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Tungsten deposits in the Fairbanks district, Alaska

by

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This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

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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 this 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 pre-Cambrian sequence of quartz mica schist, quartzite, and associated intrusives. This sequence has been intruded by Mesozoic porphyritic granite, which is believed to have been the source of the metalliferous deposits. Tertiary granodiorite is also exposed in the district.

The scheelite deposits are segregated geographically into 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 northern 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 of WO_3 as scheelite concentrates have been produced from three inclined shafts on the Stepovich lode.

The Cleary Hill Mines Company, who operated the Stepovich mine from 1942-44, sold 1923 units of WO_3, largely as concentrates, to the Metals Reserve Company. 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 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 is believed to have been an amphibolite mass exposed in the Stepovich mine along the footwall of the lode. Surface explorations by the Bureau of Mines, United States Department of the Interior, and underground development by private operators suggest that about 7,000 tons of indicated ore containing about 3 percent of WO_3 may still be present. This tonnage, however, lies at greater depth and will be more costly to mine than ore already mined. Roughly 30,000 tons of inferred ore containing 2.25 percent of WO_3 may be present, but these figures may be widely in error.

The Colbert property and the Yellow Pup prospect on the easterly extension of the Colbert lode, are located 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. Exploration work by the Bureau of Mines on the Colbert and Yellow Pup properties has demonstrated a few hundred tons of inferred ore containing about one percent of WO_3 on each of these properties. The Schubert prospect is 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 development. Of these, the Spruce Hen is the only prospect with a single well-defined lode of scheelite-bearing silicated limestone. On the basis of rather limited sampling, several thousand tons of scheelite-bearing rock containing 0.5 percent of WO_3 may be present. The other prospects are of the quartz-pegmatite stringer type and have not been sufficiently developed to expose any amount of ore.

Gold veins containing scheelite are predominant in the Pedro Dome area, although scheelite occurrences in both metamorphosed limestone and pegmatite have been found. The Wackwitz and Mizpah gold-quartz mines have produced approximately 6 tons and 1½ tons, respectively, as a by-product 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 but has not been sufficiently developed to form the basis of a reserve estimate. 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 and is especially abundant in streams draining the lode areas. Gold dredging operations by the United States Smelting, Refining, and Mining Company up to 1942 had accumulated 484 tons of dredge concentrates, containing approximately 0.6 ton of WO_3.

The most favorable areas for scheelite prospecting are in localities of country rock on the hanging-wall side of the smaller areas of porphyritic granite, since the granite, which conforms to the regional dip, would normally underlie these areas. Pegmatites from the granite in these localities would thereby have a more favorable chance of intersection with a limestone bed. In an area of extensive overburden, as in the Fairbanks district, systematic prospecting with a small post hole auger should be undertaken.

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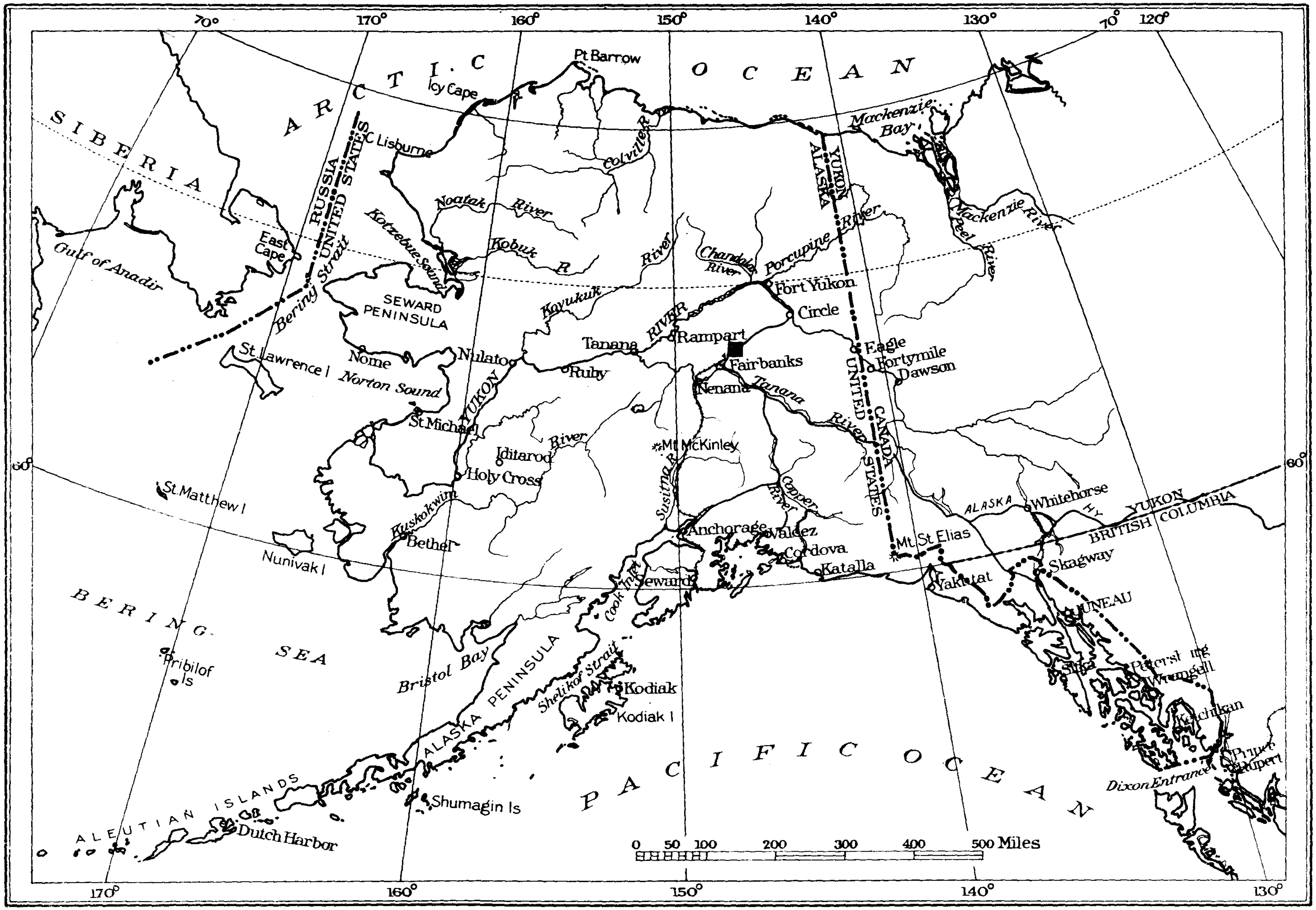

Fig. 1. Index map showing tungsten-bearing area in the Fairbanks district, Alaska

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INTRODUCTION

Location and Accessibility

Scheelite (calcium tungstate) has been found at numerous localities in the lodes and placers of the Fairbanks district, Alaska. These deposits are from 10 to 20 miles northeast of Fairbanks (see fig. 1). The Pedro Dome gold-tungsten lodes occupy the northern part of the scheelite-bearing area, and the Gilmore Dome lodes and those of the Steele Creek-First Chance Creek area lie along the southern part. The geographic relationships are shown in figure 2.

