Pamphlet No. 108 June, 1956

TUNGSTEN DEPOSITS OF SOUTH-CENTRAL IDAHO

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FOREWORD

The material of this Pamphlet 108, as issued by the Idaho Bureau of Mines and Geology, has been prepared by Dr. Earl F. Cook to guide in the prospecting and development of tungsten deposits in Idaho. The paper is of special significance at this time because it will serve as a specific aid to the development of important tungsten resources while it appears that guaranteed price supports for this mineral commodity will remain in effect.

J. D. Forrester, Director
Idaho Bureau of Mines and Geology
July, 1956

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ILLUSTRATIONS

INTRODUCTION

An investigation of the tungsten deposits of south-central Idaho has been undertaken by the Idaho Bureau of Mines and Geology in order to determine the extent and intensity of tungsten mineralization in the region, to study the geology of the known deposits, to set up some guides for tungsten prospecting, and to assess the economic possibilities of the newer discoveries.

The months of July and August, 1954, were spent in the field. More than 25 deposits, some of which had been discovered within the previous year, were examined; the more promising of these deposits were mapped geologically. Deposits investigated are located mainly in Blaine, Custer, and Valley Counties, from the Lava Creek district in the south (near Craters of the Moon National Monument) to the Big Creek district (north of Yellow Pine). The locations of these deposits are shown on Figure 1. In September, 1955, some of the properties were revisited.

The wholehearted cooperation of claim holders and mine owners facilitated the field work and made this report more informative than it otherwise could have been. Special acknowledgment is due as follows: for hospitality and information--Edward Hager and the Cordero Mining Company, Elmer Enderlin, Charles Ford, James Clutus, and Paul Uresti; for geologic data and production history--Q. F. Treseder, Joseph Ausich, Arthur Chambers, John Jensen, Laurence Heagle, Keith Medill, Jack Martin, Milton Young, Robert McRae, Keith Wallace, and J. Ray Weber; for transportation and guidance--Harvey Beverlin, V. R. Markle, Arthur Storr, Clint Gunderson, Ira Lambert, Ken Deming, C. B. Lindberg and Laurence Gini. A visit to the Ima Mine was made instructive through the courtesy of J. C. MacFarlane and Charles Hathhorn. Information freely given by Thor Kiilsgaard and Howard Nicholson of the U. S. Geological Survey was especially helpful. Rewarding discussions of regional geology were had with C. P. Ross, A. L. Anderson, Dwight Schmidt, and Harold Powers. R. R. Reid critically reviewed the manuscript and made several helpful suggestions.

The writer was ably assisted both in the field and in laboratory study of the Wildhorse rocks and ore by Heungwon Lee. Much of the discussion of the geology of the Wildhorse area in this report is drawn from Lee's thesis, presented in partial fulfillment of the requirements for a Master's degree in geology at the University of Idaho in June, 1955.

The Yellow Pine and Ima mines, which have been the major tungsten producers in Idaho, although located in south-central Idaho were not studied during this investigation, since adequate geologic descriptions of these two mines are already in print.

GEOLOGY OF THE DEPOSITS AS A GROUP

GEOLOGIC SETTING

Most of the tungsten occurrences of south-central Idaho are concentrated in a northwest-trending zone which cuts obliquely across the margin of the Idaho batholith (Fig. 2). Although this tungsten belt parallels some faults and anticlines of Cenozoic age, the mineralization was probably localized by older structures developed during the Laramide orogeny.

The tungsten deposits are found mainly in altered sedimentary rocks near contacts with granitic rocks. The host rocks include quartzite, argillite, and marble, as well as granitic rocks, and they range in age from pre-Cambrian to late Cretaceous or early Tertiary.

SCHEELITE DEPOSITS

General features

Scheelite is the principal tungsten mineral of the Idaho tungsten belt. In the southern part of the belt the scheelite commonly occurs in tactite formed from an impure calcareous rock near a granitic contact. The associated granitic rocks are in some places intrusive, elsewhere of metasomatic origin. In several of the deposits scheelite-bearing tactite is closely associated with alaskite or leucogranodiorite dikes containing irregular pods of vitreous quartz formed by replacement of the alaskite. The alaskite dikes have an erratic texture which is locally pegmatitic and they have been mapped by other workers as aplite, pegmatite, or aplite-pegmatite. They rather commonly contain scattered sulphides, mainly pyrite. In the northern part of the tungsten belt the association of tungsten with alaskite is likewise notable but there the tungsten occurs in quartz rather than in tactite, and the country rock is quartzite or quartz monzonite in place of calcareous rock.

In many of the deposits some or all of the scheelite fluoresces yellow, indicating a relatively high molybdenum content. Such scheelite is commonly called powellite, although mineralogists restrict the term to occurrences in which molybdenum exceeds tungsten.

Relation to host-rock lithology

With the notable exception of the deposits in the Mackay area, the scheelite-tactite association has been found only in relatively impure calcareous rocks, ranging from the micaceous marble of the Wildhorse area to the limy argillite of the Buckskin and Phi Kappa mines. In the Wildhorse area, for example, tactite is found only in micaceous marble and not in pure marble, although both kinds of marble are cut by "alaskite" dikes. The solutions which caused the formation of tactite in this area probably did not import a great variety of elements; con-

