Tungsten Deposits in the Fairbanks District Alaska

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By F. M. BYERS, JR.

MINERAL RESOURCES OF ALASKA

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Description of the scheelite deposits in relation to geologic features, with suggestions for further exploration

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[Plates are in pocket]

TUNGSTEN DEPOSITS IN THE FAIRBANKS DISTRICT, ALASKA

By F. M. Byers, Jr.

ABSTRACT

Although principally a gold-mining camp since 1902, the Fairbanks district, Alaska, has been a tungsten-producing district at intervals since 1916. The tungsten deposits discussed in the present report are 10 to 20 miles northeast of Fairbanks within the Yukon-Tanana upland. The tungsten occurs as the mineral scheelite (calcium tungstate) in thin beds and lenses of metamorphosed limestone and calcareous mica schist, in quartz pegmatites, and in gold quartz veins.

The limestone is a very minor part of an early Precambrian sequence of quartz-mica schist, quartzite, and associated intrusives. This sequence was intruded by porphyritic granite of Mesozoic age, which is probably the source of the metalliferous deposits. Tertiary granodiorite is also exposed in the district.

The scheelite deposits are segregated geographically in three areas: the Gilmore Dome area and Steele Creek-First Chance Creek area in the southern part of the district and the Pedro Dome area in the north-central part. The Stepovich mine in the Gilmore Dome area contains the largest known scheelite deposit in the district. During the periods 1915–18 and 1942–44 about 4,000 units (20 pounds to a short ton unit) of WO_3 as scheelite ore and concentrates have been produced from 3 inclined shafts on the Stepovich lode.

The Stepovich lode is a series of silicated limestone lenses, which were probably derived from a continuous bed of limestone a few feet thick. During regional metamorphism the limestone was squeezed into "rolls" and discontinuous bodies and was largely replaced by silicate minerals, quartz, and scheelite. The richest ore shoots in the lode occur at intersections of quartz pegmatite dikes with the limestone. A secondary factor in the localization of the pegmatite dikes and the ore shoots was probably an amphibolite mass exposed in the Stepovich mine along the footwall of the lode.

The Colbert property and the Yellow Pup prospect on the easterly extension of the Colbert lode are on a lode similar and parallel to the Stepovich lode and about 1,000 feet to the south. The Colbert lode contains more abundant silicate minerals, especially garnet, but scheelite is much less abundant than in the Stepovich lode. The Schubert prospect contains a minor occurrence of scheelite in metamorphosed limestone at the contact of a large body of porphyritic granite.

The Spruce Hen, Blossom, Tanana, Tungsten Hill, and Columbia prospects in the Steele Creek-First Chance Creek area are only in the prospect stage of de-

velopment. Of these, the Spruce Hen is the only one with a single well-defined lode of scheelite-bearing silicated limestone. The others are of the quartz pegmatite stringer type and have not been sufficiently worked to expose any amount of ore.

Gold veins containing scheelite are predominant in the Pedro Dome area, though scheelite has been found in metamorphosed limestone and pegmatite. The Wackwitz and Mizpah gold quartz mines have produced small tonnages of scheelite concentrates as a byproduct of gold production. Scheelite has also been found in the Cleary Hill, Johnson, Rainbow, and Tolovana gold mines, and probably occurs in other gold mines in the area. The Leslie prospect has exposed a scheelite-bearing lode of metamorphosed limestone. The Egan prospect was staked on a minor, but interesting, occurrence of scheelite in a pegmatite of porphyritic granite.

Scheelite as a placer mineral has been found in the gravels of most of the streams of the Fairbanks district; it is especially abundant in streams draining the lode areas.

The most favorable areas for scheelite prospecting are in country rock on the hanging-wall side of the smaller masses of porphyritic granite, as these granite masses, which conform to the regional dip, would normally underlie these areas. Pegmatites from the granite in these localities would thereby have had a more favorable chance of intersection with limestone beds that now are at or near the present surface. In an area of extensive overburden, as in the Fairbanks district, systematic prospecting with a small posthole auger should be undertaken.

INTRODUCTION

LOCATION AND ACCESSIBILITY

Scheelite (calcium tungstate) has been found at many localities in the lodes and placers of the Fairbanks district, Alaska. These deposits are from 10 to 20 miles northeast of Fairbanks (fig. 24). The Pedro Dome gold-tungsten lodes occupy the northern part of the scheelite-bearing area; the Gilmore Dome lodes and those of the Steele Creek-First Chance Creek area lie along the southern part. The geographic relationships are shown on plate 23.

All the tungsten deposits are accessible by truck during the summer months by secondary roads—some in poor condition—which connect with the Steese Highway, a graded road (pl. 23). The distance to Fairbanks from the point where the Steese Highway leaves the map on the southern border is 7½ miles. Automobiles, trucks, and bulldozers are available for purchase or hire in Fairbanks.

Fairbanks, with a population of over 5,000, can be reached from Seattle, Wash., by at least three different routes involving land, sea, and air transportation. The oldest established sea-land route is via boat from Seattle, Wash., to Seward, Alaska, and thence to Fairbanks via the Alaska Railroad. The rail distance from Seward to Fairbanks is 468 miles.

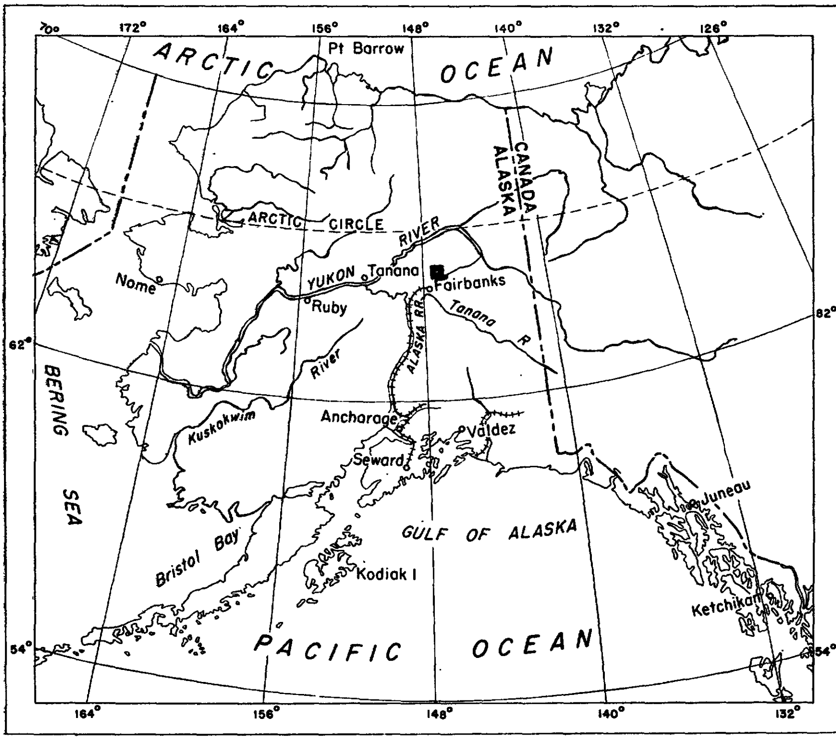

FIGURE 24.—Index map showing area of tungsten-bearing rocks in the Fairbanks district, Alaska.

TOPOGRAPHY AND DRAINAGE

The area of the tungsten deposits is characterized by gently rolling mature topography having an average relief of about 1,000 feet. The area is typical of the upland lying between the Yukon and Tanana Rivers.

The entire area is within the drainage basin of the Tanana River, which lies about 10 miles south of the southern border of the tungsten area as shown on plate 23. The main streams, the Chatanika River in the northwestern part and Goldstream Creek in the southwestern part, flow in broad flat-bottomed valleys whose floors range from 600 to 800 feet in altitude within the tungsten-bearing area. These streams flow westward to the Tanana River. Steele and Smallwood Creeks in the southern part of the area flow southward, and Fairbanks and Fish Creeks in the eastern part of the area flow eastward. The head of Goldstream Creek is at the confluence of Pedro and Gilmore Creeks.

The ridges between the headwaters of the streams are rounded divides at altitudes ranging from about 1,800 to about 2,200 feet. In places, chiefly where two or more ridges intersect, low rounded domes rise as high as 2,600 feet. Two of these domes—Pedro Dome in the north-central part of the area and Gilmore Dome in the southern part of the area (pl. 23)—are about 2,600 feet and 2,400 feet in altitude, respectively, and are convenient topographic features for locating the tungsten-bearing lodes in the vicinity.

CLIMATE AND VEGETATION

The climate of the Fairbanks district is subarctic with short, warm summers characterized by 16 to 20 hours of sunlight and long, cold winters with temperatures reaching −60°F. A summary of climatic data from the Weather Bureau station at Fairbanks is given in the table below.

Climatological data at the Fairbanks Weather Bureau station 1900–48

Month	Mean temperature (°F)	Average precipitation (inches)	Average snowfall (inches)
January	−11. 2	0. 97	11. 7
February	−1. 6	. 49	7. 2
March	9. 5	. 70	8. 1
April	29. 2	. 28	2. 7
May	46. 9	. 57	. 4
June	58. 3	1. 30	(1)
July	60. 1	1. 92	. 0
August	54. 8	2. 10	. 1
September	43. 6	1. 31	. 7
October	26. 7	. 85	6. 5
November	4. 1	. 72	7. 4
December	−7. 1	. 63	8. 7
Annual	26. 1	11. 84	53. 9

1 Less than 0.05 inch.

The Fairbanks Weather Bureau station is located at a relatively low altitude near the lowest part of the Tanana Valley, and hence the summary in the table may be misleading to anyone contemplating work in the hilly country northeast of Fairbanks. The annual range of temperature at the higher average altitude of the tungsten area is somewhat lower than in Fairbanks. Unofficial temperatures recorded at several mining camps in the tungsten area are generally 5° to 10°F cooler in summer than the temperature recorded at the same time in Fairbanks and are often as much as 30°F warmer in winter, because of the tendency of the cooler air to settle into the valleys on still days, which are prevalent in winter. Total precipitation is greater in the tungsten area than in Fairbanks. A somewhat greater annual precipitation occurs on the summit of Gilmore Dome, where the richest tungsten deposits are found, than at Fairbanks. The snowfall in Fairbanks in early November of 1943 was 2 inches whereas on Gilmore Dome it was 6 inches. Frequently during the winter the Steese Highway becomes temporarily blocked with snowdrifts in the vicinity of the pass (2,200 feet) between Pedro and Cleary Creeks (pl. 23).