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 gravel road (see fig. 2). The distance to Fairbanks from the point where the Steese Highway leaves figure 2 on the southern border of the map area 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, Washington, by at least three different routes involving land, sea, and air transportation. The oldest-established sea-land route is via the Alaska Steamship vessels from Seattle, Washington, to Seward, Alaska, and thence to Fairbanks via the Alaska railroad. The rail distance from Seward to Fairbanks is 468 miles.

Topography and Drainage

The area of the tungsten deposits is characterized by gently-rolling mature topography having an average relief of approximately 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 in figure 2. 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. Acording to local usage, 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 up to 2,600 feet. Two of these domes--Pedro Dome in the northern part of the area, and Gilmore Dome in the southern part of the area--(see fig. 2), are approximately 2,600 feet and 2,400 feet in altitude, respectively, and are convenient topographic features to which tungsten-bearing lodes in the vicinity are referred.

Climate and Vegetation

The climate of the Fairbanks distrist is sub-Arctic with short, hot summers characterized by 16-20 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 presented in Table 1.

Table 1. Climatological data at the Fairbanks Weather Bureau station 1900-1948.

Month	Mean Temperature F	Average Precipitation (inches)	Average Snowfall (inches)
Jan.	-11.2	0.97	11.7
Feb.	- 1.6	0.49	7.2
March	9.5	0.70	8.1
April	29.2	0.28	2.7
May	46.9	0.57	0.4
June	58.3	1.30	*
July	60.1	1.92	0.0
Aug.	54.8	2.10	0.1
Sept.	43.6	1.31	0.7
Oct.	26.7	0.85	6.5
Nov.	4.1	0.72	7.4
Dec.	-7.1	0.63	8.7
Annual	26.1	11.84	53.9

* less than .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 Table 1 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 5-10°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, owing to the tendency of the cooler air to settle into the lower altitudes on still days, which are prevalent in winter. Total precipitation is greater in the tungsten area than in Fairbanks. It is estimated that possibly twice the annual precipitation occurs on the summit of Gilmore Dome, where the richest tungsten deposits are found, than at Fairbanks. Two inches of snowfall in Fairbanks in early November of 1943 were found to be represented by six inches on Gilmore Dome. Frequently, during the winter the Steese Highway becomes temporarily blocked with snow drifts in the vicinity of the pass (2,200 feet) between Pedro and Cleary creeks (see fig. 2).

Most of the ground is permanently frozen, in some places to a depth of 300 feet. Ice-filled cavities and fissures are frequently encountered in mining operations. The surface 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 the breakup may range nearly two weeks on either side of 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, quaking aspen, and white birch. The white spruce is largest and most abundant with trunks up to 2 feet in diameter. In the Fairbanks tungsten area the timber line ranges from 2,000 to 2,300 feet in altitude, and for about 200 feet below timber line the trees are stunted and do not reach their maximum size.

History of the area

The Fairbanks district became established as a mining area with the discovery of placer gold in 1902. Development work on 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 of WO_3. During the years 1915-1918 between 20 and 50 tons of scheelite concentrates containing about 65 percent of WO_3 were produced from the Gilmore Dome area. After 1918 the price dropped to less than $12.50 a unit and all development work ceased.

In 1931 minor underground development work was done on Gilmore Dome 1/,

1/ Hill, J. M., Lode deposits of the Fairbanks district: U. S. Geol. Survey Bull. 849-B, p. 157, 1933.

but no ore was produced. The Cleary Hill Mines Company began operations at Gilmore Dome in 1942 and continued mining during 1943 and the early part of 1944. As a result of these 1942-44 mining operations Cleary Hill Mines produced 2,196 units of WO_3, largely as concentrates containing over 64 percent of WO_3.

Field work

During the early period of tungsten production from 1915-18 geologists of the Geological Survey examined the tungsten deposits at Gilmore Dome and in the Steele Creek-First Chance Creek area 2/. In August and September

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2/ Brooks, A. H., and others, Mineral resources of Alaska: U. S. Geol. Survey Bull. 642, pp. 61-62, 1916.

Mertie, J. B., Jr., Lode mining in the Fairbanks district: U. S. Geol. Survey Bull. 662, pp. 418-424, 1918.

Chapin, Theodore and Harrington, George L., Mining in Fairbanks, Ruby, Hot Springs, and Tolstoi districts: U. S. Geol. Survey Bull. 692, pp. 324-327, 1919.

1942, a Geological 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. During June-September 1942 and early 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 author prepared maps of these trenches and also of the recent mine workings of the Cleary Hill Mines Company on Gilmore Dome, and continued tungsten investigations elsewhere in the district. During the summer of 1945 several days were spent on Gilmore Dome mapping Cleary Hill Mines Co. workings 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. 3/

3/ Thorne, Robert L., and others, Tungsten deposits in Alaska: U. S. Bureau of Mines Report of Investigations 4174, 51 pp., 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.

The writer gratefully acknowledges the cooperation and assistance of Mr. Ralph E. Wyer, manager of the Cleary Hill Mines Company, in connection with furnishing data on their operation of the Stepovich mine, and of Mr. L. C. Doheny, supervising engineer of the Reconstruction Finance Corporation, in connection with furnishing office facilities in Fairbanks. Mr. Louis D. Colbert and Mr. Elmer Stohl kindly 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 4/.

4/ Prindle, L. M., Katz, F. J., and Smith, P. S., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, 220 pp., 1913.

The Fairbanks tungsten-bearing area of figure 2 is entirely within a much larger area of highly metamorphosed pre-Cambrian rocks designated by earlier workers as the Birch Creek schist. According to Mertie 5/ the Birch Creek schist forms the bedrock surface of about one-fifth the country between the Yukon and Tanana rivers and is regarded as early pre-Cambrian. 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 which Mertie 6/ has assigned to 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 are commonly found in the country rock farther from the igneous border and occasionally contain scheelite. All the mineral deposits of the Fairbanks district are believed by Mertie 7/ to be derived from the Mesozoic intrusive rocks.

5/ Mertie, J. B., Jr., The Yukon-Tanana Region: U. S. Geol. Survey Bull. 872, pp. 46-59, 1937.

6/ Idem, pp. 215-216.

7/ Idem, pp. 241-242.

Rocks

Metamorphic rocks

The Birch Creek schist in the tungsten area consists largely of metamorphosed sedimentary types, of which the most common are quartz-mica schist, quartzite schist and quartzite. The quartz-mica schist contains quartz, biotite, and muscovite with 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, that 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 evident, is along the north side of the porphyritic granite in the Gilmore mineralized belt.

Igneous rocks

The metamorphic rocks have been invaded by granodiorite, porphyritic granite, and altered porphyritic dike rocks of dioritic and granitic affinities. On figure 2 each of these intrusive rocks has been shown separately.

The granodiorite at Pedro Dome is an irregular elongate body extending from the head of Moose 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 1-1/4 square miles. A smaller area of the same intrusive is about one mile SE. of Pedro Dome.

According to Prindle, Katz, and Smith 8/, the granodiorite "ranges

8/ Prindle, Katz, and Smith, op. cit., p. 68.

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 both in the Pedro Dome gold belt and in the Gilmore mineralized belt and is considered by Mertie 9/ to have

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9/ Mertie, J. B., Jr., The Yukon-Tanana Region, Alaska: U. S. Geol. Survey Bull. 872, pp. 241-243, 1937.