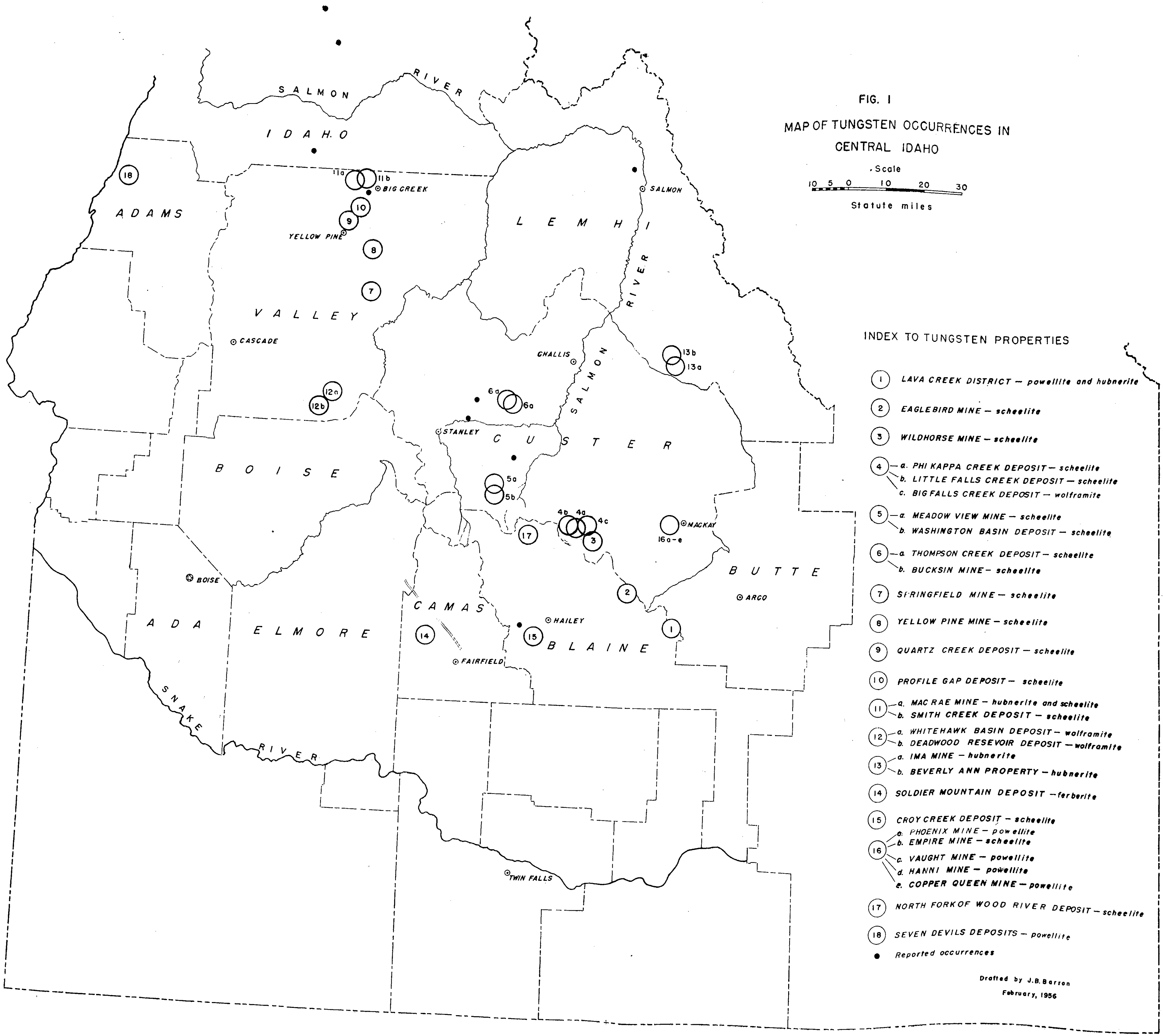


FIG. 1
MAP OF TUNGSTEN OCCURRENCES IN CENTRAL IDAHO

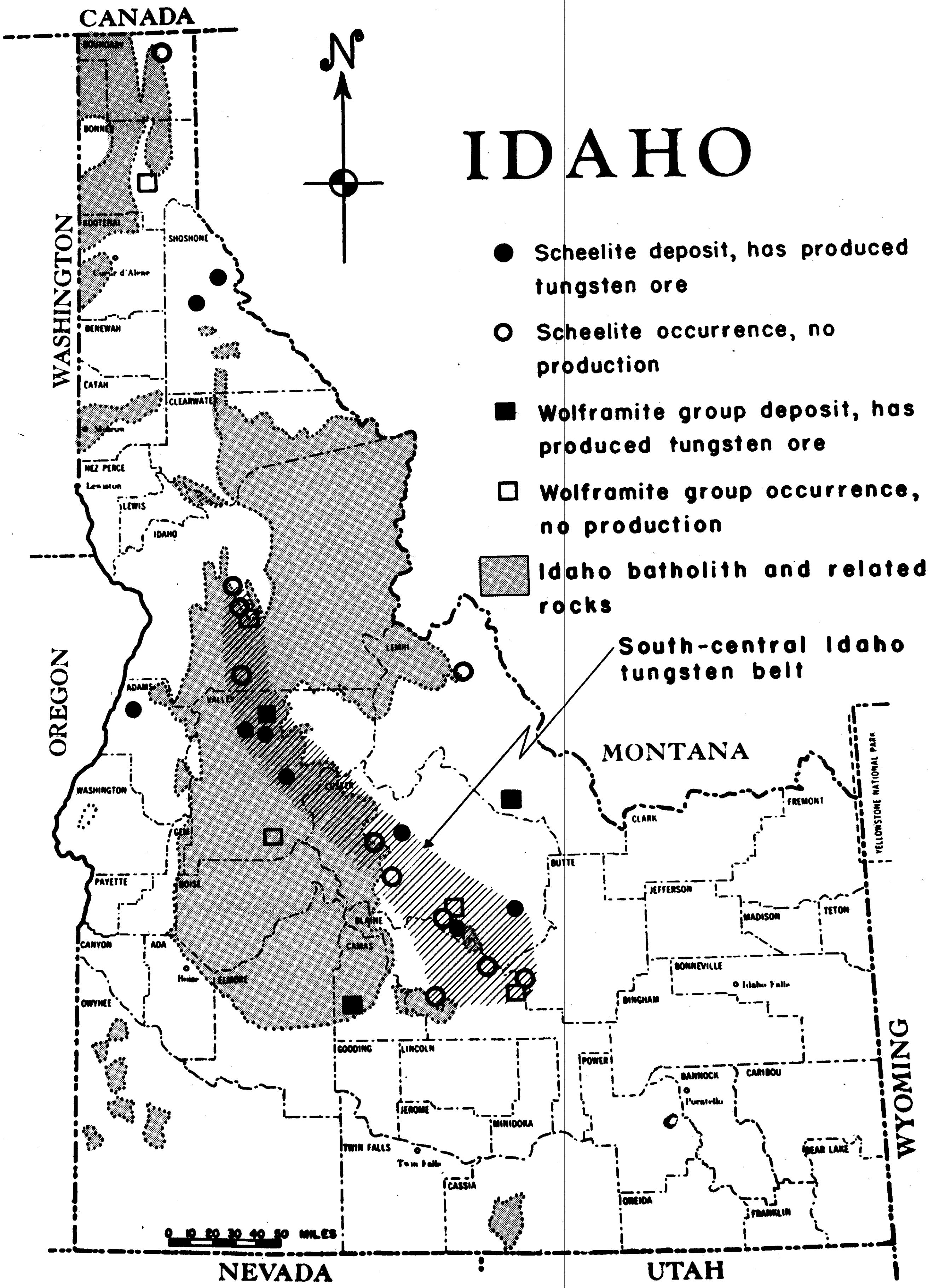


FIG. 2 -TUNGSTEN OCCURRENCES IN IDAHO.

sequently, tactite formed only in those rocks which already contained most of the necessary elements. On the other hand great volumes of iron and other elements must have been added to the relatively pure limestone of the Mackay area in order to produce the large masses of tactite which are found there.