The ground in the bottoms of stream valleys is permanently frozen, in some places to a depth of about 300 feet. The permanently frozen ground decreases markedly upslope, and the ridges are free of permafrost (Troy L. Péwé, 1951, oral communication). Ice-filled cavities and fissures, however, are frequently encountered in lode mining operations. The streams generally freeze around the middle of October and do not thaw until early May. At Fairbanks the breakup of river ice in the Tanana River generally occurs during the first week in May, but it may come nearly 2 weeks before or after this date.

A heavy mantle of vegetation covers the area and includes coniferous and deciduous trees, flowering plants, ferns, and mosses. Below an altitude of about 2,000 feet the mosses and ferns form a thick mat so that traversing becomes difficult. This vegetal covering is thin or lacking in heavily forested patches. The common trees are white spruce, cottonwood, alder, quaking aspen, and white birch. The white spruce is largest and most abundant, with trunks as much as 2 feet in diameter. In the Fairbanks tungsten area the timberline ranges from 2,000 to 2,300 feet in altitude, and for about 200 feet below timberline the trees are stunted.

HISTORY OF THE AREA

The Fairbanks district became established as a mining area with the discovery of placer gold in 1902. Exploitation of several tungsten deposits in the Fairbanks district began in 1915 under the stimulus of an increased average price of $24.59 a unit for concentrates containing 60 percent or more WO_3. During the years 1915–18, 10 tons of scheelite concentrates containing about 65 percent of WO_3 and 300 tons of hand-sorted ore containing 8 percent of WO_3 were produced from the Gilmore Dome area (Thorne and others, 1948, p. 8). After 1918 the prices dropped to less than $12.50 a unit and all development work ceased.

In 1931 minor underground work was done on Gilmore Dome (Hill, 1933, p. 157), but no ore was produced. The Cleary Hill Mines Co. began operations at Gilmore Dome in 1942 and continued mining during 1943 and the early part of 1944. As a result of these mining operations during 1942–44, Cleary Hill Mines produced 2,196 units of WO_3, largely as concentrates containing over 64 percent of WO_3.

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FIELD WORK AND ACKNOWLEDGMENTS

During the early period of tungsten production, from 1915 through 1918, the Geological Survey examined the tungsten deposits at Gilmore Dome and in the Steele Creek-First Chance Creek area. (See Brooks and others, 1916, p. 61–62; Mertie, 1917, p. 418–424; and Chapin and Harrington, 1919, p. 324–327.) In August and September 1942, a Survey party consisting of J. B. Mertie, Jr., W. C. Overstreet, and P. L. Killeen investigated the tungsten and antimony deposits of the Fairbanks district. From June through September 1942, and early in 1943, H. R. Joesting and Eskil Anderson, of the Alaska Territorial Department of Mines, conducted geologic and magnetometer surveys of the Gilmore Dome tungsten area. From July to the middle of November 1943, the Federal Bureau of Mines tested the two tungsten-bearing lodes at Gilmore Dome by surface trenching with bulldozer and by channel sampling. During that time the writer prepared maps of the trenches and also of the recent mine workings of the Cleary Hill Mines Co. on Gilmore Dome, and continued tungsten investigations elsewhere in the district. This field work was done under the general supervision of George O. Gates. During the summer of 1945, several days were spent on Gilmore Dome mapping workings of the Cleary Hill Mines Co., which were completed after the 1943 field season.

The report covering the U. S. Bureau of Mines development work on the Gilmore Dome tungsten lodes was released in June 1948, as Report of Investigations 4174 (Thorne and others, 1948).

The present report is based in part upon an earlier report, having the same title, that was prepared for the war agencies in 1943 by J. B. Mertie, Jr., and W. C. Overstreet.

Mr. Ralph E. Wyer, manager of the Cleary Hill Mines Co., furnished data on the operation of the Stepovich mine, and Mr. L. C. Doheny, supervising engineer of the Reconstruction Finance Corporation, furnished office facilities in Fairbanks. Mr. Louis D. Colbert and Mr. Elmer Stohl contributed information on the Colbert lode and Yellow Pup properties, respectively.

GEOLOGY

REGIONAL SETTING

The geologic features of the Fairbanks district have been described by Prindle, Katz, and Smith (1913).

The Fairbanks area of tungsten-bearing rocks (pl. 23) is entirely within a much larger area of highly metamorphosed Precambrian rocks designated by earlier workers as the Birch Creek schist. According to Mertie (1937, p. 46–59), the Birch Creek schist forms the bedrock surface of about one-fifth of the country between the Yukon and Tanana Rivers and is regarded as early Precambrian. No older rocks are known in this part of Alaska. Within the area of Birch Creek schist are smaller areas of several varieties of intrusive granitic rocks to which Mertie (1937, p. 215–216) assigned Mesozoic and Tertiary ages. Bordering some of these intrusive rocks are contact-metamorphic zones of country rock in which scheelite deposits are commonly found. Gold quartz veins, several of which are known to contain scheelite, are commonly found in the country rock farther from the igneous border. All the mineral deposits of the Fairbanks district are believed by Mertie (1937, p. 241–242) to be derived from the intrusive rocks of Mesozoic age.

ROCKS

METAMORPHIC ROCKS

The Birch Creek schist in the tungsten area consists largely of metamorphosed sedimentary rocks, of which the most common are quartz-mica schist, schistose quartzite, and quartzite. The quartz-mica schist contains quartz, biotite, and muscovite and minor amounts of apatite, magnetite, albite, and other accessory minerals. Other metamorphic rocks that form a minor part of the country rock are hornblende schist, amphibolite, gneiss, carbonaceous schist, and crystalline limestone.

Lenticular beds of crystalline limestone averaging a few feet in thickness crop out in two general zones. Each zone is composed of small discontinuous bodies, which originally may have been several continuous beds. One of these zones lies along the north side of the Pedro Dome belt; the other, which is much less conspicuous, is along the north side of the porphyritic granite in the Gilmore mineralized belt.

IGNEOUS ROCKS

The metamorphic rocks are cut by granodiorite, porphyritic granite, and altered porphyritic dike rocks of dioritic and granitic composition. On plate 23 each of these intrusive rocks has been shown separately.

The granodiorite at Pedro Dome is an irregular elongate body extending from the headwaters of Dome Creek easterly for 3½ miles to a point beyond Pedro Dome. The width averages about 0.2 mile at its western end and reaches a maximum width of 0.6 mile at its eastern end; the total area is about 1¼ square miles. A smaller area of the same intrusive is about 1 mile southeast of Pedro Dome.

According to Prindle, Katz, and Smith (1913, p. 68), the granodiorite "ranges from dark gray to light gray in color, from medium to fine in grain * * * the minerals observed in different varieties are quartz, soda-lime feldspar, alkali feldspar, biotite, hornblende, pyroxene, titanite, ilmenite and other iron minerals, zircon and apatite."

The porphyritic granite is exposed in the Pedro Dome gold belt and in the Gilmore mineralized belt and is considered by Mertie (1937, p. 241–243) to have given rise to the gold and tungsten mineralization. A small mass of porphyritic granite is exposed 1 mile southeast of Pedro Dome. The principal body of the porphyritic granite, however, lies in the Gilmore mineralized belt and extends easterly from the head of Engineer Creek for about 7½ miles to the head of Pearl Creek. Over most of this distance the width varies from ½ to 1¾ miles, and the total area is about 7½ square miles. The main porphyritic granite mass is markedly irregular at its western end, terminating in several sill-like apophyses. An outlying cupola of the same mass lies about a mile north of its eastern end. The rock is rather coarse grained with an average grain size of one-fourth inch. Grayish, clear quartz grains are embedded in white feldspar. The minerals of the porphyritic granite are quartz, microcline, oligoclase, muscovite, biotite, zircon, apatite, sphene, and magnetite.

The altered granitic intrusives are porphyritic rocks, largely dikes. They are white friable rocks that are stained yellowish brown with ferruginous matter. Prindle, Katz, and Smith (1913, p. 73) regard these dikes as offshoots from the mass of porphyritic granite, which have been subsequently altered by hydrothermal emanations from the porphyritic granite itself.

Quartz pegmatite dikes ranging from a fraction of an inch to about 1 foot in thickness cut the Birch Creek schist north of the main stock of porphyritic granite and are clearly derived from the granite. Many of the same minerals present in the pegmatite dikes are in the granite; namely, quartz, microcline, oligoclase, muscovite, zircon, apatite, sphene, and magnetite. Quartz is predominant and ranges from 50 to 99 percent of the rock by volume. Thus, the pegmatites containing the higher quartz content approach true quartz veins in composition. Skarn minerals, such as garnet, zoisite, and others, are found in association with minerals of the pegmatite close to the intersections of the pegmatites with beds of crystalline limestone. Pegmatites have not been found associated with the small stocks of porphyritic granite in the northern part of the area but are probably present. The quartz pegmatite dikes in general strike northwestward and dip steeply northeast.

STRUCTURE

No detailed mapping has been done in the Fairbanks district on the structure of the Birch Creek schist and its associated intrusions. Outcrops of the schist are relatively rare, and most of them appear to be slumped. The generalized statements of Prindle, Katz, and Smith (1913, p. 75–76) are the most recent on the general structure of the Birch Creek schist within the Fairbanks district.

The Birch Creek schist is believed by the earlier workers to have been tightly folded. The bedding is in most places nearly parallel to the schistosity. The regional strike is N. 60°–80° E. In the Gilmore mineralized belt, comprising the Gilmore Dome and Steele Creek-First Chance Creek areas, the schist has an average dip of about 35° N., but dips, ranging from horizontal to 70° N., prevail over distances of a few tens of feet. In a few places, owing to minor drag folding, reversals of dip occur. Minor, discontinuous, steeply dipping faults, striking northerly, cut the schistosity and have displacements ranging from a few feet to several tens of feet. The structure of the Pedro Dome gold-scheelite mineralized belt is extremely complex and has not yet been deciphered. The general strike of the schist is about N. 75° E. with low dips both northward and southward. The structure is further complicated by an intricate network of faults and veins. According to James M. Hill (1933, p. 84), who examined many gold-lode properties in the vicinity, the Pedro Dome mineralized belt is apparently on the axis of a low anticlinal fold. This deduction would appear contradictory to the general idea of tight folding held by the earlier workers, but these two opposing structural concepts cannot be resolved without further field work.

The intrusive rocks are roughly concordant with the enclosing Birch Creek schist, as the contact parallels the schistosity. The east-northeasterly orientation of the bedrock surfaces of nearly all the intrusive rocks shown on plate 23 suggests that the dominant structural control in their emplacement was the foliation of the Birch Creek schist.