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given rise to the gold and tungsten mineralization. One mile southeast of Pedro Dome is a small mass of porphyritic granite. 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 $7\frac{1}{2}$ miles to the head of Pearl Creek. Over most of this distance the width varies from one-half mile to 1-3/4 miles, and the total area is about $7\frac{1}{2}$ 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 stained yellowish brown with ferruginous matter. Prindle, Katz, and Smith 10/ regard these dikes as offshoots from

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10/ Prindle, L. M., Katz, F. J., and Smith, P. S., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 73, 1913.

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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 one foot in thickness cut the Birch Creek schist north of the main stock of porphyritic granite and are clearly derived from it. Many of the same minerals are present in the pegmatite dikes as 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. Pegmatites have not been found associated with the small stocks of porphyritic granite in the northern part of the area but are doubtless present. The quartz pegmatite-dikes in general strike northwesterly and dip steeply northeast. The intersections of these dikes with beds of crystalline limestone have formed small pods of scheelite-bearing silicated limestone or skarn rock. 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 the limestone beds.

Structure

No detailed structural 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 those that are exposed indicate the probability of slumping. The generalized statements of Prindle, Katz, and Smith 11/ published in 1913 are the most recent available on the general structure of the Birch Creek schist within the Fairbanks district.

11/ Idem, pp. 75-76.

The Birch Creek schist is probably tightly folded, as the dip of the bedding is in most places nearly parallel to that of 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 and in a few places reversals of dip occur, owing to minor drag folding. 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 belt of gold-scheelite mineralization is extremely complex and has not yet been deciphered. The general strike of the schist is about N. 75° E., but low dips both northerly and southerly are present. The structure is further complicated by an intricate network of faults and veins. According to James M. Hill 12/, who examined many gold lode properties

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12/ Hill, James M., Lode deposits of the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 849-B, p. 84, 1931.

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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, inasmuch as the attitude of the contact between them parallels that of the schist. The east-northeasterly extension of the bedrock surfaces of nearly all the intrusive rocks shown in figure 2 suggests that the dominant structural control in their emplacement was the foliation of the Birch Creek schist.

TUNGSTEN DEPOSITS

Lode tungsten deposits, containing scheelite as the tungsten mineral, occur in 3 main areas: the Gilmore Dome area, the ridge between Steele Creek and First Chance Creeks, designated in this report as the Steele Creek-First Chance Creek area, and the Pedro Dome area (see figure 2). 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 constitutent in the gold-quartz veins and hence is only recoverable as a by-product of gold mining.

The available evidence indicates that the tungsten metallization was derived from the porphyritic granite, because the pegmatite dikes associated with the scheelite deposits contain the same accessory minerals as are present in the porphyritic granite. Scheelite occurs in the pegmatites near crystalline limestone beds intercalated within the schist. The crystalline limestone is generally the 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, it appears that the primary control of the tungsten deposits is the intersection of a mineralized fissure with a calcareous bed. Near the porphyritic granite rich scheelite deposits occur as replacements of limestone beds, at the places where the pegmatite dikes cut the limestone beds, farther from the granite the gold-quartz veins generally contain small low-grade scheelite bodies only where limestone or calcareous beds are intersected.

Scheelite has been found in the placer concentrates at many places in the Fairbanks district. In the Gilmore Dome area it has been found in the placers of Fish, Pearl, and Gilmore creeks. In the Steele Creek-First Chance Creek area it has been found in the gravels of Rose, First Chance, and Goldstream creeks and undoubtedly is present in the gravels of Steele and Engineer creeks. In the Pedro Dome area scheelite has been found in 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, but no scheelite-bearing lodes have yet been identified in this area.

Gilmore Dome area

The Gilmore Dome area is 14 miles northeast of Fairbanks and situated at the eastern end of the main mass of porphyritic granite. It can be reached by either of two automobile roads, each about six miles in length, which join the Steese Highway near the 13 mile and 20 mile posts out of Fairbanks (see fig. 2). 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 Company 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, discovered by Albert Johnson in 1915. Since 1942 several other scheelite deposits have been discovered in the area. These are on the Colbert lode, the Yellow Pup (Stohl et al) prospect, and the Schubert prospect. Figure 3 shows patented and unpatented claims and the ownership of each for the Stepovich, Colbert, and Yellow Pup properties; figure 4 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 have been 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 degrees north. The Stepovich and Colbert lodes lie about 0.4 mile and 0.2 mile, respectively, north of the main body of porphyritic granite and about 0.7 mile and 0.9 mile south of the outlying cupola of the same granite (see fig. 2). The two surface exposures of porphyritic granite may be connected beneath Gilmore Dome.

The Yellow Pup prospect is located 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 figures 3 and 4, lies to the southwest of the Colbert claims and is probably staked on a small lens of scheelite-bearing, silicated schist.

The properties in the Gilmore Dome area are described in greater detail under separate headings that follow:

Stepovich lode

By far the most development work on tungsten properties at Gilmore Dome has been on the Stepovich lode, and for that reason it will be described in greater detail than the other deposits. Since its discovery in 1915 about 2,000 feet of underground development 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 in figure 5. During the period 1915-1918 two inclined shafts, about 325 feet apart on two adjoining properties 14/, were driven northward down the dip of the lode at an angle of about 30 degrees (see figures 4 & 5). These shafts are now caved. Shortly after World War I, Michael Stepovich, Sr., acquired both properties and patented seven claims (see fig. 3). A 170-foot adit was driven by Stepovich in 1931 but 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 two older shafts with drifts at approximately 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 on account of the low angle of the dip of the lode. An adit was driven in 1943 to intersect the east end of the drift on the "150 level" (see fig. 5). 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 Michael Stepovich, Sr., in the latter part of 1944, the property has been owned by his two sons.

14/ Mertie, J. B., Jr., Lode mining in the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 662-H, pp. 418-21, 1917.

From July to October 1943 the Bureau of Mines dug twenty-four bulldozer trenches on the Stepovich lode to determine the extent and grade of the ore. These trenches are shown in figures 5 and 6. Trench no. 3 is not shown, because it is covered by the dump from the 1943 tunnel.

Rocks. -- The chief rock units comprising 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 in figures 5 and 6. The silicated rock includes both silicated mica schist and a small amount of granular scheelite-bearing rock, not containing sufficient scheelite to be classed as ore.

The crystalline limestone occurs as discontinuous, irregular bodies along the same stratigraphic horizon in the schist and has determined the site of mineralization. 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 Company.

The granular scheelite ore forms irregular lenses, which replace crystalline limestone. The ore consists of a granular aggregate of minerals typical of contact-metamorphic deposits. The scheelite ore contains predominantly 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 meliphanite was further confirmed when beryllium was detected spectographically in the ore.

Some scheelite-bearing quartz pegmatite occurs as parallel stringers with the lode and is actually gradational with the granular scheelite ore. Where these quartz pegmatites intersect the lode their strike is N. 40°- 60° W. and their dip about 60° NE. As pointed out in a previous section (see p. 9), these pegmatites were derived from the porphyritic granite, shortly after its emplacement.