In the scheelite-quartz deposits there has been far less depositional control by the host-rock. In fact the location of these deposits seems controlled only by favorable structure and nearness to a source of tungsten. However, at the McRae Mine in the Big Creek district there does appear to be a lithologic control within some of the deposits, huebnerite-scheelite ore within a lenticular quartz vein being found in bands parallel to the bedding of the inclosing quartzite.

Relation to granitic rocks

The granitic rocks associated with the south-central Idaho scheelite deposits range in composition from granite and alaskite to granodiorite and leucogranodiorite and in size from dikes a few inches thick to the Idaho batholith itself. In some localities (for example, at White Knob in the Mackay area) the granitic bodies are intrusive whereas in other areas (Wildhorse and Meadowview mines) the granitic rocks are more probably of replacement or metasomatic origin. Although the associated granitic rocks locally have aplitic or pegmatitic texture, more generally they are medium-grained rocks. One of their outstanding characteristics is the scarcity or absence of dark minerals. Now plutonic rock without dark minerals is termed leucocratic and a leucocratic granite is called alaskite. A granodiorite without dark minerals is known as a leucogranodiorite. Because in field mapping it is rarely possible to distinguish between alaskite and leucogranodiorite, "alaskite" has been used in this report as a field term covering both.

The association of scheelite with granitic rocks may be genetic or structural or both. If the granitic rocks are the "parents" of the tungsten deposits, these deposits apparently can have two different origins (for the granitic rocks themselves have two) unless granitization (the development of granitic rocks by replacement of pre-existing rocks) itself is a contact phenomenon, a high-temperature phase of igneous metamorphism. If this be true, the elements of each of the tungsten deposits investigated may have originated in a magma and been carried to their present resting places by solutions of magmatic derivation, solutions which in some places had previously transformed some of the country rock into granite. Even where the associated rock is clearly igneous, however, the tungsten-bearing solutions must have come from a deeper, still molten part of the magma after the upper part had solidified because scheelite is rather commonly found in fractures which cut the igneous rock.

It is also possible that the tungsten, or some of it, is not of magmatic origin but has been mobilized within metamorphosed sedimentary rocks and transported by solutions during granitization. Sullivan (1948) pointed out that tungsten ions are rejected by the other ions in acidic rock formed by granitization and thereby undergo concentration.

In some deposits the localization of scheelite-tactite bodies near granitic bodies may be the result of the restriction of good solution channelways to the immediate vicinity of these bodies. If the rock in any area is most broken around the periphery of an intrusive mass, hot ore-bringing solutions will rise through this broken zone whether the solutions originated in a magma or not.

As will be pointed out later the tungsten belt of south-central Idaho seems to follow structures which originated in Laramide deformation. However, similar Laramide structures without associated tungsten deposits are widespread. In other words, the localization of the Idaho tungsten deposits needs further explanation than control by Laramide structures. In some of the tungsten localities along the tungsten belt solutions and granitic material rose along anticlinal arches; such structures allowed hot material to rise higher than in adjacent synclines. On the other hand there are Laramide anticlines farther east in Idaho which contain neither granite nor tungsten. It would appear, therefore, that at some time in the Late Cretaceous the geothermal gradient was steeper along the tungsten belt than elsewhere, with a resulting mobilization of granitic material and tungsten-bearing solutions. Perhaps faulting was deep-seated in this zone and tapped sources of heat not reached by fractures in other areas.

The granitic material whose introduction accompanied or slightly preceded the tungsten mineralization formed light-colored dikes ranging in texture from aplitic to pegmatitic. There is a general but not close coincidence between the areas wherein such dikes are found and the location of the tungsten deposits. Such dikes are abundant in the Wildhorse area, at the Yellow Pine mine, and in the Big Creek region. They are found also at the Meadowview mine; it is interesting to note on Ross' (1937) map of the Bayhorse region that aplite dikes are more numerous near the Meadowview than anywhere else in the region. No tungsten deposits are known in the Casto quadrangle, but again it is interesting that aplite and pegmatite dikes are practically restricted to the southwest corner of the quadrangle, on the line of the tungsten belt (see Ross 1934). Two localities where tungsten is apparently not associted with such dikes are the Mackay area and the Thompson Creek area (including the Buckskin mine).

Relation to tactite

Tactite is a rock consisting essentially of lime silicate minerals. Such rocks are limited in extent and are generally formed by local or partial replacement of a calcareous rock. The two principal minerals of tactite are garnet and epidote, although either may be greatly subordinate or absent. In addition several other minerals such as wollastonite, vesuvianite, tremolite, zoisite, and chlorite may be present. Tungsten-bearing tactive commonly contains quartz in addition to the lime silicate minerals.

Although the calcium in scheelite ($CaWO_4$) is probably derived from the host rock, scheelite shows a marked aversion to limestone or marble (the most obvious and convenient sources of calcium) in preference for tactite. In none of the deposits examined was scheelite found in limestone; it occurs in tactite, in quartz veins, in the associated granitic rock (rarely), but not in limestone.

This tactite preference on the part of scheelite has been explained by Lee (1955) on the basis of ionic radii. Among the elements in tactite and the various country rocks, including marble, with which tungsten-bearing solutions may have come in contact are the following:

Element	Valence	Ionic Radius (A.U.)
W	+6	0.67
C	+4	0.18
Na	+1	0.98
K	+1	1.33
Ca	+2	1.01
Al	+3	0.57
Si	+4	0.41
Fe	+2	0.79
Fe	+3	0.67
Mg	+2	0.75

Tungsten, aluminum, ferric iron, and silicon have high valence and low ionic radii. Under favorable temperature-pressure conditions tungsten might tend to enter the crystal lattice of a mineral rich in one or more of these other three ions, since replacement is facilitated by similarity in size and valence of the ions involved. Should the mineral contain some calcium and oxygen also the tungsten might combine with them to form scheelite, $CaWO_4$.

The common minerals in tactite and other possible host rocks are:

orthoclase-microcline: $KAlSi_3O_8$
muscovite-sericite: $H_2KAl_3(SiO_4)_3$
oligoclase: $3NaAlSi_3O_8 \cdot CaAl_2Si_2O_8$
epidote: $Ca_2(Al \cdot OH)(Al,Fe)_2(SiO_4)_3$
diopside: $CaMg(SiO_3)_2$
chlorite: $H_8Mg_5Al_2Si_3O_{18}$

calcite: $CaCO_3$
quartz: SiO_2
biotite: $(H,K)_2(Mg,Fe)_2Al_2(SiO_4)_3$
actinolite: $Ca(Mg,Fe)_3(SiO_3)_4$
grossularite: $Ca_3Al_2(SiO_4)_3$
andradite: $Ca_3Fe_2(SiO_4)_3$

vesuvianite: calcium aluminum silicate

In this group there are five calcium aluminum or calcium iron silicates: epidote, grossularite, andradite, vesuvianite, and oligoclase.