DESCRIPTION OF DEPOSITS

Lode tungsten deposits, containing scheelite as the tungsten mineral, occur in three main areas: the Gilmore Dome area, the ridge between Steele Creek and First Chance Creek, designated in this report as the Steele Creek-First Chance Creek area, and the Pedro Dome area (pl. 23). Essentially all tungsten production has come from the Gilmore Dome area. The Gilmore Dome and Steele Creek-First Chance Creek deposits lie on the north side of the elongate stock of porphyritic granite, and their position is probably determined by a belt of calcareous schist containing thin limestone beds. These limestones are replaced by scheelite and skarn minerals, such as diopside, green hornblende, garnet, zoisite, and vesuvianite. The scheelite of the Pedro Dome area occurs chiefly as a minor constituent in the gold quartz veins and hence is only recoverable as a byproduct of gold mining.

The origin and localization of the tungsten appear clearly indicated in those deposits studied in detail. The tungsten metallization was probably derived from the porphyritic granite, for the pegmatite dikes associated with the scheelite deposits contain the same accessory minerals that are present in the porphyritic granite. Scheelite occurs in the pegmatites near crystalline limestone beds intercalated within the schist. The crystalline limestone is host to rich scheelite ore shoots at the intersection of the pegmatite dikes or pegmatitic quartz veins with the limestone. Scheelite-bearing gold quartz veins are notably richer in scheelite at places where calcareous beds in the schist are intersected, but the scheelite ore shoots within the gold quartz veins are much smaller than the skarn scheelite deposits. In places, the calcareous beds adjacent to the gold quartz veins have been partly replaced by scheelite to as much as a foot from the vein. Thus, the primary control that localized the tungsten deposits is the intersection of a mineralized fissure with a calcareous bed. The grade and size of the deposits, however, decrease in general with increasing distance from the porphyritic granite.

Ground-water leaching of scheelite in the weathered zone seems to have occurred in a few places on the upper 10 feet of the Stepovich lode and possibly on the Spruce Hen lode (R. M. Chapman, 1952, written communication).

Scheelite has been found in the placer concentrates at many places in the Fairbanks district: in the Gilmore Dome area in the placers of Fish, Pearl, and Gilmore Creeks; in the Steele Creek-First Chance Creek area in the gravels of Rose, First Chance, and Goldstream Creeks, and undoubtedly in the gravels of Steele and Engineer Creeks; and in the Pedro Dome area in the gravels of Fox, Dome, Eldorado, Bedrock, Chatham, Cleary, and Fairbanks Creeks. Scheelite also occurs in the placer concentrates of Ester Creek about 10 miles west of Fairbanks.

GILMORE DOME AREA

The Gilmore Dome area is 14 miles northeast of Fairbanks, at the eastern end of the main mass of porphyritic granite. The area can be reached by either of 2 automobile roads, each about 6 miles in length, which join the Steese Highway near the 13-mile and 20-mile posts out of Fairbanks (pl. 23). The shorter route from Fairbanks branches from the Steese Highway where Gilmore and Pedro Creeks join to form Goldstream Creek. The other route was made available in 1943 when the Cleary Hill Mines Co. constructed a road 4 miles long from Gilmore Dome to the Fish Creek road. This route was used during 1943 and 1944 to haul tungsten ore from Gilmore Dome to the Cleary Hill Mines mill on Cleary Creek.

The richest and largest of the known tungsten deposits in the Gilmore Dome area is the Stepovich lode, which was discovered by Albert Johnson in 1915. Since 1942 several other scheelite deposits have been discovered in the area. These are on the Colbert lode and the Yellow Pup and Schubert prospects. Plate 24 shows the surface development work on these properties by local prospectors and by the U. S. Bureau of Mines during 1943.

The Stepovich and Colbert lodes were formed by replacement of calcareous layers in the country rock, which consists mainly of quartz-mica schist. The lodes and the schist strike about N. 70° E. and dip about 35° N. The Stepovich and Colbert lodes lie about 0.6 mile and 0.4 mile, respectively, north of the main body of porphyritic granite and about 0.7 mile and 0.8 mile south of the outlying cupola of the same granite (pl. 23).

The Yellow Pup prospect is on an apparent extension of the Colbert lode to the northeast. Scheelite also occurs sporadically outside the two main lodes as scattered grains in lenses of silicated schist and in pegmatitic quartz veins which transect the schist and the lodes. The Schubert prospect, not shown on plate 24, lies to the southwest of the Colbert claims and is probably staked on a small lens of scheelite-bearing silicated schist.

STEPOVICH LODE

By far the most development work on tungsten properties at Gilmore Dome has been on the Stepovich lode. Since the discovery of the lode in 1915 about 2,000 feet of underground work has been done on the Stepovich property, 1,700 feet of which was on the lode. The underground workings of the Stepovich mine are shown on plate 25. During the period 1915–18, 2 inclined shafts, about 325 feet apart on 2 adjoining properties (Mertie, 1917, p. 418–421), were driven northward down the dip of the lode at an angle of about 30° (see pls. 24 and 25). These shafts are now caved. Shortly after World War I, Mike Stepovich, Sr., acquired both properties and patented 7 claims. A 170-foot adit was driven by Stepovich in 1931, but it did not intersect the main lode. From the spring of 1942 to the summer of 1944, the Cleary Hill Mines Co. leased the claims held by Stepovich. Development work by this company consisted of a 170-foot inclined shaft midway between the 2 older shafts with drifts at about 50 feet and 150 feet down the dip of the lode. These drifts are designated in this report as the "50 level" and "150 level" instead of the "50-foot level" and the "150-foot level" as originally named, because the drifts are considerably less than these depths below the surface on account of the low angle of dip of the lode. An adit was driven in 1943 to intersect the east end of the drift on the 150 level (pl. 25). The mine has been idle since early summer of 1944, when the Cleary Hill Mines lease on the Stepovich property was terminated. Since the death of Mike Stepovich, Sr., in the latter part of 1944, the property has been owned by his widow, Mrs. Vuka Stepovich, and his two sons, Mike, Jr., and Michael.

During the years 1915–18, about 10 tons of scheelite concentrates containing about 65 percent of WO_3 and 300 tons of sorted ore containing about 8 percent of WO_3 were produced, according to Mike Stepovich, Sr. (Thorne and others, 1948, p. 8). The crude ore is reported to have contained about 2 percent of recoverable WO_3. The World War I production came from the 2 caved shafts to the east and west of the Cleary Hill Mines shaft (pl. 25). No data are available on the proportions of ore mined from each of these World War I workings.

From the early summer of 1942 until May 1944, the Cleary Hill Mines Co. produced a total of 2,196 units of WO_3, which came almost entirely from the inclined shaft workings near the summit of Gilmore Dome. The tungsten production, which comprised ore and middling and table concentrates, is summarized in the table below. The ore was processed by wet gravity separation on tables at the Cleary Hill Mines mill on Cleary Creek. The entire production was sold to the Metals Reserve Company, Reconstruction Finance Corporation, Washington, D. C.

Tungsten production of the Cleary Hill Mines Co. from the Stepovich lode

[Data from files of Metals Reserve Company, Reconstruction Finance Corporation, Washington 25, D.C.]

Year	Type	Tonnage	Grade (percent)	Units of WO_3
1942	Ore	60. 084	4. 55	273
1943	Concentrates	9. 170	68. 39	627
1944	Concentrates	17. 288	64. 27	1, 111
1944	Middlings	11. 869	15. 56	185
Totals	Ore	60. 084		273
	Middlings and concentrates	38. 327		1, 923

From July to October 1943, the Bureau of Mines dug 24 bulldozer trenches on the Stepovich lode to determine the extent and grade of the ore. These trenches are shown on plates 25 and 26. Trench 3 is not shown because it is covered by the dump from the 1943 tunnel.

ROCKS

The chief rock units constituting the Stepovich lode are crystalline limestone, granular scheelite ore—which is a replacement of the limestone—quartz pegmatite, and silicated mica schist. The distribution of these rocks in the lode is shown on plates 25 and 26. The silicated rock includes silicated mica schist and a small amount of granular scheelite-bearing rock, which, however, does not contain enough scheelite to be classed as ore.

The crystalline limestone occurs as discontinuous, irregular bodies along the same stratigraphic horizon in the schist. The average thickness of the limestone is about 2 feet, although in the crests or troughs of folds the thickness is as much as 10 feet. The limestone is white to gray and is granular in texture. It is the host rock to the granular scheelite ore at places of intersection by quartz pegmatite. Small cavities in the limestone have been exposed by the underground workings of the Cleary Hill Mines Co.

The granular scheelite ore forms irregular lenses, which replace crystalline limestone. The ore consists of a granular aggregate of typical contact-metamorphic minerals, including predominant amounts of scheelite, quartz, diopside, and hornblende. A variety of other minerals have been identified microscopically, including calcite, epidote, clinozoisite, oligoclase, anorthoclase, muscovite, biotite, chlorite, apatite, sphene, vesuvianite, axinite, garnet, and meliphanite. The last four minerals are rare. The presence of the beryllium-containing mineral melaphanite was further confirmed when beryllium was detected spectographically in the ore.

Scheelite-bearing quartz pegmatites occur in places as stringers parallel with the lode and are gradational with the granular scheelite ore. These quartz pegmatites are continuous with pegmatites that strike N. 40°–60° W. and dip about 60° NE., where they intersect the lode. As pointed out on page 188, these quartz pegmatites were probably derived from the porphyritic granite, shortly after its emplacement.

The silicated mica schist is a dense-textured thin-bedded rock with beds ranging from ½ to 1 inch in thickness. Vuggy limonitic seams about one-eighth inch thick separate the individual beds. Sparse grains of scheelite are also found along these vuggy limonitic seams. The massive part of the rock contains nearly the same assemblage of silicates that are found in the granular ore. The silicated mica schist is usually found in the hanging wall above the ore, and, because it is thin bedded, generally requires timbering to prevent its collapse.

Two other rock types, green amphibolite and silicified schist, occur in the vicinity of the lode. In the Cleary Hill Mines shaft, green amphibolite is exposed in the footwall of the lode below the 50 level, where it is at least 20 feet thick (pl. 25). The amphibolite appears to be a concordant basic intrusion or flow that was later metamorphosed. It was more competent than the enclosing beds during folding and

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yielded by fracture rather than flowage. Hornblende is the principal mineral of the amphibolite, but minor amounts of sphene, albite, orthoclase, quartz, calcite, pyrite, and pyrrhotite are present also. About 100 feet north of the lode the schist is silicified and is cut by many small quartz veinlets. The silicified schist characteristically weathers to a sandy soil.