The silicated mica schist is a dense-textured, thin-bedded rock with beds ranging from one-half to 1 inch thick. 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 generally found in the hanging-wall above the ore and generally requires timbering to prevent its collapse on account of weakness inherent from its thin-bedded character.

Two other rock types, green amphibolite and silicified schist, occur in the vicinity of the lode. Near the Cleary Hill Mines shaft green amphibolite in the form of lenticular intrusive bodies forms the footwall of the lode. One of these bodies is exposed in the shaft below the "50 level" where it is at least 20 feet thick (see fig. 5). 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 comprising the Stepovich lode averages about N. 70° E. and about 35 degrees northwest, respectively. Variations in the strike, caused by "rolls" or secondary flexures, range from N. 15° E. in the Cleary Hill Mines adit (fig. 5) to S. 50° E. (N. 50° W.) in the face of the west drift on "150 level " (fig. 5). Variations in the dip are largely the result of drag folding along the crystalline limestone. Dips ranging from 70° northwest through horizontal to 15° southeast have been recorded. A major drag fold is found in the main shaft workings of the Stepovich mine; its crest line and trough, indicated by the appropriate symbols on Figure 5, 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 southwestern limit of the drag fold is beyond the limits of the mine workings. This drag fold is believed to have been localized by the association of less incompetent limestone of the lode with the more competent sill-like intrusive of amphibolite in the footwall (sections AA' and DD', fig. 5).

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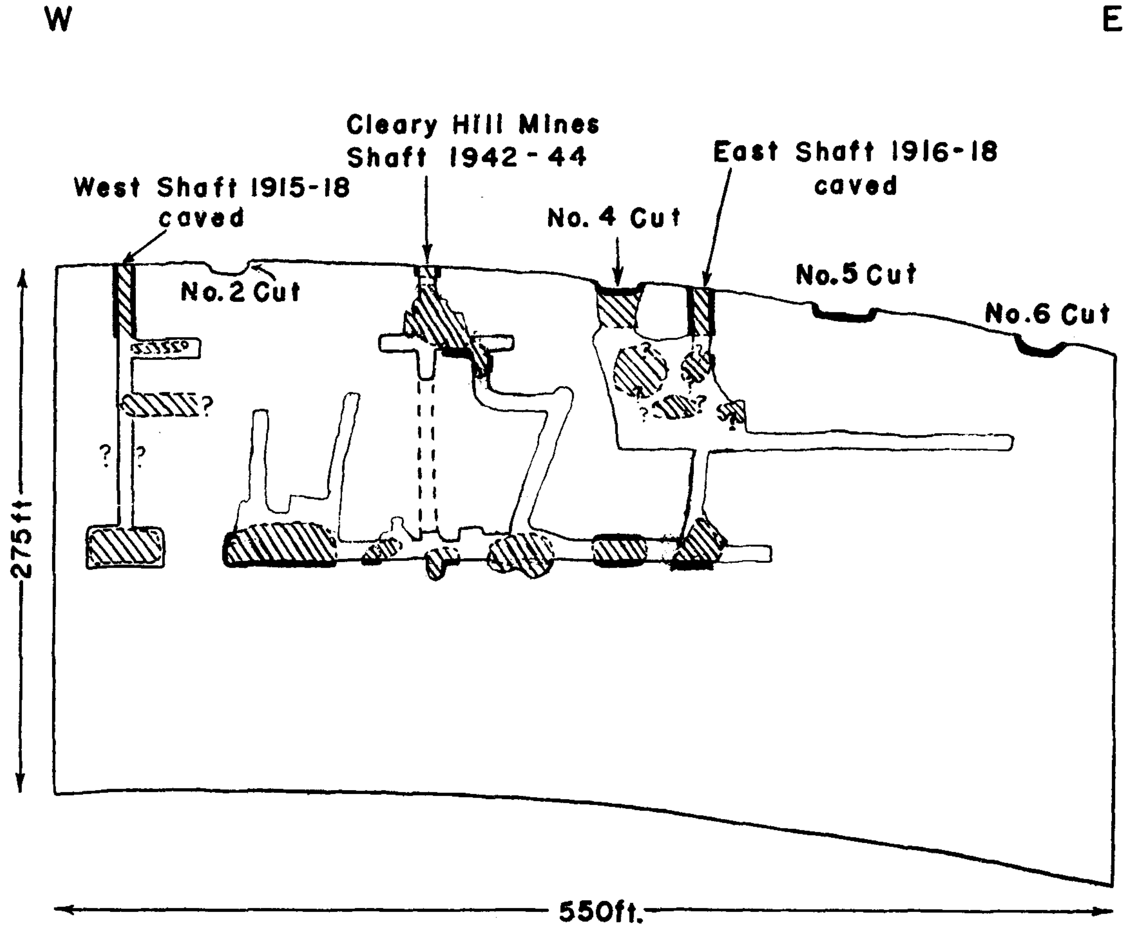

EXPLANATION

II

Ore reported or observed in workings

Ore mined out

Fig. 7: Block containing indicated ore in Stepovich lode projected on plane parallel to lode.

The lode has been cut by several northerly striking faults, dipping steeply northeast. The direction of movement could not be determined along the faults except as inferred from the shift of the trace of the lode on the mine levels or ground surface. The displacement of the lode, horizontally, along the major faults ranged from about 10 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 trench 24, the shift has been progressively southward (see fig. 4). Some of the faults are inferred by offsets in the lode between adjacent trenches where the lode is exposed.

Groundwater leaching of scheelite.--In the zone of weathering, which rarely exceeds 10 feet in depth, the ore is a spongy brownish-black material. The grade of this ore appears to be significantly reduced by the solution of scheelite, the effects of which produce etched and pitted grains of scheelite. This phenomenon is confined chiefly to the Stepovich lode near the top of Gilmore Dome, where mechanical erosion is practically non-existent. Scheelite is slightly soluble in water (0.2-0.3 grams per 100) so that solution of scheelite in a porus weathered zone could take place over a sufficiently long period of time. This effect can hardly be neglected in any appraisal of the lode based only on surface exposures. Fortunately, sufficient underground development on which to base reserve estimates has been done on the lode.

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 Company.

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 development in workings extending from the Cleary Hill Mines shaft has been on granular ore approximately 1½ feet in thickness. Several pegmatitic quartz veins intersect the lode at the shaft, which apparently has been sunk on the richest ore shoot (section A-A', fig. 5). 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 (fig. 5) also passed through ore (fig. 7). According to Mertie 15/

15/ Mertie, J. B., Jr., op. cit. 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 in figure 5 were done after Mertie's visit in 1916. The outlines of these older workings were obtained from the Cleary Hill Mines Company, whose workings early in 1944 intersected the World War I workings.

The caved west shaft also passed downward through a number of ore shoots (see fig. 7). Chapin reported in 1917 16/ that

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16/ Chapin, Theodore, and Harrington, G. L., Mining in Fairbanks, Ruby, Hot Springs, and Tolstoi districts, Alaska: U. S. Geol. Survey Bull. 692-F, pp. 325-326, 1919.

> "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."