In light of this it is interesting to note that scheelite is definitely associated with epidote, grossularite, or vesuvianite in most of the contact tungsten deposits of Idaho. Andradite is rare in these deposits but where it is found, as in the Mackay district, tungsten deposits are associated with it. Oligoclase has only a small calcium content and therefore would not be as favorable a host mineral as the other four; however, in some of the Wildhorse leucogranodiorite specks of scheelite are associated with sericitized oligoclase.

The intimate relationship of scheelite and tactite might lead one to believe that both had formed during the same sequence of mineralization, but this is not necessarily true. Detailed study of such deposits has generally shown that the tungsten is introduced some time after the formation of the lime silicate minerals. Despite this evidence of a time lapse between tactite and scheelite formation, most investigators think that the tungsten metallization represents a waning phase of a sequence of mineralization which began with the formation of the lime silicate minerals at or near the edge of a hot intrusive mass. On the other hand there is rarely any direct evidence to support this conclusion. For the Idaho deposits there are several different possible interpretations of the age relations of tungsten-bearing tactite and associated granitic rocks:

(a) The tactite, the granitic rock, and the tungsten in any one deposit may be essentially the same age, but they may differ in age from deposit to deposit.

(b) The tactite and the associated granitic rock may be of the same age in any one deposit (although differing in age from deposit to deposit) but the tungsten may be younger and of the same age in all deposits.

(c) The tactite and the tungsten and the associated granitic rock may be of any age, providing only that in any one deposit the granite is older than the tactite which is in turn older than the tungsten.

The second-named (b) of these three possibilities fits the evidence better than the other two. Although in some deposits tactite could conceivably be much younger than the associated granitic rock, the nearness of tactite to a granitic contact in <u>every</u> deposit is difficult to explain other than on the basis of genetic connection and nearness in age. Because the associated granitic rocks differ in age, the tactite bodies probably do also. On the other hand, the virtual restriction of scheelite to bodies of tactite does not mean that the scheelite and the tactite are necessarily of the same age, but merely that tactite is by far the most favorable available host for scheelite. It is probably significant that in the Casto quadrangle, despite considerable contact metamorphism, including tactite development, associated with mid-Tertiary intrusive bodies, there are no reported tungsten deposits. The tactite in the Casto quadrangle was probably formed subsequent to the tungsten metallization epoch. The probable localization of the tungsten belt by Laramide structures, the lack of influence of the later northeast structures, and the close association of scheelite with alaskitic dikes in several localities, all suggest a single period of tungsten mineralization. Although these dike rocks may differ in age from place to place it seems more likely that they were formed in one general period of granitization.

In summary it appears that the granitic rocks and the tactite of the contact deposits vary in age from place to place. The tungsten mineralization, however, is of essentially the same age in all deposits, which is probably why some of the younger tactite bodies contain no tungsten, they having been formed after the tungsten mineralization. The tungsten deposited in quartz-scheelite veins is probably the same age as the tungsten in the tactite-scheelite bodies.

Relation to structure

The Idaho batholith is one of the dominant structural features of central Idaho. Immediately east of its border, in south-central Idaho, 30,000 feet of sedimentary beds, largely of Paleozoic age, were markedly deformed during disturbances that preceded and accompanied the emplacement of the batholith (Ross 1947, p. 1125).

Ross (1947, p. 1129) points out that the Paleozoic rocks of this region have folds trending N. 30° W. to N. 40° W., most of which are more or less overturned toward the east, some being broken by steep thrust faults. Although there has been some rejuvenation of structures along this same trend in Tertiary time, the major deformation probably occurred in Laramide (late Cretaceous or very early Tertiary) time.

In addition to this northwest trend there is a northeast trend well expressed in a zone of deformation and intrusion which extends northeast from north of Boise diagonally across central Idaho to the Montana boundary (Ross 1947, p. 1127). Where the faults, folds and intrusive masses of this trend can be dated, they are post-Challis. The main folds in the Challis formation, at least in the Salmon quadrangle, have northeast trends (Anderson 1956, p. 50) and appear to be part of this mid-Tertiary structure trend.

The alignment of the south-central Idaho tungsten belt with northwest-trending folds and faults in its southern portion suggests that the tungsten mineralization may have been in part controlled by these structures, which originated in Laramide time. There is apparently no tungsten associated with the northeast-trending mid-Tertiary structures.

In its northern part the tungsten belt parallels a series of north-south faults and dikes. Some of the dikes are probably of Tertiary age and some of the faults were almost undoubtedly active during the Tertiary.

However, there is no direct evidence as to the time when this faulting started. This north-south trend may have originated during the Laramide disturbances and have been rejuvenated throughout the Quaternary.

On a broad scale, then, tungsten location is a function of structure. In addition, the tungsten-bearing quartz veins are controlled by local structure; the outstanding example is the ore body at the Yellow Pine mine which was found at the intersection of northeast-trending faults with a north-trending fault. The tactite tungsten deposits, on the other hand, are controlled not by structure, but by the location of tactite, and this in turn is controlled by sedimentary lithology and structures which allowed ingress of granitic material and tactite-forming solutions.

Inferred conditions of formation

In the late Cretaceous, leucocratic granitic rocks were emplaced along Laramide structural trends in southcentral Idaho. To a considerable extent the emplacement was metasomatic. Where the newly formed rocks transected impure calcareous rocks, masses of tactite were formed. The end stage was the introduction of silica-rich tungsten-bearing solutions. These siliceous solutions erratically replaced the leucocratic rocks, permeated tactite, and in some places formed quartz veins. Scheelite was formed both in the silicified tactite and in the quartz veins.

The dominance of replacement criteria, the absence of cavity-filling evidence and the presence of high-temperature minerals indicate that pressure and temperature were relatively high during the formation of these deposits, which should therefore probably be placed in the hypothermal or mesothermal zones of Lindgren's classification. The scheelite of the Yellow Pine ore body has been considered to be of low-temperature origin but this is a matter of interpretation of evidence which is somewhat obscured by several stages of mineralization.

The common close association of scheelite with quartz in these deposits suggests that the tungsten-bearing solutions were siliceous.

Age of mineralization

The tungsten mineralization probably predates most of the Cenozoic faulting and igneous activity. It is probably genetically related to a Laramide emplacement of granitic rocks at or near the close of the Cretaceous period.

A. L. Anderson (1951) has pointed out that many of the ore deposits formerly believed to be genetically related to the Idaho batholith actually were emplaced much later than the batholith. According to Anderson (1952b p. 55)

> "The Idaho batholith a notable product of recrystallization replacement processes, has been a producer of pegmatites and aplites but not of ores.................. Except for local granitization as an early intense phase of wallrock alteration, the Idaho ore deposits show no relation whatsoever to large scale granitization such as is involved in batholithic emplacements."