STRUCTURE

The strike and dip of the bed constituting the Stepovich lode average about N. 70° E. and about 35° NW., respectively. Variations in the strike, caused by "rolls" or secondary flexures, range from N. 15° E. in the Cleary Hill Mines adit (pl. 25) to N. 50° W. in the face of the west drift on the 150 level (pl. 25). Variations in the dip are largely the result of drag folding along the crystalline limestone. Dips ranging from 70° NW. through horizontal to 15° SE. have been recorded. A major drag fold is found in the main shaft workings of the Stepovich mine; its crestline and trough, indicated by the appropriate symbols on plate 25, are horizontal, or nearly so. The drag fold disappears along the strike to the northeast, inasmuch as only a flattening of dip to the northwest is found in the easternmost raise in the east drift of the 150 level. The drag fold extends southwest beyond the limits of the mine workings. This drag fold was probably localized by the association of incompetent limestone of the lode with the more competent sill-like intrusive of amphibolite in the footwall (sections *A–A′* and *D–D′*, pl. 25).

The lode is cut by several northward-striking faults, dipping steeply northeast. The direction of movement could not be determined along the faults. The horizontal shift of the lode along the major faults ranges from about ten to several tens of feet. In the vicinity of the Stepovich mine the shift of the lode along adjacent faults is in opposite directions, but toward the eastern part of the lode, from Bureau of Mines trench 4 to 24, the shift has been progressively southward (pl. 24). Some of the faults are inferred by offsets in the lode between adjacent trenches in which the lode is exposed.

GROUND-WATER LEACHING OF SCHEELITE

There was some evidence in bulldozer trenches that smaller grains of scheelite in weathered permeable parts of the Stepovich lode have been partly or completely dissolved by descending ground water. In the zone of weathering, which extends to about 10 feet in depth, scheelite grains, less than 1 mm in diameter, are embedded in a spongy brownish-black matrix, consisting in part of limonite and hydrated manganese(?) oxides. On close examination, the scheelite is seen to be etched and pitted. Some of the crystals are friable remnants from which most of the inner parts appear to have been dissolved. In other places, irregular masses of nonporous scheelite-bearing rock are enclosed in spongy dark rock, barren of scheelite. This spongy rock has not been recognized at depth and is probably the product of weathering. Thin incrustations of scheelite also occur along joints in more massive parts of the lode where it grades updip into the spongy rock. These incrustations have not been recognized at depth, and they may be the result of redeposition of scheelite from solution. These observations were made on the lode mainly near the Gilmore Dome summit, on which a deep residual soil has accumulated since probably some time during the Tertiary, inasmuch as no Pleistocene glaciation has occurred in the Fairbanks district. It would seem, therefore, that the effects of possible scheelite leaching are found at the place where expected, namely, in a portion of the lode that has been exposed to weathering during a long period of time.

Descending ground water, particularly if it is slightly acid, may have dissolved the scheelite at Gilmore Dome. Scheelite is sparingly soluble even in pure water (0.027 gram per liter) (Seidell, 1940, p. 347) but is somewhat more soluble in a 0.1 normal solution of sulfuric acid (H_2SO_4) (Gannett, 1919, p. 71). No sulfide mineral that might serve as a source of sulfuric acid has been observed in the Stepovich lode, but sparse pyrite, from which sulfuric acid would form on oxidation, might have been oxidized to form the limonite of the spongy rock. Moreover, sparse sulfur, probably in pyrite, ranges from 0.04 to 0.23 percent (p. 198) in ore samples taken from the Stepovich lode. Hence, a sparse amount of sulfuric acid would be formed in descending ground water on oxidation of the pyrite.

Scheelite might also have been dissolved during a long period by carbonic acid after the pyrite had been completely oxidized. The generally cool, moist environment on Gilmore Dome would cause an increase of carbon dioxide in the ground water. The resulting carbonic acid (H_2CO_3) might react with scheelite ($CaWO_4$) in the following manner:

$$2H_2CO_3 + CaWO_4 \downarrow \rightleftarrows Ca(HCO_3)_2 + H_2WO_4.$$

Although both the reactants and the products are only slightly ionized and slightly soluble, a continuous supply of carbon dioxide-charged ground water over the long period of time during which the deposits have been exposed to weathering would shift the reaction toward the right and remove scheelite from more permeable parts of the lode. That scheelite does dissolve in the proper ground-water environment is also suggested by Hess (1917, p. 64) and by Emmons (1917, p. 432) in their observations of botryoidal scheelite coatings, which they regard as of supergene origin.

DISTRIBUTION OF SCHEELITE

The Stepovich lode was traced by the Bureau of Mines in bulldozer trenches for 1,700 feet east and 500 feet west of the inclined shaft sunk by the Cleary Hill Mines Co.

The best grade and most numerous ore shoots are concentrated in a zone extending about 350 feet east and 200 feet west from the Cleary Hill Mines shaft and an unknown distance down the dip of the lode.

About 35 percent of the underground workings that extend from the Cleary Hill Mines shaft has been on granular ore approximately 1½ feet thick. Several pegmatitic quartz veins intersect the lode at the shaft, which apparently has been sunk on the richest ore shoot (section *A-A′*, pl. 25). Granular ore ranging from 1 foot to 1½ feet in thickness was exposed in Cleary Hill Mines trenches 4, 5, and 6, at distances of 100 feet, 200 feet, and 300 feet, respectively, east of the shaft. Except in the floor of the 150 level and in the face of the west drift, all the ore exposed in 1943 has been mined. The old east shaft sunk in 1916 (pl. 25) also passed through ore. According to Mertie (1917, p. 421),

The development work consists of a 75-foot inclined shaft along the cleavage of the country rock, which, though irregular, strikes in general about N. 70° E. and dips 33° N. The ore shoot which is followed by the inclined shaft, is 10 feet wide and from 4 to 6 feet high.

The stope and the old drift shown on plate 25 were completed after Mertie's visit in 1916. Data on these older workings were obtained from the Cleary Hill Mines Co., whose workings early in 1944 intersected those made during World War I.

The caved west shaft also passed downward through a number of ore shoots. Chapin and Harrington (1919, p. 325-326) report that

The vein ranges in thickness from 2 to 12 feet and more, but the richest ore is confined to lenses from 2 to 5 feet thick * * * Thin stringers of scheelite-bearing quartz of later(?) origin than the replaced rock follow the bedding planes and cut across them.

The mine is being developed by an inclined shaft driven along the vein. In September 1917, this shaft had been extended for 160 feet and dips at an angle of 40° to 18°. In places the shaft widens out to stopes and chambers, and the lower part has been opened to a width of 40 feet.

From Chapin's description it appears that these scheelite ore shoots are similar to those in the Cleary Hill Mines shaft. The lode, however, in trenches 1 and 2 (pls. 24 and 25), 70 feet west and 40 feet east, respectively, from the caved west shaft, contains limestone and silicated mica schist but no granular ore.

Beyond the limits of that part of the lode 350 feet east and 200 feet west from the Cleary Hill Mines shaft, the lode is narrower, the ore shoots are more widely spaced, and the ore is lower in grade. Trenches 12 and 13, excavated by the Bureau of Mines approximately

330 feet and 500 feet west of the Cleary Hill Mines shaft (pls. 24 and 26), exposed 15 inches and 8 inches, respectively, of brownish-black friable weathered material containing sparse grains of scheelite, together with 1 small specimen of unweathered granular ore containing an estimated 2 percent of WO_3. The presence of unweathered nonporous granular ore in weathered dark friable rock suggests that most of the scheelite originally in this weathered material may have been removed by ground-water leaching. The Stepovich lode could not be positively identified in any trenches west of trench 13a, although 3 silicated zones containing sparse scheelite are recognized in trenches 14–18 (pls. 24 and 26).

A pit in Cleary Hill Mines trench 8, which is 550 feet northeast of the shaft, has partly exposed an ore shoot (pl. 26) that has the form of a drag fold. The top side of the shoot is in the residual mantle. This shoot is probably comparable in size to the major ore shoots in the lode and hence may extend as much as 50 feet west of the pit.

Shallow underground work on the lode in the 1943 adit (pls. 24 and 25) exposed 3 small shoots (pl. 25) with an aggregate of about 10 tons of ore. Just above the 1943 adit the part of the lode exposed in trenches 1 and 2 contains only sparse grains of scheelite (pl. 25). The lode is unexposed for 80 feet east of the portal of the 1943 adit.

Trenches 4–10 across the lode and trench 20 along its strike from 80 to 580 feet east of the 1943 adit have exposed the lode for a distance of 420 feet (pls. 24 and 26). This part of the lode has been faulted at 3 places, but the only fault of any apparent significance is exposed in trench 20 in a pit midway between trenches 4 and 5 (pls. 24 and 26). Two ore shoots and 2 small lenses of scheelite-bearing rock have been exposed in the bottom of trench 20. One of the shoots with an average width of 1.1 feet is exposed in trenches 4 and 20 for a total distance of 60 feet. The eastern and western ends of this shoot are not exposed, although to the east the shoot terminates within a few feet of an inferred fault (pl. 26) of about 15 feet displacement. The other shoot is exposed in trenches 6 and 20 for a distance of 70 feet (pl. 26); it has an average width of slightly over 2 feet. The dip of this shoot ranges from horizontal to 30° toward the north. A narrow zone of scheelite-bearing rock is exposed in trench 7 and in pits along trench 20 for 40 feet (northeastward from trench 7, pl. 26). The average thickness of the zone is less than 0.7 foot, and the ore is low grade. In pit W of trench 20, about midway between trenches 8 and 9, there is exposed the western part of a small lens of ore not more than 12 feet in length. The widths of the ore in the east side of pit W is 1.5 feet.

In the next 350 feet east of the offset recognized between trenches 10 and 11, the lode is again exposed for 150 feet in trench 22 (pls. 24 and 26). In this distance several small discontinuous high-grade lenses of ore are present. Most of the lenses are only a few feet in length and average about 0.6 foot in width. The longest exposed shoot, 17 feet in length, is in trench 22 between pits A and B (pl. 26). In trench 22 and other nearby trenches, the schist and the lode have been weathered and limonite stained so that the lode cannot easily be distinguished from the country rock. It appears from a slight offset of the silicified schist between trenches 19 and 24 (pl. 24) that the lode may be just south of trenches 23 and 24.