Chapin apparently did not consider that the quartz-scheelite veinlets might have been feeders of the ore shoots in the replaced rock, as deduced from this writer's observations in Cleary Hill Mines workings. From Chapin's description it appears that these scheelite ore shoots are similar to those in the Cleary Hill Mines shaft. The lode in trenches 1 and 2, (see figs. 4 and 5) however, at points 70 feet west and 40 feet east of this old 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 lode, it 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 (figs. 4 and 6) exposed 15 inches and 8 inches respectively of black, friable, weathered material containing sparse grains of scheelite, together with one small specimen of unweathered granular ore containing an estimated 2 percent of WO_3. Most of the scheelite originally present in this weathered material probably has been removed by ground water leaching. The Stepovich lode could not be positively identified in any trenches west of trench 13a, although three silicated zones containing sparse scheelite are recognized in trenches 14-18 (figs. 4 and 6).

A pit in Cleary Hill Mines trench 8, which is 550 feet northeast of the shaft, has partly exposed an ore shoot (fig. 6) which has the form of a drag fold. The exposed part of the shoot has a nearly horizontal attitude and the top side of the shoot is in the residual mantle. This shoot is believed to be comparable in size to the major ore shoots in the lode and hence may extend as much as 50 feet west of the pit in which it is exposed.

Shallow underground development work on the lode in the 1943 adit (figs. 4 and 5) exposed 3 small shoots (see fig. 5) 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 (see fig. 5). The lode is unexposed for 80 feet east of the portal of the 1943 adit.

Trenches 4, 5, 6, 7, 8, 9, and 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 (see figs. 4 and 6). 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 (see figs. 4 and 6). Two ore shoots and two small lenses of scheelite-bearing rock have been exposed in the bottom of the 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 (see fig. 6) of about 15 feet displacement. The other shoot is exposed in trenches 6 and 20 for a distance of 70 feet (fig. 6) and has an average width of slightly over 2 feet. The dip of this high-grade shoot ranges from horizontal to 30 degrees 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, fig. 6). 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 (see figs. 4 and 6). 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 (see fig. 6). In trench 22 and other nearby trenches the schist and the lode have been weathered and limonitized 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 (see fig. 4) 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 (see section A-A'; fig. 5; trenches 13 and 14, fig. 6). 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.

Dump from 4 pits, 1,050 to 1,200 feet east of trench 24, the easternmost trench exploring the lode, consists chiefly of garnetized rock with sparse scheelite (see fig. 4).

Localization of ore shoots.--Two main factors that are believed to have localized the ore shoots of granular ore in the Stepovich lode are 1) 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 2) the introduction of tungsten-bearing solutions through the fissures 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 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 as the granular ore shoots appear to "mushroom" around the zone of intersection.

A primary 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 was probably the presence of green amphibolite. 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 rigid brittle amphibolite first caused greater concentration of the limestone at the loci of minor flexures during periods of stress and later shattered more than the surrounding schist thus permitting influx of tungsten-bearing pegmatitic solutions. At any rate 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 17/, a magnetic anomaly readily detectible by

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17/ Joesting, H. R., and Anderson, Eskil, Preliminary report on scheelite deposits in the Fairbanks district: Alaska Terr. Dept. Mines files.

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magnetometer survey, is associated with the amphibolite.

Production and reserves.--During the years 1915-18 between 20 and 50 tons of scheelite concentrates containing about 65 percent of WO_3 were produced. The crude ore is reported to have contained about 2 percent of recoverable WO_3.

Table 2.

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

Year	Type	Tonnage	Grade percent	Units of WO_3
1942	ore	60.084	4.55	273.382
1943	concentrates	9.170	68.39	627.136
1944	concentrates	17.288	64.27	1111.099
1944	middlings	11.869	15.56	184.681
Totals:	ore	60.084		273.3
	middlings and concentrates	38.327		1922.8

The World War I production came from the two caved shafts to the east and west of the Cleary Hill Mines shaft (fig. 5). No data are available as to 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 comprised ore, middling concentrates and table concentrates and is summarized in Table 2. 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.

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 Assay office at Fairbanks, Alaska. The location, width, and tenor of all channel samples taken of the Stepovich lode are shown in figures 5 and 6. The analyses of nine channel samples taken from the upper part of Cleary Hill Mines shaft are also shown in figure 5.

The 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 one percent; therefore 5 percent of WO_3 probably is a more accurate estimate of the average tenor of any large tonnage of this ore. Mined ore does not contain 5.0 percent of WO_3, owing to an admixture of the barren silicated schist from the hanging-wall.

Ore and waste dumps as mined were sampled to determine their grade. The high-grade ore mined in 1942 from the first 50 feet of the Cleary Hill Mines shaft contained 4.55 percent of WO_3. A composite grab sample taken from the surface of the ore dump from the "150 level" was analyzed in the Chemical Laboratory of the Geological Survey and found to contain 3.21 percent of WO_3. Some ore is lost in blasting the waste rock prior to removing the ore. A composite grab sample of the fine material (below $\frac{1}{2}$ 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 ten tons of ore mined from the first 110 feet of the 1943 adit contained 0.59 percent of WO_3. An average of the two large ore shoots exposed in trench 20 (see fig. 6) 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 0.10 percent. The maximum content of phosphorus allowed by the Metals Reserve Company without penalty is 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 present 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 18/, the phosphorus

18/ Thorne, R. L. and others, Tungsten deposits in Alaska: U. S. Bur. Mines Rept. Investigations No. 4174, pp. 17-22, 1948.

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 seven ore samples for minor constituents are given in Table 3.

Table 3.

Minor constituents (in percent) in ore from the Stepovich Lode 1/

Sample Number	WO_3	MoO_3	S	P_2O_5	As	MnO	Sb	Bo	Sn
42AMt117	5.64	0.015	0.04	0.27	0.01	0.11	trace	-----	-----
42AMt157	0.51	.015	.07	.73	.007	1.08	trace	trace	-----
42AMt206	23.49	.015	.23	.27	.01	.05	trace	trace	trace
42AMt297	2.50	.02	.10	.17	<.01	.09	trace	-----	-----
42A013	1.84	.02	.14	.21	.02	.55	trace	trace	-----
42A057	9.49	.06	.09	.12	<.01	.21	trace	-----	-----
42AK111	1.37	.02	.17	.28	<.01	.84	trace	trace	-----
Arithmetic mean	6.41 2/	.024	.12	.29	± .01	.42			

1/ Mertie, J. B., Jr., and Overstreet, Wm. C., Tungsten Deposits of the Fairbanks District, Alaska: U. S. Geol. Survey unpublished war minerals investigations report, 1942-43.

2/ Ore mined to end of 1942 reported to have mean tenor of 4.58% WO_3.
117. West wall of inclined shaft, 23 feet from surface. First ore shoot.
157. Open cut No. 5, about 200 feet east of the portal to inclined shaft.
206. West wall of inclined shaft, 38½ feet from surface. Second ore shoot.
297. Face of east drift, 19 feet from inclined shaft.
13. Open cut No. 4, about 100 feet east of the portal of inclined shaft.
57. North wall of east drift, 10 feet from inclined shaft.
11. Open cut No. 6, about 350 feet east of the portal to inclined shaft.

The last three elements in the foregoing table were identified spectographically. Spectrographic analyses also were made for copper, lead, bismuth, zinc, silver, cerium and thorium, but none of these metals was detected.