Anderson, in line with this conclusion, places all of the post-batholith, pre-Challis (pre-late Oligocene) ore deposits in an Early Tertiary metallogenic epoch unrelated to the batholith, but instead associated with lamprophyre dikes intruded at rather shallow depth. Interestingly, however, (Anderson 1952b, p. 59) points out that

> "such constituents as are more or less typical of the granitic crust--uranium, tungsten, tin, and molybdenum--might be expected to be concentrated during the granitization process."

The evidence from the tungsten deposits seems to confirm this expectation of Anderson's and to date the tungsten mineralization as earlier than any of his recognized Tertiary metallogenic epochs.

The tungsten mineralization is younger than the main mass of the batholith, for the tungsten belt cuts obliquely across the edge of the batholith, and the tungsten is associated with quartz veins and "alaskite" dikes which cut the batholith.

The tungsten was probably emplaced prior to the Challis volcanism. At the Buckskin mine northwest of Clayton scheelite-bearing tactite has replaced calcareous argillite; the resistance imparted to the relatively weak argillite caused the formation, in pre-Challis time, of a hill containing the tactite. This hill was buried by Challis volcanics and has just recently been exhumed by erosion. Unless the tungsten entered the tactite long after its formation (which seems unlikely) the tungsten is pre-Challis. At this same deposit a lamprophyre dike of probable Challis age cuts the tactite, and is therefore younger. Additional evidence supporting a pre-Challis age for the tungsten is the absence of tungsten associated with the northeast-trending belt of post-Challis faults and intrusive bodies in the Casto quadrangle.

At the Yellow Pine mine a probable Challis feeder dike contains stibnite but none of the older gold and tungsten-bearing minerals. Although White (1940, p. 265) and Cooper (1951, p. 172) both concluded that the gold-tungsten-antimony mineralization sequence was all contained in one Tertiary mineralization epoch, Currier (1935, p. 19) and Bailey (1934, p. 163) may have been right in claiming that only the antimony is Tertiary and that the gold (and, by inference, the tungsten) is earlier, perhaps Cretaceous.

That the tungsten deposits are closer in age to the batholith than to the Challis volcanics can be inferred from their association with "aplite-pegmatite" dikes whose source may be in the batholith and which were emplaced at considerable depth, from their mineralogic associations (molybdenite, pyrrhotite, lime silicates) which denote high temperature, and from the dominance of replacement features which suggest fairly high-temperature-pressure conditions of formation. Furthermore there appears to be no evidence of genetic association with the later basic dikes. Incidentally, the existence of Cretaceous mineralization in Idaho was demonstrated a number of years ago when Reed (1937) found some placer fragments of uraninite (containing gold) in the Warren district, which yielded a late Cretaceous age by radioactive measurement.

In summary, the tungsten mineralization in southcentral Idaho probably represents a Laramide metallogenic epoch. Although it may be either late Cretaceous or Paleocene in age, it is distinctly older than the early Tertiary epoch which Anderson associates with pre-Challis lamprophyres. The tungsten deposits were formed at greater depths and higher pressure than the lamprophyre-associated deposits. This metallogenic epoch may be related to what Anderson (1952a) calls the younger group of batholith rocks "formed at shallower depths than the older rocks," whose emplacement seems controlled in part by Laramide structures and probably took place near the end of Cretaceous time.

BLACK TUNGSTEN DEPOSITS

General

Except for the quartz-huebnerite-scheelite deposits at the McRae mine in the Big Creek area, the deposits in which the tungsten mineral is a member of the wolframite group (ferberite, wolframite, huebnerite) have little in common with the scheelite deposits. The black tungsten deposits are not restricted to the narrow scheelite belt; in fact the major black tungsten deposit (Ima) occurs far east of the scheelite zone. The black tungsten deposits, except for those at the Ima and McRae properties, show evidence of deposition at lower temperatures and pressures than the scheelite deposits. They are quartz veins instead of tactite deposits. Finally, some of them show evidence of deposition at a date later than Laramide time.

Conditions and time of origin

Some of the black tungsten deposits were deposited under relatively high temperature and pressure; examples are the deposits at the McRae and Ima mines in which replacement was the dominant process of deposition and in which the ore deposits are associated with granitic rocks of metasomatic origin. The deposits at Soldier Mountain, Big Falls Creek, and Blizzard Mountain, on the other hand, were formed under low temperature and pressure; they contain coarsely crystalline black tungsten, chalcedonic quartz, and drusy cavities. Only the higher temperature black tungsten deposits contain scheelite.

In the Lava Creek district (Blizzard Mountain) huebnerite is found in a vein which is partly in post-Challis granite. At this locality as well as at Soldier Mountain the tungsten-bearing veins occupy northeast fractures, presumably of post-Challis age. The Lava Creek and Soldier Mountain deposits apparently were formed at a later time (and at shallower depths) than the scheelite of the Idaho tungsten belt. On the other hand the black tungsten in those deposits which also contain scheelite was probably deposited under higher temperature and pressure (presumably at greater depth), possibly during the same Laramide metallogenic epoch in which the scheelite deposits were formed. The black tungsten deposited under epithermal (low temperature and pressure) conditions is possibly mid Tertiary in age.

DESCRIPTIONS OF INDIVIDUAL DEPOSITS

SCHEELITE DEPOSITS

Lava Creek district (1)

Disseminated powellite is exposed in an adit on the Sam and Tom property on the northeast flank of Boyle Mountain in the Lava Creek district. The adit is at an elevation of about 9,000 feet in the southcentral part of section 12, T. 2 N., R. 23 E., Butte County. The property can be reached by poor dirt road from Martin, which is one mile north of Craters of the Moon National Monument.

The powellite is irregularly and sparsely disseminated in metamorphosed limestone adjacent to and on the under side of a syenite dike. The syenite is, according to Anderson (1929, p. 25),

> "pale green to bluish gray, slightly porphyritic and has a few scattered albite phenocrysts and hornblende (altered to epidote) in a microcrystalline groundmass of short tabular orthoclase crystals and a little interstitial quartz."

The limestone strikes N. 25° W. and dips 60° southwest. Tactite consisting of garnet and epidote partially replaces the limestone to a distance of four feet from the dike. The contact of the dike with the metamorphosed limestone is a fault which strikes N. 45° W. and dips 60° southwest. A silver-lead vein cuts across the limestone and the syenite N. 85° W. and presumably is later than the tungsten.

A channel sample taken across one foot of mineralized tactite perpendicular to the dike assayed 0.17 percent WO_3.