Sporadic small lenses of silicated rock containing scheelite are in the footwall and the hanging wall, at distances generally within 50 feet of the main lode (section *A–A′*, pl. 25; trenches 13 and 14, pl. 26). These lenses are low grade, probably containing less than 1 percent of WO_3, and range from a fraction of an inch to about 1 foot in width and from a few feet to possibly 20 feet in length.

The dumps from 4 pits—1,050 to 1,200 feet east of trench 24, which is the easternmost Bureau of Mines trench exploring the lode—consist chiefly of garnetized rock with sparse scheelite (pl. 24).

LOCALIZATION OF ORE SHOOTS

Two main factors that probably cause the localization of the shoots of granular ore in the Stepovich lode are the tendency of the crystalline limestone to flow under regional stresses to loci of lower pressure at the crests and troughs of minor flexures, and the introduction of tungsten-bearing solutions through the fissures that are now filled with quartz pegmatite. At few mines is the relationship between the agents of transportation and deposition of ore material as well shown as at the Stepovich mine. The quartz pegmatites contain scheelite in increasing abundance as the crystalline limestone zone is approached, and they are in many shoots gradational with the granular ore. In the Cleary Hill Mines shaft, the quartz pegmatite "feeders" appear to have been "dammed" by the limestone, inasmuch as the granular ore shoots seem to "mushroom" around the zone of intersection.

The green amphibolite (p. 191) was possibly a local factor accounting for the drag folding of the limestone, the greater abundance of the quartz pegmatites, and the consequent richer ore shoots in the lode near the summit of Gilmore Dome. The amphibolite apparently is confined to the footwall of the lode only in the vicinity of the Cleary Hill Mines workings near the summit of the Dome. The hypothesis is offered that the competent brittle amphibolite first caused greater concentration of the incompetent limestone at the loci of minor flexures during periods of compressional stress and then shattered more than the surrounding less competent schist, thus permitting influx of tungsten-bearing pegmatitic solutions. The association of amphibolite, limestone drag folds, abundant pegmatites, and abundant ore shoots lends weight to this hypothesis and might presumably serve as a guide to locating additional ore shoots—especially when, according to Joesting and Anderson,[1] a magnetic anomaly, detectible by magnetometer survey, is associated with the amphibolite.

GRADE

Eighty-eight samples of scheelite-bearing rock were taken from the Stepovich lode, 67 by the Bureau of Mines and 21 by the Geological Survey. The latter, consisting of 18 channel samples and 3 grab samples, were analyzed in the chemical laboratory of the Geological Survey. The analyses of the Bureau of Mines samples were made by the Territorial Department of Mines assay office at Fairbanks, Alaska. The location, width, and tenor of all channel samples taken of the Stepovich lode are shown on plates 25 and 26. The analyses of 9 channel samples taken from the upper part of Cleary Hill Mines shaft are also shown on plate 25.

The weighted average tenor of 32 channel samples taken in the workings of the Cleary Hill Mines shaft and in Cleary Hill Mines trenches 4, 5, and 6 across an average width of 1.5 feet is 6.1 percent of WO_3. Two samples, containing 13.96 and 23.49 percent of WO_3, raise the average grade nearly 1 percent; therefore 5 percent of WO_3 probably is a more accurate estimate of the average tenor of the ore shoots. However, mined ore contained somewhat less than 5.0 percent of WO_3, mainly owing to an admixture of the barren silicated schist from the hanging wall. The high-grade ore mined in 1942 from the first 50 feet of the Cleary Hill Mines shaft contained 4.58 percent of WO_3. A composite grab sample taken from the surface of the ore dump from the 150 level was found by the Geological Survey to contain 3.21 percent of WO_3. Some ore is lost in blasting the waste rock before removing the ore. A composite grab sample of the fine material (below ½-inch mesh) in the waste dump from the 150 level contained 0.28 percent of WO_3.

The ore shoots in the lode farther from the inclined shaft than those described above are somewhat lower in grade. A grab sample from 10 tons of ore mined from the first 110 feet of the 1943 adit contained 0.59 percent of WO_3. The weighted average of the 2 large ore shoots exposed in trench 20 (pl. 26) is 2.25 percent across an average width of 1.6 feet. The analyses of scheelite ore in the lode farther to the east have not been averaged because the ore is in small separated pods.

Analyses of the ores for constituents other than WO_3 also were made in the chemical laboratory of the Geological Survey. Twelve samples of ore had an average phosphorus content of 0.20 percent. The maxi-

[1] Joesting, H. R., and Anderson, Eskil, 1943, Preliminary report on scheelite deposits in the Fairbanks district: Juneau, Alaska, Alaska Terr. Dept. Mines files, 10 p.

mum content of phosphorus allowed in concentrates by the Metals Reserve Company without penalty was 0.05 percent. Scheelite concentrates prepared from this ore, however, are likely to have a much lower content of phosphorus than the ore, because the phosphorus is largely in minute grains of apatite embedded in quartz, which is eliminated in the gravity concentration of the scheelite. In beneficiation tests by the U. S. Bureau of Mines (Thorne and others, 1948, p. 17–22), the phosphorus content was reduced to 0.04 percent. The other objectionable constituents of the ore are in such small amounts that none of them would subject the concentrates to any smelting penalty. Average analyses of 7 ore samples for minor constituents are given in the table below.

Minor constituents (in percent) in ore from the Stepovich lode [1]

Sample no.	WO_3	MoO_3	S	P_2O_5	As	MnO	Sb	Be	Sn
42AMt117	5.64	0.015	0.04	0.27	0.01	0.11	Tr.	--------	--------
42AMt157	.51	.015	.07	.73	.007	1.08	Tr.	Tr.	--------
42AMt206	23.49	.015	.23	.27	.01	.05	Tr.	Tr.	Tr.
42AMt297	2.50	.02	.10	.17	.01	.09	Tr.	--------	--------
42A013	1.84	.02	.14	.21	.02	.55	Tr.	Tr.	--------
42A057	9.49	.06	.09	.12	.01	.21	Tr.	--------	--------
42AK111	1.37	.02	.17	.28	.01	.84	Tr.	Tr.	--------
Arithmetic mean	[2] 6.41	0.024	0.12	0.29	±0.01	0.42	--------	--------	--------

[1] Mertie, J. B., Jr., and Overstreet, W. C., 1943, Tungsten deposits of the Fairbanks district, Alaska: U. S. Geol. Survey war minerals rept., p 8. [Unpublished.]
[2] Ore mined to end of 1942 reported to have mean tenor of 4.58 percent WO_3.

42AMt117. West wall of inclined shaft, 23 feet from surface. First ore shoot.
42AMt157. Opencut 5, about 200 feet east of the portal to inclined shaft.
42AMt206. West wall of inclined shaft, 38½ feet from surface. Second ore shoot.
42AMt297. Face of east drift, 19 feet from inclined shaft.
42A013. Opencut 4, about 100 feet east of the portal of inclined shaft.
42A057. North wall of east drift, 10 feet from inclined shaft.
42AK111. Opencut 6, about 350 feet east of the portal to inclined shaft.

The last three elements in each sample, antimony, beryllium, and tin, were identified spectrographically. Spectrographic analyses also were made for copper, lead, bismuth, zinc, silver, cerium, and thorium, but none of these metals were detected.

The irregular size, shape, and distribution of the ore shoots render highly speculative any estimate of ore reserves. Hence, ore reserves of the Johnson-Stepovich lode belong in the category of inferred ore. Ore shoots are common in the lode for 1,600 feet of strike length that extends about 500 feet west and 1,100 feet east of the Cleary Hill Mines shaft. If the lode extends 800 feet downdip (half the strike length, in accordance with general practice), a few tens of thousands of WO_3 units may be inferred in ore shoots ranging in WO_3 content from about 0.5 percent to slightly more than 5 percent. Several thousand WO_3 units are likely to be recovered from high-grade shoots near the Cleary Hill Mines Co. workings, where quartz pegmatite "feeder" dikes intersect crystalline limestone host rocks.

COLBERT LODE

Fourteen claims were located on and near the Colbert lode and were under option to the Cleary Hill Mines Co. during 1943. The discovery pit, which contains the westernmost exposure of the lode, is 1,000 feet S. 30° E. from Cleary Hill Mines shaft. During 1943 the lode was traced by the Bureau of Mines for 2,000 feet east from the discovery pit by 18 bulldozer trenches. Two trenches were also excavated on a narrow silicated zone nearly 200 feet north of the middle part of the main lode (pl. 24).

The Colbert lode dips 35°–45° NW. and has been offset a few tens of feet at its western end, presumably by crosscutting faults similar to those cutting the Stepovich lode. The thickness of the Colbert lode is extremely variable; it pinches out in places and is as much as 50 feet wide in trench 9 (pl. 27). The Colbert lode is much lower grade than the Stepovich, probably because the ore replaces mainly calcareous schist rather than crystalline limestone, although in the wider parts of the lode small fine-grained limestone remnants are present. It is also possible that temperature and pressure may have been too high during the tungsten metallization to permit the deposition of high-grade scheelite ore, because of the nearness of the Colbert lode to the porphyritic granite (pl. 23).

The three main types of rock are dense banded silicated schist, pink garnet tactite, and granular grayish-green silicated limestone. The dense banded rock consists of light-gray bands of quartz, oligoclase, a little orthoclase, sphene, and apatite; and greenish-gray bands of diopside, clinozoisite, calcite, hornblende, chlorite, epidote, biotite, and muscovite. These bands in places are separated by black vuggy seams containing many small grains of scheelite. The garnet tactite consists largely of garnet with minor amounts of quartz; scheelite was not observed anywhere in the tactite. The silicated limestone is granular and consists predominantly of calcite, quartz, chlorite, and scheelite, with a few grains of oligoclase and sphene; this rock in part comprises the ore shoots in the lode.

Scheelite occurs abundantly in 3 known ore shoots and in many widely spaced small pockets of silicated limestone whose maximum dimensions are generally less than 1 foot. Scheelite is also present as scattered grains in zones as much as 2 feet wide along vuggy seams in banded silicate rock and is sparsely distributed throughout the width of the lode. One small shoot of ore is partly exposed in the discovery pit for a length of 8 feet and a width of 2 feet (pl. 27). About 1,000 feet east of the discovery pit, a second ore shoot is inferred for a distance of 40 feet between the pit in trench 4 and pit A in trench 6 (pl. 27), although the ore may not be continuous between the 2 pits. The third ore shoot is exposed in trenches 10 and 14; it has a length of 20 feet and a maximum width of 2 feet (pl. 27). East of this shoot the Colbert lode is very weakly mineralized and in places pinches out completely.