The irregular size, shape, and distribution of the ore shoots render highly speculative any estimate of ore reserves. Hence, the ore reserves of the Johnson-Stepovich lode belong in the categories of indicated and inferred ore.

Two methods are used in determining the tonnage of indicated ore, and they give essentially the same result. The first method is based on the abundance of ore now or formerly present in the workings of the two original shafts and the Cleary Hill Mines shaft (see fig. 7). The second method is based on actual production from essentially a known volume of the workings in the lode.

The portion of the lode considered to contain the indicated ore extends 200 feet west and 350 feet east of the Cleary Hill Mines inclined shaft, and 275 feet down the dip (see fig. 7). In both methods the tonnage of indicated ore is derived by reducing calculations to a WO_3-unit basis.

In the first method one-half the block is considered to be ore as an initial approximation, because about one-half of the mining and development work has been in ore (see fig. 7), which was recovered by selective mining. On the basis of sampling the average width of the ore shoots is 1.5 feet; hence, using a volume-tonnage conversion factor of 12, 9,450 tons of ore containing 5 percent of WO_3 may have been present—equivalent to 47,000 units of WO_3. But with roughly 2,500 units mined in World War I and 2,000 in World War II, about 4,500 units of WO_3 have been mined out, leaving 42,500 units as reserves. The shaft of the Cleary Hill Mines Co. however, was started on the best exposure of ore, and the old World War I shafts likewise began on ore shoots. Therefore, because the ore shoots probably are not so abundant in other parts of the lode as in the shafts, the figure of 42,500 units is reduced by one-half; hence, about 21,250 units of WO_3 are indicated in the lode. On the basis of actual mining experience the grade of the ore mined has been about 3 percent so that 7,000 tons of ore of this grade are indicated.

According to the second method, the indicated ore is computed from the following proportionality:

$$\frac{Am}{Au} = \frac{(WO_3)m}{(WO_3)u}$$

Where Am and Au are projection areas of the workings and of the unmined part of the lode, respectively, upon the same surface as the block containing indicated ore (fig. 7), and $(WO_3)m$ and $(WO_3)u$ are units of WO_3, mined and unmined (indicated ore), respectively, in the block. The projection area of the workings, Am, is approximately 14,000 square feet. The projection area of the unmined part of the block, Au, is the difference between the total projection area of the block and that of the workings, Am, and is approximately 137,000 square feet. An approximate total of 4,500 units of WO_3 has been produced since 1915 from workings with a projection area, Am, of 14,000 square feet so that the total unmined units of WO_3 in the lode having projection area, Au, equals 44,000.

Again, as in the first method, this figure is reduced by half, because the mine workings naturally tend to coincide with the ore, so that 22,000 units of WO_3 or 7,000 tons containing 3 percent of WO_3 constitute the indicated ore--a remarkably close check with the first method.

Obviously, the greatest subjective factor in arriving at the tonnage of indicated ore is the one-half--the so-called "lenticularity factor". This factor could be assumed as unity if mine workings were randomly driven through the lode or were driven according to a grid pattern. But mining operations almost always stop after having mined what ore was in sight so that such a sample of the lode based on production records is, in essence, "salted". Finally, the indicated ore, roughly 7,000 tons containing 3 percent of WO_3, lies deeper and will therefore be considerably more costly to mine than what has been mined already.

The inferred ore in the Stepovich lode extends 500 feet west and 1,100 feet east of the shaft and 800 feet down the dip of the lode, but excludes the ground containing the indicated ore. The body of rock containing the inferred ore has an estimated ore content of one-fifth the total volume, based on the ratio of ore to gangue in the 1943 adit and in the trenches outside the zone of indicated ore. The average width and grade of the inferred ore, as measured in the two ore shoots exposed in the pits of trench 20, are 1.6 feet and 2.25 percent of WO_3. Therefore, using a tonnage conversion factor of 12, the Stepovich lode contains 30,000 tons of inferred ore having a WO_3 content of 2.25 percent. This estimate, however, is based on few data, considering the large volume of rock involved, and hence may be widely in error.

Colbert lode

Fourteen claims have been located on and near the Colbert lode (see fig. 3) and were under option to the Cleary Hill Mines Co. during 1943. The discovery pit, which contains the westernmost exposure of the lode, is located 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 (see fig. 4).

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 (see fig. 8). The Colbert lode is much lower grade than the Stepovich lode, 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 (see fig. 2).

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, and nowhere was observed to contain scheelite. The silicated limestone, is crystalline and consists predominantly of calcite, quartz, chlorite, and scheelite with a few grains of oligoclase and sphene. This rock in part constitutes the ore shoots in the lode.

Scheelite occurs abundantly in three known ore shoots and in many widely spaced small pockets of silicated limestone whose maximum dimensions are generally less than one foot. Scheelite is also present as scattered grains in zones up to 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 (see fig. 8). 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 (see fig. 8), although the ore may not be continuous between the two pits. The third ore shoot is exposed in trenches 10 and 14 and has a length of 20 feet and a maximum width of 2 feet (see fig. 8). 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 three samples taken by the Geological Survey on the Colbert lode are shown in figure 8. The sample taken by the Geological Survey in the Colbert discovery trench (see fig. 8) also was analyzed for several constitutents other than tungsten. The analysis is presented in Table 4.

Table 4.

Chemical analysis (in percent) of minor constituents in ore from Colbert discovery trench 1/

Molybdenum trioxide	MoO_3	0.005 percent
Sulfur	S	0.06 percent
Phosphorus pentoxide	P_2O_5	0.23 percent
Arsenic	As	less than 0.01 percent
Manganese oxide	MnO	0.51 percent
Antimony	Sb	trace
Tin	Sn	trace
Copper	Cu	nil
Lead	Pb	nil
Bismuth	Bi	nil

1/ Mertie, J. B., Jr., and Overstreet, Wm. C., Tungsten Deposits of the Fairbanks District, Alaska: U. S. Geol. Survey Unpublished War Mineral investigations report, 1942-43.

The reserves of the Colbert lode amount to a few hundred tons of inferred ore which are contained in three small shoots (p.23). The average tenor of the three shoots is 1.3 percent of WO_3 across an average width of 1.6 feet.

Yellow Pup prospect

A scheelite zone in a vertical cut 10 feet high was uncovered by Elmer Stohl, William Birklid, and M. S. Anderson in the valley floor of Yellow Pup Creek (see fig. 4). This is the discovery cut of the Marie No. 2 claim. Several other claims have been staked adjacent to the Marie No. 2 (see fig. 3). 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 and 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 open-cut was sampled by the Geological Survey party, and was 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 (see fig. 4), 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 would also lie on an extension of the Colbert lode. Three bulldozer trenches (not shown fig. 4) were excavated in September 1944 at the site of the Murray and Savage pits by the U. S. Bureau of Mines 19/ to explore the lode on the Yellow Pup prospect. These

19/ Thorne, Robert L. and others, Tungsten deposits in Alaska: U. S. Bur. Mines R. I. 4174, Fig. 5, 1948.

bulldozer trenches exposed three small easterly-trending scheelite-ore shoots west of the discovery cut and similar to those in the Colbert lode.

Although the lodes on the Yellow Pup prospect have not been explored as thoroughly as the Colbert lode, the sporadic distribution and apparent small size of the visible ore shoots probably would limit the reserves to a few hundred tons of inferred ore containing about one percent of WO_3.

