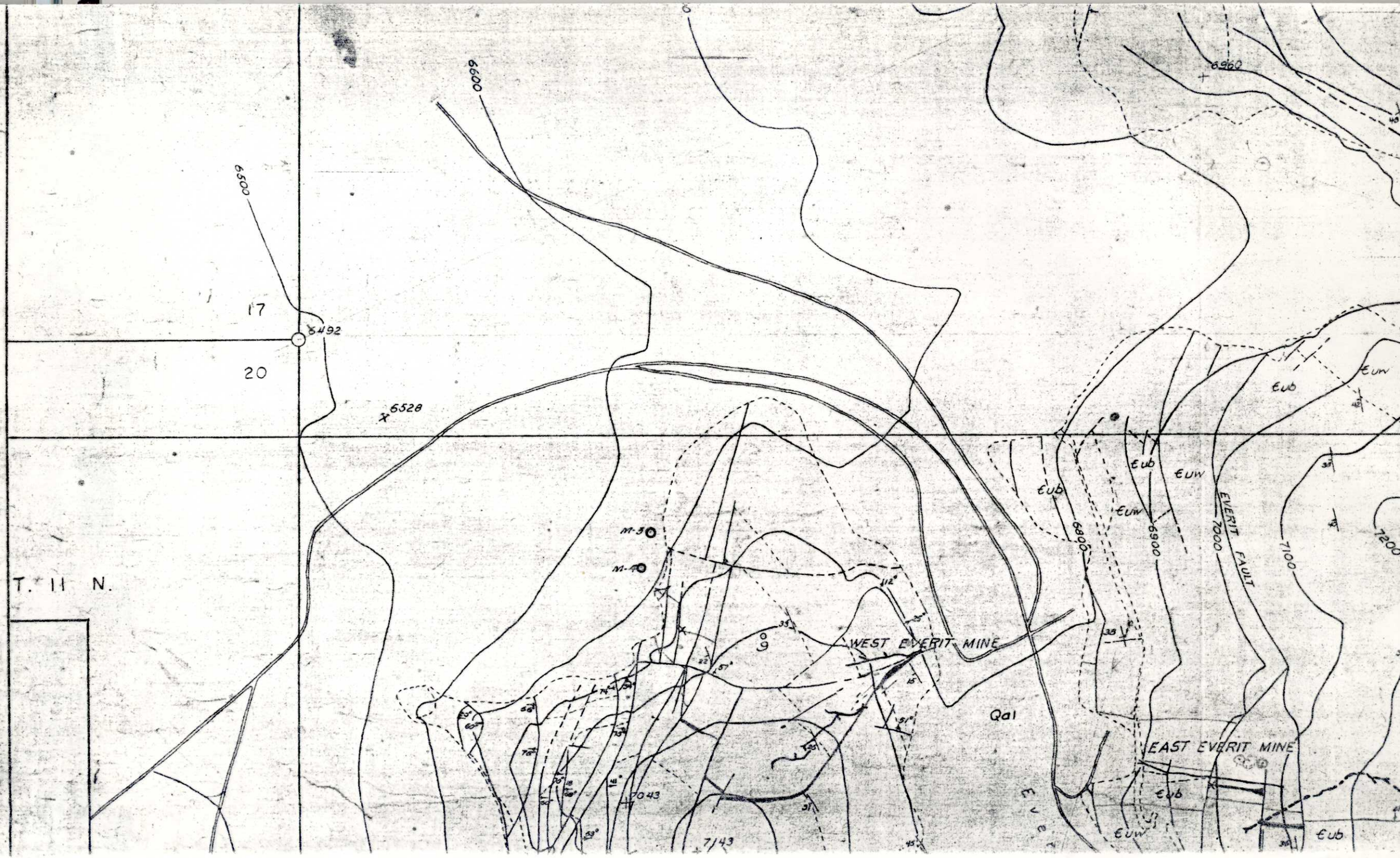
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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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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

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.

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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 8. 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.