Locations and results of analyses of 25 samples taken by the Bureau of Mines and of 3 samples taken by the Geological Survey on the Colbert lode are shown on plate 27. The sample taken by the Survey in the Colbert discovery trench (pl. 27) also was analyzed for several constituents other than tungsten. The chemical analysis, in percent,[2] is presented in the table below. The weighted average tenor of the ore shoots is 1.3 percent of WO_3 across an average width of 1.6 feet.

Tungsten trioxide (WO_3)	1.56
Molybdenum trioxide (MoO_3)	.005
Sulfur (S)	.06
Phosphorus pentoxide (P_2O_5)	.23
Arsenic (As)	$<.01$
Manganese oxide (MnO)	.51
Antimony (Sb)	Tr.
Tin (Sn)	Tr.
Copper (Cu)	Nil
Lead (Pb)	Nil
Bismuth (Bi)	Nil

YELLOW PUP PROSPECT

A scheelite zone in a vertical cut 10 feet high was uncovered in 1943 by Elmer Stohl, William Birklid, and M. S. Anderson in the valley floor of Yellow Pup Creek (pl. 24). As seen in the face of the cut, the scheelite-bearing zone ranges from 1 foot to 2 feet in width and dips steeply to the north. The footwall and hanging wall are weathered dark-stained rocks, probably originally garnet tactite. The ore is a quartz pegmatite similar to that cutting the Stepovich lode. The rock consists of quartz, oligoclase, muscovite, and scattered grains of apatite and scheelite. A 5-ton ore pile beside the opencut was sampled by the Geological Survey and found to contain 0.59 percent of WO_3.

Many pits and trenches exposing scheelite-bearing garnet tactite and green silicate rock were excavated along the western border of the Yellow Pup prospect by Charles Murray and Pat Savage. The scheelite-bearing silicated zones are approximately on the projected surface trend of the Colbert lode eastward (pl. 24), although apparently several mineralized zones parallel to the schistosity are present. By extrapolating the trend of the Colbert zone a few hundred additional feet eastward, the discovery cut of the Yellow Pup prospect also would lie on an extension of the Colbert lode.

[2] Mertie, J. B., Jr., and Overstreet, W. C., 1943, Tungsten deposits of the Fairbanks district, Alaska: U. S. Geol. Survey war minerals rept., p. 10. [Unpublished.]

Three bulldozer trenches (not shown on pl. 24) were excavated in September 1944 at the site of the Murray and Savage pits by the U. S. Bureau of Mines (Thorne and others, 1948, pl. 25) to explore the lode on the Yellow Pup prospect. These bulldozer trenches exposed three small east-trending scheelite-ore shoots west of the discovery cut, which are similar to those in the Colbert lode.

SCHUBERT PROSPECT

A 35-foot trench, dug by Gus Schubert, exposes the granite-schist contact on the divide between Johnson and Gilmore Creeks approximately 0.8 mile S. 67° W. of the Cleary Hill Mines inclined shaft (pl. 23). The trench is nearly at right angles to the bedding, which strikes N. 35°–40° E. and dips vertically. The bedrock exposed in the bottom of the trench from southeast to northwest is as follows:

	Feet
Porphyritic granite	20
Glassy quartz	½
Hornfelsic mica schist	7½
Scheelite-bearing silicated limestone and limestone	7

The silicated limestone resembles that of the Colbert lode. Scheelite occurs as sparsely scattered grains in a 2-inch band within the silicated limestone. This prospect is the only place in the Gilmore Dome area where scheelite-bearing rock has been exposed at the contact zone of the main body of granite.

STEELE CREEK-FIRST CHANCE CREEK AREA

Scheelite occurs at several places on a ridge between the heads of Steele and First Chance Creeks (pl. 23) near the western end of the large body of porphyritic granite that lies south and southwest of Gilmore Dome. The Old Gilmore Road, which joins the present Steele Creek Road about a mile from the Steese Highway, follows along this ridge. All of these occurrences are within 5 miles of the Old Gilmore Road turnoff.

All the tungsten prospects in the Steele Creek-First Chance Creek area were examined by Mertie (1917, p. 422–424) and Chapin and Harrington (1919, p. 326–327). The following descriptions are based largely upon these earlier reports, inasmuch as most of the workings were caved when examined in 1943.

The discovery of scheelite deposits on Gilmore Dome in 1915 gave an impetus to prospecting for other tungsten lodes. By the summer of 1916, five prospects, known as the Spruce Hen, Columbia, Blossom, Tanana, and Tungsten Hill, had been located. Prospecting on them continued by means of adits, shafts, and trenches for 2 or 3 years, but these workings are now caved (pl. 28). Only minor development was done on the Tungsten Hill prospect; these workings, therefore, are not shown on plate 28. All tungsten mining ceased in 1918 with the sudden decline in the market price of tungsten ores.

Quartz schist and quartz-mica schist are the most common country rocks in this area, with less abundant crystalline limestone, hornblende schist, and recrystallized basic igneous rocks. The metamorphic rocks are intruded by the large mass of porphyritic granite (pl. 23). The scheelite deposits lie at or near the irregular western contact of this granite. Scheelite is disseminated in tactite, silicated limestone, in and along the edges of granitic and pegmatitic dikes, and in small quartz veins which transect the cleavage of the country rock.

SPRUCE HEN PROSPECT

The Spruce Hen prospect lies on the divide between the headwaters of Steele and First Chance Creeks (pl. 28). Old development work at the Spruce Hen group of claims consisted of two shafts and many trenches and prospect pits.

Scheelite mineralization has been traced by pits and trenches for over 800 feet. The trend of the mineralized zone, inferred from scheelite-bearing rock exposed on the dumps of the workings, is N. 60° E. (see inset, pl. 28). More than 1 lode appears to be present, but, owing to lack of exposures, it could not be determined whether there are 2 parallel lodes or several arranged in echelon. The scheelite lode was exposed in 1943 by only 1 pit and 1 trench near the center of the workings. In the trench the lode is badly weathered and constitutes part of the mantle rock. The widths of the lode in the pit and the trench are 3.2 and 3 feet, respectively. The southwest shaft is reported to have been sunk 70 feet along an incline or 30° on a northwest-dipping body of ore 3 feet thick. This is apparently a different scheelite-bearing zone from the one exposed in the trench and pit. The shaft at the northeast end of the workings was sunk in prospecting for gold and did not intersect the tungsten lode.

Small grains of scheelite are disseminated through the lode along with abundant garnet, diopside, quartz, clinozoisite, vesuvianite, and calcite. Fluorite is also present in the lode. The dump of a pit 60 feet northeast of the southwest shaft contains blocks of a dark-green fine-grained altered igneous rock consisting chiefly of hornblende. Some of these blocks contain high-grade concentrations of scheelite in zones as much as 6 inches wide. The character, size, and tenor of the deposit from which this ore came could not be determined.

Locations and analyses of 4 lode samples in place and 1 ore dump sample from the Spruce Hen lode are shown in the inset of plate 28. The ore dump sample contained 0.25 percent of WO_3, but this analysis is almost certainly low, inasmuch as ore dumps from the lode have been sampled many times by prospectors and others, who have removed the higher grade specimens of ore (H. R. Joesting, 1943, written communication). The 4 samples of the lode in place averaged 0.44 percent of WO_3.

The lode sample containing 0.16 percent of WO_3 and the ore-dump sample were analyzed for several other constituents, including some that might prove deleterious in the processing of the ore. These 2 analyses, in percent,[3] are shown in the table below.

	Lode	*Ore dump*
Tungsten trioxide (WO_3)	0. 16	0. 25
Beryllium oxide (BeO)	Tr.	None
Manganese oxide (MnO)	. 87	. 67
Phosphorus pentoxide (P_2O_5)	Tr.	Tr.
Molybdenum trioxide (MoO_3)	. 005	. 005
Antimony (Sb)	Tr.	Tr.
Arsenic (As)	$<$. 01	$<$. 01
Sulfur (S)	. 54	. 10

Lode. West slope of ridge at head of First Chance Creek and 1.4 miles S. 8° E. from mouth of Rose Creek. Pit near southwest end of workings.

Ore dump. West slope of ridge at head of First Chance Creek and 1.4 miles S. 8° E. from mouth of Rose Creek. Dump ore from shaft at southwest end of workings.

BLOSSOM PROSPECT

The Blossom prospect is about three-quarters of a mile southwest of the Spruce Hen prospect and on the same ridge (pl. 28). Workings on the Blossom group of claims in 1943 consisted of an inclined shaft, 10 trenches, and 9 small prospect pits. Five hundred feet southeast from these workings, near the top of the ridge, are 2 trenches, an inclined shaft, and 2 prospect pits (pl. 28). All the workings at the Blossom prospect are caved.

The south shaft was sunk 20 feet vertically, then it was inclined at an angle of 30°. No exposures are available in the shaft; but when the mine was being developed during 1916, a scheelite-bearing layer of weathered schist 3 to 4 feet thick containing rich quartz-scheelite stringers was reported. Scheelite is in zones one-fourth inch wide in quartz-mica schist along contacts with quartz veinlets 1 to 3 inches thick.

The north shaft, inclined at an angle of 28°, cuts through quartz-biotite schist, amphibole schist, and a dike of porphyritic granite. Scheelite-bearing quartz veinlets, ½ to 3 inches thick, penetrate the quartz-biotite schist and the porphyritic granite. Scheelite also occurs in the schist in ¼-inch zones along the contacts with quartz veinlets. Some of the quartz veinlets contain about 25 percent of scheelite, but they are less than one-half inch thick and are not numerous.

The tungsten deposits on the Blossom prospect are apparently of the quartz-stringer type and do not occur in beds of lime-rich silicates.

[3] Mertie, J. B., Jr., and Overstreet, W. C., op. cit., p. 16.

It would seem that the lack of a suitable limestone bed on the Blossom prospect accounts for the dissemination of the scheelite in the quartz veinlets, which are normally the "feeders" of tungsten-bearing ore-forming solutions at the time of ore deposition. Apparently there has been some minor localization of the quartz stringers by certain beds in the schist complex.

Only ore dumps were available for sampling on the Blossom prospect, and the two best of these were sampled by J. B. Mertie, Jr., in 1942. Sample 51 was taken from the ore dump at the caved vertical shaft at the northeast end of the workings just above the 1,850-foot contour (pl. 28). Sample 264 was from the ore dump at the pit 20 feet west of the caved inclined shaft near the bend in the road at the southern end of the workings. Possibly part or all of this ore dump may have come from the inclined shaft. Analyses, in percent,[4] of these samples are given in the table below.