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 (see fig. 2). 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:

porphyritic granite	20 feet
glassy quartz	½ foot
hornfelsic mica schist	7½ feet
scheelite-bearing silicated limestone and limestone	7 feet

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 area

Several occurrences of scheelite are located on a ridge between the heads of Steele and First Chance creeks (see fig. 2) 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 Gilmore road turn-off.

All the tungsten prospects in the Steele Creek-First Chance Creek area were examined by Mertie 20/ in 1916 and Chapin 21/ in 1917. The descriptions

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20/ Mertie, J. B., Jr., Lode mining in the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 662-H, pp. 422-24, 1917.

21/ Chapin, Theodore, and Harrington, George L., Mining in Fairbanks, Ruby, Hot Springs, and Tolstoi districts, Alaska: U. S. Geol. Survey Bull. 692-F, pp. 326-27, 1919.

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following and those of the individual prospects are based largely upon these earlier descriptions, inasmuch as most of the workings were caved at the time of the writer's examination 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 groups of claims, 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 two or three years but these workings are now caved (see fig. 9). Only minor development was done on the Tungsten Hill claim, for which reason these workings are not shown in figure 9. Development work 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 invaded by the large mass of porphyritic granite (fig. 2). 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 (fig. 9). Old development work at the Spruce Hen group of claims consisted of two shafts and a number of 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). More than one lode appears to be present, but, owing to lack of exposures, it could not be determined whether there are two parallel lodes or several arranged en echelon (see inset, fig 9). The scheelite lode is exposed in only one pit and one 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 of 30 degrees 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 (see inset, fig. 9). 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, meta-igneous rock consisting chiefly of hornblende. Some of these blocks contain high-grade concentrations of scheelite in zones up to 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 one ore dump sample from the Spruce Hen lode are shown in the inset of figure 9. 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 22/. The four samples of the lode in place averaged 0.44

22/ Joesting, H. R., personal communication

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percent of WO_3. This average is reduced by the sample containing 0.16 percent of WO_3 and hence is probably too low. On the basis of the writer's examination of the lode with an ultraviolet lamp, it is believed that a more representative average grade is attained by a weighted average of the three higher analyses. The two analyses of the samples containing 0.46 and 0.73 percent of WO_3 are averaged together as one analysis because they came from the same pit. This average analysis and the analysis of the sample from the adjacent trench are then averaged together giving a weighted average grade of 0.5 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 analyses are shown in Table 5.

Table 5

Analysis (in percent) of two samples from Spruce Hen prospect for constituents other than WO_3 1/

		lode	ore dump
Beryllium oxide	BeO	trace	none found
Manganese oxide	MnO	0.87	0.67
Phosphorus pentoxide	P_2O_5	trace	trace
Molybdenum trioxide	MoO_3	0.005	0.005
Antimony	Sb	trace	trace
Arsenic	As	<0.01	<0.01
Sulfur	S	0.54	0.10

1/ Mertie, J. B., Jr., and Overstreet, Wm. C., Tungsten Deposits of the Fairbanks District, Alaska: U. S. Geol. Survey Unpublished war minerals investigation report, 1942-43.

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 (fig. 9). Workings on the Blossom group of claims in 1943 consisted of an inclined shaft, ten trenches, and nine small prospect pits. Five hundred feet southeast from these workings, near the top of the ridge, are two trenches, an inclined shaft, and two prospect pits (fig. 9). 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 degrees. 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 half an inch to 3 inches thick, penetrate the quartz-biotite schist and the porphyritic granite. Scheelite is also developed in the schist in quarter-inch zones along the contacts with quartz veinlets. Some of the quartz veinlets contain about 25 percent of scheelite, but they are less than a 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. It would appear 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 (see fig. 9). 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 this ore dump may have come from the inclined shaft. Analyses of these samples are presented in Table 6.

Table 6.

Analyses (in percent) of samples taken in 1942 from ore dumps on Blossom prospect 1/

		No. 51		No. 264
Tungsten trioxide	WO_3	2.02		1.44
Manganese oxide	MnO	0.12		0.01
Phosphorus pentoxide	P_2O_5	0.45		0.13
Molybdenum trioxide	MoO_3	0.01		0.005
Antimony	Sb	trace		trace
Arsenic	As	0.02	less than	0.01
Sulfur	S	0.07		0.06

1/ Mertie, J. B., Jr., and Overstreet, Wm. C., Tungsten Deposits of the Fairbanks District, Alaska: U. S. Geol. Survey Unpublished War Minerals investigation report, 1942-43.

51. Tungsten Hill, about 2-1/8 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 2-1/8 miles S. 6° E. from junction of Gilmore and Pedro Creeks. 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. Apparently, between the time of sampling in the summer of 1942 and the author's examination with ultraviolet lamp in late August 1943, the ore dumps of the Blossom prospect had been stripped of the better grade ore. Only specimens containing sparse grains of scheelite could be found by the author on the Blossom prospect and none of these specimens could have contained over a few tenths of a percent of WO_3.

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.

The higher tungsten 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. Without additional work, no appreciable tonnage of inferred ore can be considered to be present.

Tanana prospect

The Tanana prospect is located in Tungsten Gulch, a tributary to First Chance Creek (fig. 9), at an altitude of approximately 1,450 feet. Workings visible in 1942 and 1943 included a caved shaft and several small prospect pits. These openings gave little information, for they had become filled with slope wash and had become overgrown with vegetation.

Mertie 23/, who examined the prospect in 1916 when the workings were accessible, wrote the following description:

23/ Mertie, J. B., Jr., Lode Mining in the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 662-H, p. 422, 1917.

> ..."The country rock on this claim is 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 group of claims was located in 1916 on the southwest side of Tungsten Gulch opposite the Tanana claims. No workings are shown on figure 9, because the few prospect pits dug in 1916 had been completely obliterated by the time of Mr. Mertie's and the author's visits in 1942 and 1943, respectively. The pits on the Tungsten Hill prospect were examined in 1916 by Mr. Mertie 24/, however, who is quoted below:

> "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."

24/ Mertie, J. B., Jr., Lode mining in the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 662-H, p. 424, 1917.

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 (see fig. 9) and consisted in 1943 of two adits, four trenches, a prospect pit, and two shafts, all caved. In 1916, the upper adit was driven 80 feet along a three-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 (see fig. 2), 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 closely associated in the Wackwitz, Cleary Hill, and other gold mines. The contact metamorphic and pegmatite types are found on the Leslie and Egan prospects, respectively.

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 (see fig. 2). 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.

The principal development work at the Wackwitz mine consists of three adits driven eastward into the hill on different levels. The country rock is quartz mica schist, quartzite, and minor limestone which 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 northerly 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, 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 northerly 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 at the time of the writer's visit in 1943.

Scheelite is rare in all the veins exposed east of the fault. West of the fault, the Wyoming vein is estimated by the Wackwitz brothers to have yielded about 6 tons of scheelite concentrates 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 WO_3. In a sublevel above the same drift, a small, high-grade ore shoot, formed by replacement of fine-grained limestone, measured 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, No. 230, is a sample of the scheelite ore dump at the portal of the lower adit. This material was taken entirely from the Wyoming vein, but as the tenor of this vein is variable, the sample should represent the average tenor of No. 5 vein. Samples No. 231 and No. 232 were taken from the Wyoming vein where exposed in the back of the drift on the lowest level. The analyses of these samples are presented in Table 7.