Eaglebird mine (2)

The Watkins tunnel at the Eaglebird mine in the Muldoon (Little Wood River) district cuts at least two narrow shear zones which contain scheelite. This tunnel is in the northwest quarter of section 36, T. 4 N., R. 21 E., Blaine County, at an elevation of about 8,600 feet, on the north side of Garfield Canyon near its head. The scheelite occurs in narrow fracture zones in silicified limestone of the Wood River formation a few hundred feet from a quartz monzonite porphyry stock. The intrusive rock (Anderson and Wagner 1946a) is pinkish gray and porphyritic with white andesine phenocrysts and biotite, augite, and hornblende all embedded in a fine-grained pinkish groundmass consisting largely of orthoclase and quartz.

In and near the Watkins tunnel the silicified limestone strikes N. 15° W. and dips 60-70° east. The principal mineralized shear zone is encountered about 425 feet in from the portal of the northerly trending tunnel; the shear strikes N. 80° W. (normal to the tunnel) and dips 80° north; crosscuts have been driven off the main tunnel to explore this zone. Six samples taken at various points along this shear zone by the International Smelting and Refining Company assayed 0.02 to 0.69 percent WO_3.

Wildhorse mine (3)

Location

In 1953 and 1954 several scheelite deposits were found along Wildhorse Creek in the northwestern part of T. 5 N., R. 20 E., Custer County. Wildhorse Creek is a northward-flowing tributary of Big Lost River. The tungsten area lies about 30 miles east of Sun Valley, but because the Trail Creek road to Sun Valley and Ketchum is closed during the winter access is by road via the Big Lost River Valley to a railhead at Mackay, 50 miles away. The mine camp is 10 miles south of the junction of Wildhorse Creek with Big Lost River and about four miles northeast of Hyndman Peak (12,078 feet). The tungsten deposits cropp out at elevations between 7,700 and 8,300 feet.

History and production

The first deposit was discovered in August, 1953. The following month the Cordero Mining Company leased the deposits from the original discoverers. In September, 1954, a 40-ton mill was in operation processing ore stockpiled from open-pit operations on three deposits, known as Beaver, Steep Climb, and Hard to Find, all within an area two miles long and three-quarters of a mile wide (Fig. 3). The mill has operated with only brief shutdowns since; by September, 1955, over 3,800 tons of ore with an average content of 0.87 percent WO_3 and a gross value of $212,000 had been milled.

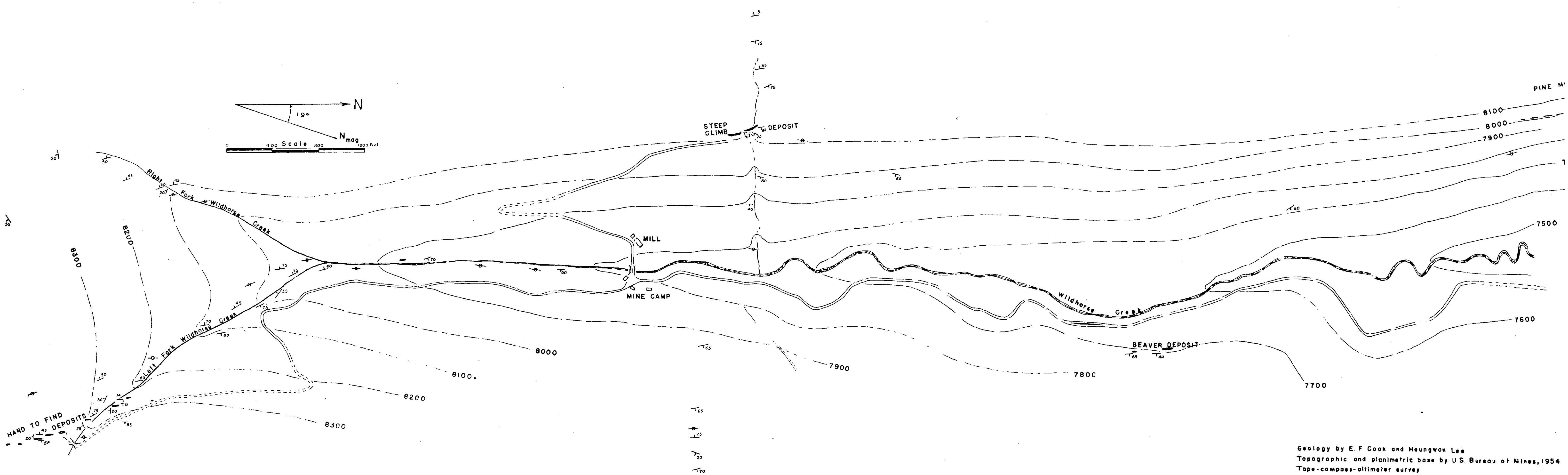


FIG. 3

MAP OF WILDHORSE TUNGSTEN DEPOSITS, SHOWING LOCATION AND SOME GEOLOGIC STRUCTURE

Geologic setting

The rocks in the mine area are principally metamorphic although some small bodies may be of intrusive origin. The principal rock type is gneiss, locally containing marble lenses. The gneiss is cut and invaded by light-colored granitic rock; where the admixture is intimate the result is migmatite; elsewhere the granitic bodies are more distinctly dikes and this dike rock was called "alaskite" in the field although the microscope reveals that some of it is really leucogranodiorite.

Foliation in the gneiss is parallel to the marble inclusions. If we assume that the gneissic structure parallels original bedding in the sediments from which the gneiss was formed, the rocks of the Wildhorse area appear to have been folded into an asymmetric anticline whose axis trends N. 20° W.; the steep flank is on the east and the entire structure may have been thrust from west to east and later cut by high-angle faults parallel to the fold axis.

Umpleby, Westgate, and Ross (1930, p. 47) noted the inclusions in the Wildhorse gneiss:

> "Schlieren, or black inclusions of more micaceous and hornblendic rock, are common in the gneiss. In many places they are lenticular masses parallel to the banding of the gneiss and are themselves banded... In the cirque at the head of the south fork of Wildhorse Creek there is a small irregular mass of crystalline limestone... The presence of these bodies of sedimentary rock and the pronounced banding in the gneiss suggest that the gneiss may perhaps be of sedimentary origin and have been subsequently altered."

The gneiss, migmatite and local bodies of schist are gradational across strike although some sharp layering is found in some of the schist. The age of these metamorphic rocks is unknown.

Undisturbed relics and gradational contacts indicate that the migmatite was formed by partial replacement of pre-existing schist and gneiss. The igneous-appearing portions of the migmatite consist chiefly of plagioclase (oligoclase), quartz, and a small amount of mica and amphibole.