	51	264
Tungsten trioxide (WO_3)	2.02	1.44
Manganese oxide (MnO)	.12	.01
Phosphorus pentoxide (P_2O_5)	.45	.13
Molybdenum trioxide (MoO_3)	.01	.005
Antimony (Sb)	Tr.	Tr.
Arsenic (As)	.02	<.01
Sulfur (S)	.07	.06

51. Tungsten Hill, about 2⅛ miles S. 6° E. from junction of Gilmore and Pedro Creeks. North side of hill and about 450 feet northwest of Old Gilmore Road. Shaft at northeast end of workings.

264. Tungsten Hill, about 2⅛ miles S. 6° E. from junction of Gilmore and Pedro Creek. Southeast side of hill and about 80 feet west of Old Gilmore Road. Pit in workings.

The method of sampling the ore dumps in 1942 consisted of crawling over the dumps under a heavy tarpaulin, which excluded most of the daylight, and picking up all the pieces of rock which the ultraviolet lamp showed to contain scheelite. The high WO_3 content of the Blossom prospect samples is due to the selection of those ore specimens for analysis that contained the quartz-scheelite stringers, and hence is hardly representative of any large body of rock. The higher P_2O_5 content (from apatite) and the lower MnO and S contents of samples from the Blossom prospect when compared with the amounts of these constituents in samples from the Spruce Hen prospect would be expected in the pegmatite-type quartz-stringer deposit of the Blossom prospect, in contrast to the tactite type of scheelite deposit characterized by the Spruce Hen prospect.

TANANA PROSPECT

The Tanana prospect is located in Tungsten Gulch, a tributary to First Chance Creek (pl. 28), at an altitude of about 1,450 feet. Workings visible in 1942 and 1943 included a caved shaft and several small

[4] Mertie, J. B., Jr., and Overstreet, W. C., op. cit., p. 16.

prospect pits. These openings revealed little geologic information, for they had become filled with slope wash and were overgrown with vegetation.

Mertie (1917, p. 422) examined the prospect in 1916 when the workings were accessible and wrote the following description:

The country rock on this claim is a quartzite schist, the cleavage of which strikes N. 30° E. and dips 35° NW. The lode consists of a mineralized zone, 3 feet thick, which lies parallel with the major structure of the country rock. It is the structure of the schist, in fact, which has determined the site of the ore deposition. The scheelite occurs in stringers of soft, decomposed, iron-stained schist, from 2 to 6 inches in width. Many of these stringers contain little quartz-scheelite veinlets, which are very rich in tungsten and carry also some gold. The stringers of decomposed schist are said to carry both scheelite and gold. The country rock separating the schist stringers in the lode also carries a little scheelite, possibly as much as 1 percent. A specimen of scheelite-bearing pegmatite, taken from the bottom of the incline, shows the intimate genetic connection of the deposit with granitic rocks.

A gold quartz vein striking N. 8° W. and dipping 60° E. cuts the schist and the scheelite lode above described. This vein carries gold in about the same amount as the scheelite lode. In view of the fact that gold and scheelite do not appear to have been deposited synchronously at the other properties visited, it is probable that the gold in this scheelite lode is a result of local enrichment by the gold quartz vein. Both structural and mineralogic data therefore point to the conclusion that the scheelite mineralization took place before the formation of the gold quartz veins, at least at this particular locality.

TUNGSTEN HILL PROSPECT

The Tungsten Hill prospect was located in 1916 on the southwest side of Tungsten Gulch opposite the Tanana prospect. No workings are shown on plate 28, because the few prospect pits dug in 1916 had been completely obliterated by the time of Mertie's visit in 1942 and the writer's in 1943. The pits on the Tungsten Hill prospect were examined in 1916 by Mertie (1917, p. 424) who writes:

Four scheelite lodes had been discovered on these claims by August, 1916, and it is likely that others are present. On the Grand Duke Nikolas claim a scheelite lode in the schist country rock had been exposed in an open cut. This deposit consists of 6 to 8 feet of decayed schist, carrying scheelite. Vein quartz containing a little gold is also present, cutting the mineralized zone.

On the Tungsten No. 1 claim another open cut had been made in a country rock of mica schist and quartzite schist. A zone mineralized by scheelite is present, but the width of the lode was not apparent from the work done.

On the General Joffre claim a scheelite lode, 14 feet wide, has been exposed. The lode as a whole was considered low-grade ore; but it contains in the central part an 18-inch stringer of decayed schist, which is of considerably higher grade.

These claims certainly deserve further prospecting, for they are as advantageously situated with regard to the granite as other scheelite claims in the district on which workable lodes have been developed.

COLUMBIA PROSPECT

The Columbia prospect is near the head of Steele Creek Valley. Workings are located on the west side of the valley through altitudes ranging from 1,500 to 1,660 feet (pl. 28) and consisted in 1943 of 2 adits, 4 trenches, a prospect pit, and 2 shafts, all caved. In 1916, the upper adit was driven 80 feet along a 3-foot zone of decayed schist containing quartz-scheelite stringers. The zone strikes N. 20° W. and dips 30° E. Porphyritic granite forms the hanging wall. Several fragments of quartz-mica schist cut by scheelite-bearing quartz were found in 1943 on a large dump outside the upper adit. The lower adit, intended to intersect the lode at a lower altitude, was entirely within the granite. No information is available on the kind of rock that was exposed in the shafts.

PEDRO DOME AREA

Four types of scheelite deposits have been found at scattered intervals along the southern side of the Pedro Dome area (pl. 23) in a belt of gold-tungsten mineralization, which extends about N. 65° E. from the head of Moose Creek, a headwater tributary of Dome Creek, to the upper valley of Fairbanks Creek, a distance of about 8 miles. Scheelite occurs chiefly in gold quartz veins which cut thin crystalline limestone beds, a few inches in thickness, or calcareous schist. The second type of scheelite deposit occurs as wall-rock replacements of these calcareous beds. The third type is represented by a single contact-metamorphic deposit which probably is close to the source of the tungsten-bearing solutions. The fourth type of scheelite deposit is genetically closest to the source of the tungsten-bearing solutions and consists of sparse scheelite grains in a pegmatite derived from the porphyritic granite.

The vein and limestone wall-rock types of scheelite deposits are closely related and are found intimately associated in the Wackwitz, Cleary Hill, and other gold mines. The contact-metamorphic type is found on the Leslie prospect and the pegmatite type on the Egan.

WACKWITZ MINE

Scheelite in gold quartz veins and in limestone-replacement bodies occurs at the Wackwitz mine on the east side of Bedrock Creek, a tributary of Cleary Creek (pl. 23). This mine is on the Wyoming and Wyoming Fraction claims, about 1,100 feet from the mouth of Bedrock Creek. It is reached by a short automobile road which branches from the Steese Highway on the northwest side of Cleary Creek. According to Mertie and Overstreet,[5] a small quantity of scheelite concentrates is reported to have been produced as a by-product of gold mining.

The principal development work at the Wackwitz mine consists of 3 adits driven eastward into the hill on different levels. The country rock is quartz-mica schist, quartzite, and thin limestone beds which

[5] Mertie, J. B., Jr., and Overstreet, W. C., op. cit., p. 20.

strike N. 85° W. and dip about 27° N. On the lowest level a vein is exposed at intervals along the drift. About 400 feet in from the portal, a crosscut extends 380 feet to the south. Three small quartz veins and a northward-trending fault zone are exposed in the crosscut. At the southern end of the crosscut a 75-foot drift at approximately right angles has been driven along the Wyoming vein (also known as vein 5), the principal scheelite-bearing vein in the mine. All the veins exposed strike approximately east and dip steeply south. The middle or main level is a drift on the Wyoming vein for 350 feet eastward and then intersects the northward-trending fault. A 100-foot crosscut to the south has picked up the Wyoming vein, and a drift has been driven 200 feet farther east along the vein. The uppermost level was caved when visited in 1943.

Scheelite is rare in all the veins exposed east of the fault. West of the fault, the Wyoming vein contains scheelite in addition to gold. In the back of the middle level, the Wyoming vein contains a 6-inch scheelite-bearing zone for 70 feet along the drift. It was estimated that this zone might contain as much as 0.3 percent of WO_3. In a sublevel above the same drift, a small, high-grade ore shoot, formed by replacement of fine-grained limestone, measures 1 by 3 feet in cross section and was estimated to contain 20 percent of WO_3. This replacement-type ore shoot was almost indistinguishable from the enclosing fine-grained limestone without the aid of an ultraviolet lamp.

Three samples were taken of the scheelite ores at the Wackwitz property. One of these, sample 230, is from the scheelite ore dump at the portal of the lower adit. This material was taken entirely from the Wyoming vein, and hence the sample should represent the average tenor of this vein. Samples 231 and 232 were taken from the Wyoming vein where exposed in the back of the drift on the lowest level. The analyses, in percent,[6] of these samples are presented in the table below. No copper, bismuth, or tin was found in these samples, but, by spectographic tests, traces of antimony were found in all 3 samples, and a trace of beryllium was found in 232.

	230	*231*	*232*
Tungsten trioxide (WO_3)	0.28	0.69	1.64
Molybdenum trioxide (MoO_3)	.005	.005	.005
Manganese oxide (MnO)	.11	.01	.07
Phosphorus pentoxide (P_2O_5)	.28	Tr.	.26
Arsenic (As)	.80	.70	.61
Sulfur (S)	.06	.26	.22

230. Dump ore at portal of mine. This ore was mined from the Wyoming vein.
231. Sample taken from face in Wyoming vein, lowest level.
232. Sample taken from face in Wyoming vein, lowest level.

[6] Mertie, J. B., Jr., and Overstreet, W. C., op. cit., p. 21.

The tenor of the Wyoming, or vein 5, is so low that tungsten can be recovered only as a byproduct of gold mining.

MIZPAH MINE

Another occurrence of scheelite ore similar to that at the Wackwitz mine is on the Black Joe and Mizpah claims of the Mizpah mine, on the north side of Fairbanks Creek, west of Too Much Gold Creek (pl. 23). The workings on this property were caved and inaccessible in 1942 but were described earlier by Mertie (1917, p. 421):

> The country rock is quartzite schist, which strikes N. 20° W. and dips 18° SW. The scheelite is present in a quartz vein, which cuts the cleavage of the schist, striking N. 80° W. and dipping about 80° S. This is really a gold-tungsten vein, for it contains both gold and scheelite. The interesting feature, however, is that the two minerals occur in different portions of the vein. Just above the 60-foot level the vein is 6 inches thick and is a gold-quartz vein, carrying little or no tungsten. Just below this level, in the same vein, the quartz is scheelite-bearing and the gold is lacking. In reality, there is a scheelite ore shoot in the quartz, with a lateral extent along the vein of about 80 feet. At the 80-foot level the vein is a low-grade gold-tungsten lode, carrying little gold and much less scheelite than at the 60-foot level. The dip of the vein at this point ranges from 45° to 85° S. It appears, therefore, that where this quartz vein carries scheelite in commercial amount gold is lacking, and that the gold-bearing part of the vein is lacking or low in scheelite.