Table 7.

Analyses (in percent) of scheelite ores from Wackwitz mine 1/

		Sample no.		
		230	231	232
Tungsten trioxide	WO_3	0.28	.69	1.64
Molybdenum trioxide	MoO_3	0.005	.005	.005
Manganese oxide	MnO	0.11	.01	.07
Phosphorus pentoxide	P_2O_5	0.28	trace	.26
Arsenic	As	0.80	.70	.61
Sulfur	S	0.06	.26	.22

1/ Mertie, J. B., Jr., and Overstreet, Wm. C., Tungsten Deposits of the Fairbanks District, Alaska: U. S. Geol. Survey, Unpublished War Minerals investigations report, 1942-43.

230. Dump ore at portal of mine. This ore was mined from No. 5 vein.
231. Sample taken from face in No. 4 vein.
232. Sample taken from face in No. 5 vein.

No copper, bismuth or tin was found in these samples, but by spectographic tests, traces of antimony were found in all three samples, and a trace of beryllium was found in No. 232.

The tenor of the no. 5 vein is so low that tungsten can be recovered only as a by-product of gold mining.

Reserves are limited to a few thousand tons of inferred ore containing an average of about 0.3 percent of WO_3.

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, of the north side of Fairbanks Creek, west on Too-Much-Gold Creek (see fig 2). The workings on this property were caved and inaccessible in 1942, but were described earlier by Mertie 25/:

25/ Mertie, J. B., Jr., Lode mining in the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 662-H, p. 421, 1917.

> "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."

One and a half tons of scheelite concentrates, averaging 50 percent of WO_3, were recovered in 1916 from the 6-inch gold quartz vein. 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 the bottom of Chatham Creek (see fig. 2). Nearly all the Cleary Hill mine production has been gold ore, but a few tens of tons of antimony ore also have been recovered. Adits have been driven on the Cleary Hill vein at 3 levels: the uppermost adit or No. 1, 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 one-eighth inch seams in the wall rock of the gold quartz vein for 300 feet along the 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 one 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 one foot. The wall rock contains thin limestone beds in that 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 No. 4 level the crystals are developed a foot from a gold quartz vein which contains no scheelite. On the No. 6 level the gold ore contains grains of scheelite in a few places.

On the west side of Chatham Creek valley, about three-eighths of a 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 limonitized 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 are also 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 probably is too low to attempt recovery of scheelite in connection with gold production. The discovery of scheelite, however, in the largest gold lode mine in the Fairbanks district suggests that scheelite is probably present in most of the other gold lode 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 (see fig. 2). The property is reached by a poor automobile road, about 2 miles in length, which branches near the head of Fox Creek from the Fairbanks-Livengood road.

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 scheelite, however, by analogy to other properties in the district, is believed to have been introduced by solutions emanating from the porphyric granite, which probably lies at slight depth beneath this prospect. The cleavage of the metamorphic rocks strikes N. 10° E. and dips 25° E.

The development work consists of an open cut 20 feet long that 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.

Ore channel sample of the entire face of 4½ feet was taken by the Geological Survey. The analysis of this sample is shown in Table 8.

Table 8.

Analysis (in percent) of scheelite ore from the Leslie prospect 1/

Tungsten trioxide	WO_3		0.48
Molybdenum trioxide	MoO_3		0.005
Sulfur	S		0.63
Phosphorus pentoxide	P_2O_5		trace
Arsenic	As	less than	0.01
Manganese oxide	MnO		0.01
Antimony	Sb		trace

1/ Mertie, J. B., Jr., and Overstreet, Wm. C., Tungsten Deposits of the Fairbanks district, Alaska, Alaska: U. S. Geol. Survey, Unpublished War Minerals investigation report, 1942-43.

On the basis of present knowledge, no estimate can be made of the size of this ore body.

Egan prospect

About a mile S. 30° E. of Pedro Dome, Dan Egan has made a large open-cut and several small trenches just north of the Steese Highway (see fig. 2). The country rock is granodiorite, which is cut by small pegmatite dikes, less than 6 inches in width, derived from the porphyritic granite. The dikes criss-cross 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 (see fig. 2). A small amount of scheelite also was found in the gold-quartz ore at the Tolovana mine, about half a mile west of the Wackwitz mine.

Scheelite is also associated with the gold-quartz ore of the Rainbow mine, about half a 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.

Scheelite 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 (fig. 2). Placer concentrates near the head of Fox Creek contained an estimated 90 percent of scheelite 26/.

26/ Robert R. Coats, personal communication.

The lodes of the Gilmore Dome and 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 and Mining Co., which owns all the dredges now operating in the Fairbanks district, has saved the concentrates from its dredges. Mr. J. D. Crawford, in charge of exploration for the company, states that approximately 484 tons of dredge concentrates have now accumulated, which he estimates as the recovery from 130 million tons of placer gravels. Two channel samples of this dump 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. Thus the dump contains approximately 0.6 tons of scheelite (0.54 tons WO_3) and 13 7 tons of cassiterite (12.1 tons Sn). These three minerals, however, are mixed with many others, for some of which the ore would be penalized. Therefore, the value of the concentrates exceeds but slightly the freight charges that would be incurred in shipping them to the States; and for this reason these concentrates are not being utilized.

Favorable areas 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 migrates into the cupola and out into the country rock.

2) A limestone bed in the metamorphosed sequence at distances ranging from one-eighth to 1 mile from the area of porphyritic granite. In beds of gentle to moderate dip, the limestone bed must be on the down dip 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 down dip 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. Also, 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 one-eighth to 1 mile north of the areas of porphyritic granite shown on figure 2 should be examined thoroughly. As pointed out above, the areas on the down dip side of the porphyritic granite are more favorable, and these areas are to the north of the porphyritic granite, since the regional dip is to the north. Local variations should be anticipated, however, and in those cases the down dip rule should apply. In prospecting country rock on the down dip 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 the zone of juncture a scheelite-bearing ore body normally might be expected.

The task of 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 down dip side of the porphyritic granite area could be accomplished best by use of a small post hole auger with one extension, permitting a test hole, 12 feet deep. Bedrock in place is reached generally within this depth on ridgetops and hillslopes. The mantle removed by the auger could be examined by means of an ultraviolet lamp. Hillsides can be covered quickly using a 100-foot grid spacing of holes, because frost action causes the mantle including any scheelite-bearing rock to migrate down slope from the bedrock source. On flat or gently dipping surfaces near the ridgetops closer spacing of holes would be necessary. Areas surrounding those 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.

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 (see fig. 2). In the Pedro Dome area, the country rock north of the two areas of porphyritic granite (see fig. 2) should be prospected thoroughly. The area surrounding the small mass of porphyritic granite near the head of Fox Creek (see fig. 2) almost certainly is mineralized with scheelite, inasmuch as placer concentrates from gold-mining in that area contained 90 percent of scheelite (see p. 37). Finally, the country rock surrounding any small, unmapped areas of porphyritic granite should be prospected.

end

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