The "alaskite" dikes appear to be later than the migmatite, at least where they cut it; in some places, however, "alaskite" and the granitic phase of the migmatite are coextensive. The migmatite has largely been formed during earth movements whereas the "alaskite" was emplaced in the late stages of orogeny or even after movement had ceased. The "alaskite" is composed chiefly of plagioclase (mostly sericitized oligoclase) and quartz with subordinate microcline and some chlorite, epidote, muscovite, garnet, pyrite and molybdenite. A white "alaskite" and a pink "alaskite" were noted in the field, but whether they differ in age was not determined.

Although the "alaskite" dikes commonly have sharp and cross-cutting contacts with the adjacent rocks, the weight of evidence favors a metasomatic origin:

(1) Undisturbed inclusions: At the Pine Mouse deposit and at the Beaver deposit unrotated inclusions of gneiss (at Pine Mouse) and marble (at Beaver) were found within "alaskite" dikes, their attitude conforming to the attitude of the main body of metamorphic rocks outside the dikes. The dike material at these two localities cannot have been forcibly injected as a silicate melt, else these wall rock fragments would have been moved.

(2) Erratic texture: Characteristic of these dikes is erratic variation in grain size and the absence of any fine-grained border phase. Pegmatitic phases as well as segregations of vitreous quartz may occur as irregular lenses anywhere within a dike. If these dikes represent injections of magma, any chilled borders they may have possessed have now been obliterated by later replacement.

(3) Incipient dikes: In this area, especially in the rock bed of Wildhorse Creek, there can be seen all stages in the development of replacement dikes controlled by transverse planes of weakness. In the first stage the line of weakness is marked only by a flexure or displacement of the gneissic banding limned in pale gray; in the next stage the gray band has become more distinct and can be recognized as a replacement band of feldspar and quartz forming along the line of displacement or shift and obliterating the original gneissic structure. With increasing grain size and rejection of biotite the feldspar-quartz band becomes more and more distinct until it is a full-fledged replacement dike. A striking feature of such dikes is their sharp contact with the country rock, although under the microscope (and even by close visual examination) this contact is seen to be abruptly gradational rather than discontinuous.

The "alaskite"-tactite contacts are also gradational; at the Steep Climb deposits, over a width of several inches, the feldspar and quartz of the "alaskite" change gradationally into the epidote-quartz-scheelite of the tactite ore body. Calcite crystals of the marble have been replaced by feldspar. Even under the microscope the gneissic or schistose banding (foliation) in the country rock shows no disturbance at or near the contact with a dike. The tentative conclusion is inescapable that these dikes were formed by replacement processes.

The area has been glaciated during the Pleistocene; as a result there is little weathering of rock outcrops and no oxidation of exposed ore deposits. The topography is youthful; Wildhorse Creek is still actively downcutting in a narrow valley several thousand feet deep. Abrupt changes in gradient and small cascades and waterfalls are common.

Nature of ore bodies

The ore mineral in the Wildhorse deposits is scheelite. It is found within tactite. Tactite is an epidote or garnet-rich rock formed by local replacement and recrystallization of calcareous rock. In the Wildhorse area tactite forms only in impure marble adjacent to "alaskite" dikes. All marble bands found in this area are less than 50 feet thick and the economically important ones at the Steep Climb, Hard to Find, and Beaver deposits probably average 10-15 feet in thickness; deformation has so thinned and thickened the original beds that accurate measurement is difficult.

Tactite consisting mainly of epidote occurs at the Steep Climb and Pine Mouse deposits. At Steep Climb it is about 5 feet thick and crops out for some tens of feet along strike. Portions of this tactite consist entirely of coarse-grained epidote and scheelite; this was a rich ore, some samples running as high as 9 percent WO_3 in the early days of mining (1954). Most of the epidote occurs in stubby doubly terminated crystals, up to 10 mm. in diameter; the scheelite forms equally large crystals. Considerable quartz and calcite are found locally in this tactite.

Chlorite-garnet tactite occurs at the Hard to Find and Beaver deposits; it consists of chlorite, diopside, red garnet, and epidote in that approximate order of abundance. A highly chloritic tactite at the Hard to Find deposit was found to be a good ore.

Control of ore deposition

"Alaskite" dikes

Tungsten ore is found in the Wildhorse area only adjacent to "alaskite" dikes. These dikes seem to be most abundant along the crest of the northwesterly trending asymmetric anticline which is the principal structural feature of the area. Dikes mapped as alaskite actually range in composition from true alaskite to leucogranodiorite. Some grains of scheelite were found within alaskite at the Steep Climb deposit.

Impure marble

Tungsten ore is found only in tactite, which forms more abundantly in impure calcareous rock than pure. There is, for instance, pure calcite marble exposed above the Steep Climb deposit and in the right fork of Wildhorse Creek below Hyndman Peak. Although these pure marble bands are cut by alaskite dikes similar to those which cut the impure bands there has been no formation of tactite and, consequently, no tungsten deposition.

The marble in which tactite has flourished is highly micaceous and almost schistose because of its content of oriented mica. The marble at the Steep Climb contains 30-40 percent impurities, mostly mica but some amphibole, epidote, and pyrite. A similar marble is the host at the Hard to Find. Mica content varies abruptly across strike, amounting to 80 or 90 percent in some thin layers within the marble. Much of the mica is phlogopite. The calcite has to a considerable extent been replaced by diopside. Near the alaskite dikes tactite has been formed, portions of which have become ore by the addition of scheelite, commonly accompanied by quartz.

Tactite

Scheelite is virtually restricted to tactite, in which it replaces garnet and epidote. A reason for such control has been suggested by Lee: Of the more common ions found in alaskite, gneiss, marble, and tactite, two are more similar to the tungsten ions in valence and size than the others. These two are the ions of aluminum and silicon. It is a well-known fact that, in replacement, the replacing ions tend to replace another ion of similar size and valence in preference to an ion of different size and valence. Under favorable temperature - pressure conditions, Lee (p. 38) argues, tungsten may tend to enter the crystal lattice of a mineral rich in aluminum and silicon. Should the mineral rich in aluminum and silicon also contain calcium, the tungsten substituting for the aluminum and silicon might combine with the calcium to form scheelite, $CaWO_4$. Lee then considers the minerals with which tungsten-bearing solutions may have had contact and finds that only two of these, epidote and grossularite garnet, are calcium-aluminum silicates. Since it is precisely these two minerals which are dominant in the Wildhorse tactite and which are replaced by scheelite, Lee's argument gains strength. Another mineral, oligoclase feldspar, is partially a calcium aluminum silicate and it is probable that the scheelite specks occasionally seen in the alaskite are replacements of oligoclase; the small calcium content of oligoclase may have limited the development of scheelite in alaskite.