A small amount of scheelite concentrates were recovered in 1916 from the 6-inch gold quartz vein.[7] No tungsten ore was seen on any of the old dumps at this property by the Geological Survey party in 1942.

CLEARY HILL MINE

During the summer of 1943 a small amount of scheelite was found in the Cleary Hill gold mine. The Cleary Hill claims adjoin those of the Wackwitz mine on the north and extend from Bedrock Creek eastward to Chatham Creek (pl. 23). Nearly all the Cleary Hill mine production has been gold ore, although a small amount of antimony ore also has been mined. Adits have been driven on the Cleary Hill vein at three levels: the uppermost adit, or first level, now caved; the Penrose and Swanson adits on the second level; and the main adit on the third level. A winze sunk inside the main adit connects with the fourth, fifth, and sixth levels. The Penrose and Swanson adits on the second level are parallel, having been driven on displaced segments of the Cleary Hill vein.

The readily accessible workings of the Cleary Hill mine were examined with the ultraviolet lamp to determine the extent of scheelite mineralization. Scheelite is present in scattered grains and ⅛-inch seams in the wall rock of the gold quartz vein for 300 feet along the

[7] Mertie, J. B., Jr., and Overstreet, W. C., op. cit., p. 22.

back of the Penrose adit and for 100 feet along the back of the Swanson adit. Most of this mineralized rock is estimated to contain as much as 0.1 percent of WO_3 across a width of 1 foot. Several feet of calcareous wall rock along the back of the Penrose adit appeared to contain about 1.0 percent of WO_3 across a width of 1 foot. The wall rock contains thin limestone beds in the part of the Penrose adit where scheelite is present.

Scheelite is disseminated in thin beds of crystalline limestone at a few places in the lower levels of the Cleary Hill mine. At one place on the fourth level crystals occur a foot from a gold quartz vein which contains no scheelite. On the sixth level the gold ore contains grains of scheelite in a few places.

On the west side of Chatham Creek valley, about three-eighth mile east of the portal of the main adit, an inclined shaft has been sunk to a depth of about 125 feet on a mineralized zone of limonite-stained quartz stringers in weathered schist. The zone strikes N. 60°–70° W. and dips 50°–60° SW. The schist in the lower 75 feet of the shaft exposes some thin beds of crystalline limestone, which contain scattered grains of scheelite. Crystals of scheelite also are sparsely distributed in the stringers. This zone does not contain more than 0.1 percent of WO_3 over a width of 3 feet.

The WO_3 content of the Cleary Hill vein is 0.1 percent or less, which may be too low to attempt recovery of scheelite even as a byproduct of gold production. The discovery of scheelite, however, in the largest lode-gold mine in the Fairbanks district suggests that scheelite may be present in many of the other lode-gold mines of the district.

LESLIE PROSPECT

The Leslie prospect is near the center of the Old Glory lode claim, on the west side of Seattle Creek about 2½ miles S. 65° W. from the summit of Pedro Dome (pl. 23). The property is reached by a poor automobile road, about 2 miles in length, which branches eastward from the Elliott Highway near the head of Fox Creek.

The bedrock at the Leslie prospect is quartz-mica schist and quartzite; but a few hundred feet to the north is a tongue of granodiorite, which is the western extension of the intrusive mass that forms the bedrock at Pedro Dome. The bedrock is metamorphosed as a result of its proximity to the intrusive, and a small dike of granodiorite crops out in the bottom of the workings. The cleavage of the metamorphic rocks strikes N. 10° E. and dips 25° E.

The development work consists of an opencut that is 20 feet long and trends east-west. In the center of this cut is a small pit. Scheelite-bearing rock is on the north, west, and south sides of this pit, but the highest grade rock is on the north side, where the ore is exposed in a face 4½ feet high. Scheelite is sparsely disseminated in the upper 2½ feet of this exposure, and the ore of higher grade is exposed in the lower 2 feet of the face.

One channel sample of the entire face of 4½ feet was taken by the Geological Survey. The analysis of this sample, in percent,[8] is given in the table below.

Tungsten trioxide (WO_3)	0. 48
Molybdenum trioxide (MoO_3)	. 005
Sulfur (S)	. 63
Phosphorus pentoxide (P_2O_5)	Tr.
Arsenic (As)	$<$. 01
Manganese oxide (Mno)	. 01
Antimony (Sb)	Tr.

EGAN PROSPECT

About 1 mile S. 30° E. of Pedro Dome, Dan Egan has made a large opencut and several small trenches just north of the Steese Highway (pl. 23). The country rock is granodiorite, which is cut by small pegmatite dikes, less than 6 inches in width, that were derived from the porphyritic granite. The dikes crosscross one another but appear to have a general westerly strike. Scheelite is sparsely distributed in small grains in the pegmatite. The deposit as a whole is extremely low grade but is of scientific interest in demonstrating the genetic relationship of the scheelite to the porphyritic granite.

MINOR OCCURRENCES OF SCHEELITE

The dumps of three additional mines, whose workings were inaccessible, were examined with an ultraviolet lamp. Scheelite occurs in the Johnson mine near the mouth of Willow Creek in the valley of Cleary Creek (pl. 23). A small amount of scheelite also was found in the gold quartz ore at the Tolovana mine, about one-half mile west of the Wackwitz mine. Scheelite also is associated with the gold quartz ore of the Rainbow mine, about one-half mile north of the confluence of Skoogy Creek with Twin Creek. Scheelite is probably a minor constituent in most of the other gold quartz veins of the district.

PLACER SCHEELITE

Scheelite has accumulated with other heavy minerals in placers derived from the areas of tungsten mineralization. It has been found in many placer concentrates in the Pedro Dome area, particularly in the valleys of Dome, Little Eldorado, Bedrock, Chatham, Cleary, and Fairbanks Creeks (pl. 23). Placer concentrates near the head of Fox Creek contained an estimated 90 percent of scheelite (Robert R.Coats, 1945, oral communication). The lodes of the Gilmore Dome and

[8] Mertie, J. B., Jr., and Overstreet, W. C., op. cit, p. 19.

Steele Creek-First Chance Creek areas also have contributed scheelite to nearby streams including Fish, Pearl, First Chance, Gilmore, Rose, and Goldstream Creeks.

The United States Smelting, Refining & Mining Co. has saved the concentrates from all the material dredged during its operations in the Fairbanks district. Two channel samples of the dump containing the concentrates were taken, one by the company and the other by the Geological Survey. The mean of these shows a content of 0.1 percent of WO_3, 2.23 percent of tin, and 0.01 percent of bismuth.

AREAS FAVORABLE FOR PROSPECTING

There remains the possibility of undiscovered scheelite-bearing lodes in the Fairbanks district. As a result of this investigation several favorable areas for prospecting can be pointed out. The essential factors favoring the existence of a potentially productive, scheelite-bearing lode are as follows:

1. A small area of porphyritic granite, which represents a truncated cupola of a larger body of porphyritic granite. During the consolidation of the granite, a fluid phase containing tungsten in solution migrated into the cupola and out into the country rock.
2. A limestone bed in the metamorphosed sequence at distances ranging from ⅛ to 1 mile from the area of porphyritic granite. In beds of gentle to moderate dip, the limestone bed must be on the downdip side of the cupola of porphyritic granite because the cupola probably conforms to the bedding and, hence, would underlie beds of the country rock on the downdip side.
3. Quartz-rich pegmatite dikes. These usually trend at nearly right angles to the contacts between porphyritic granite, country rock, and limestone.
4. Local irregularities in the structure, such as drag folds. These are not of any value as a general guide, however, until an area of scheelite-bearing rock is located. The drag folds, unfortunately, cannot be seen until considerable stripping of the overburden has been done.

In prospecting for scheelite in the Fairbanks district, the unprospected areas ⅛ to 1 mile north of the areas of porphyritic granite shown on plate 23 should be examined thoroughly. The areas on the downdip side of the porphyritic granite are more favorable, and these areas are to the north of the porphyritic granite because the regional dip is to the north. Local variations should be anticipated, however, and in those cases the downdip rule should apply. In prospecting country rock on the downdip side of the porphyritic granite areas, the logical method would be to follow either a limestone bed (commonly a series of disconnected lenses, owing to the plasticity of limestone under regional stresses), or a pegmatite dike, until the one intersected the other. At their intersection a scheelite-bearing ore body normally might be expected.

Prospecting for scheelite-bearing lodes in the Fairbanks district would be simple, if it were not for the extensive overburden. In actual practice, prospecting the country rock on the downdip side of the porphyritic granite area could be accomplished best by use of a small posthole auger with one extension, permitting a test hole 12 feet deep. Bedrock in place is reached generally within this depth on ridgetops and hillslopes. On hillslopes scheelite in the mantle could be traced to the source lode, because frost action causes the mantle, including any scheelite-bearing rock, to migrate downslope from the bedrock source. The mantle removed by the auger could be examined by means of an ultraviolet lamp. Hillsides could be covered by using a 100-foot grid spacing of holes. On flat or gently dipping surfaces near the ridgetops closer spacing of holes would be necessary. Areas around any holes yielding scheelite-bearing float could be examined more intensively with the auger until the bedrock source was located. Hand-dug or bulldozer trenches at the bedrock source then could follow the test drilling by auger. Permanently frozen ground would offer no barrier except possibly on lower slopes near valley bottoms.

The Gilmore Dome area has been prospected rather thoroughly so that there is little likelihood of any new discoveries in that vicinity. The Steele Creek-First Chance Creek area should be prospected carefully, however, as there is a fair possibility of finding undiscovered scheelite lodes north of the narrow tongue of porphyritic granite (pl. 23). In the Pedro Dome area, the country rock north of the two areas of porphyritic granite (pl. 23) should be prospected thoroughly. The area surrounding the small mass of porphyritic granite near the head of Fox Creek (pl. 23) almost certainly is mineralized with scheelite, inasmuch as placer concentrates from gold mining in that area contained 90 percent of scheelite (see p. 210). Finally the country rock surrounding any small unmapped areas of porphyritic granite should be prospected.

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