Individual deposits

Steep Climb

The Steep Climb deposit (see map, Fig. 4, and sections, Figs. 5 and 6) is located on the west side of Wildhorse Creek valley at an elevation of about 8,100 feet. Scheelite occurs in an epidote tactite which has formed by the partial replacement of a micaceous marble band adjacent to an alaskite dike. The tactite ore body is tabular, strikes about N. 15° W. and dips an average of 60° east. The alaskite dike has about the same strike but dips more flatly to the east. Average thickness of the ore body is 5 feet. Some of the epidote tactite contains abundant clear vitreous quartz. Some calcite is also found in the ore.

The ore body appears to be in two parts. Three samples taken by the Cordero Mining Company across the northern part of the body averaged

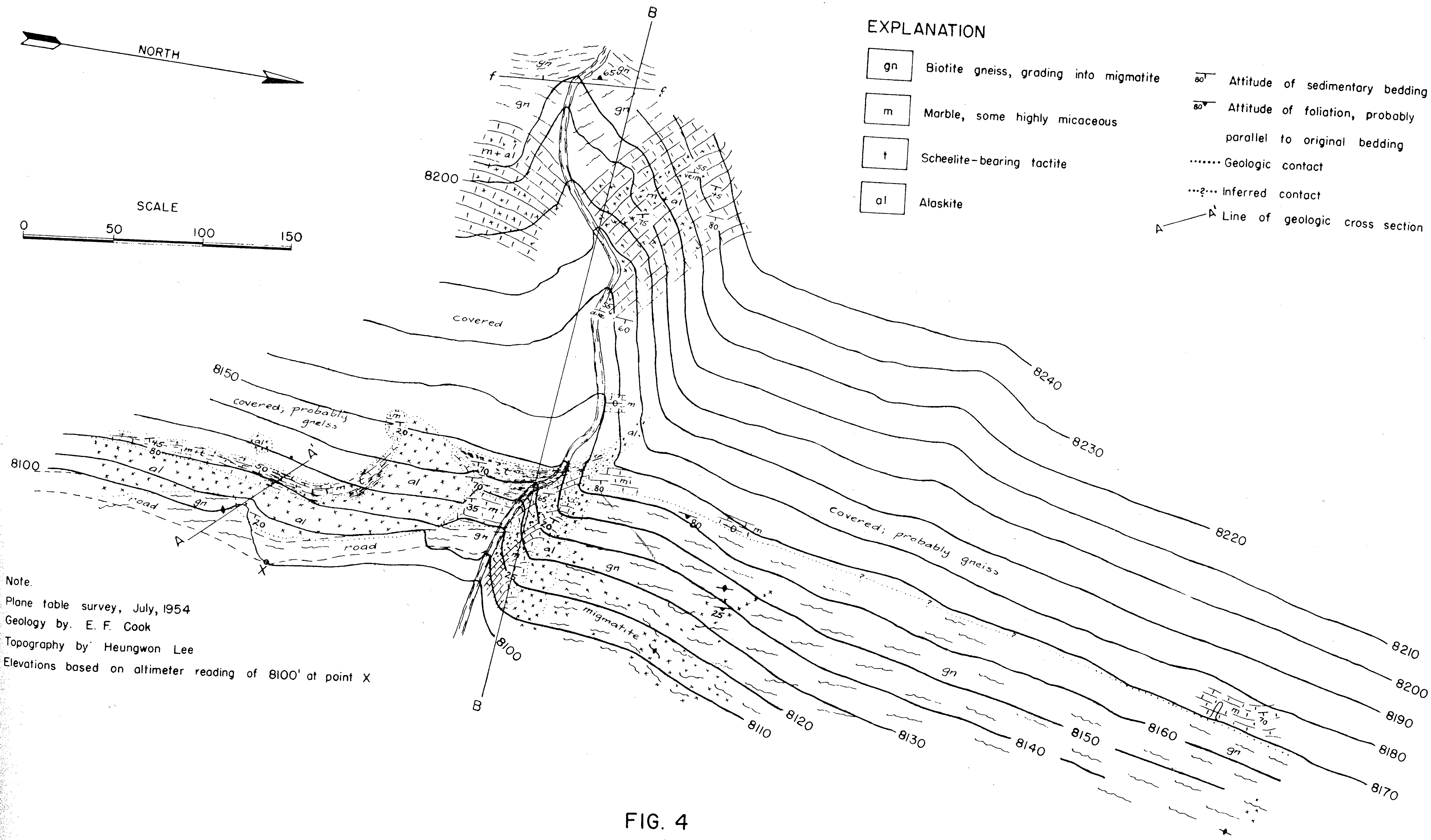


FIG. 4

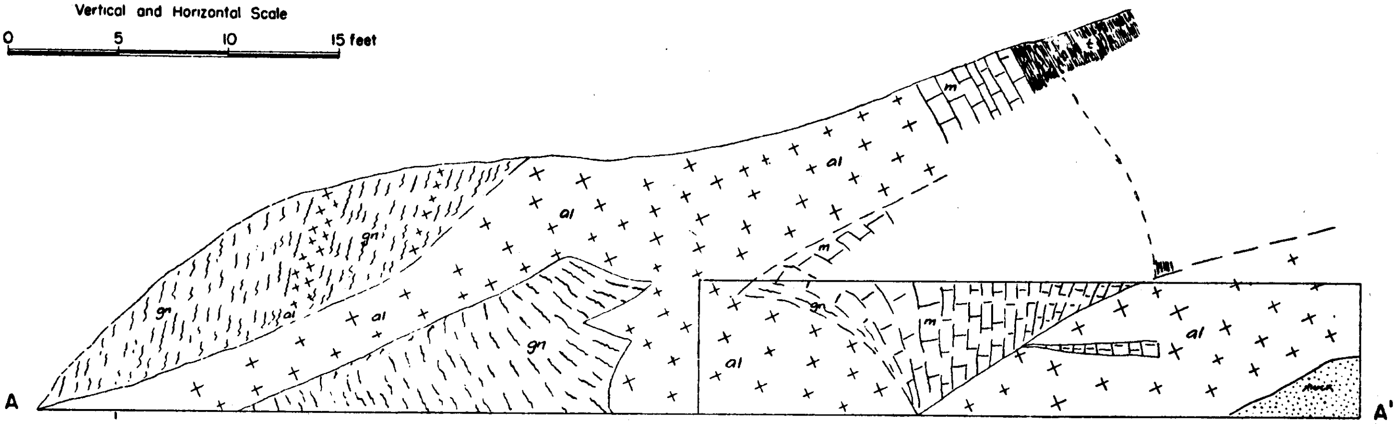
GEOLOGIC MAP OF STEEP CLIMB DEPOSIT, WILDHORSE MINE

ALTO DISTRICT, CUSTER COUNTY

FIG. 5 GEOLOGIC SECTION A-A' AT STEEP CLIMB DEPOSIT, WILDHORSE MINE

Vertical and Horizontal Scale

0 5 10 15 feet



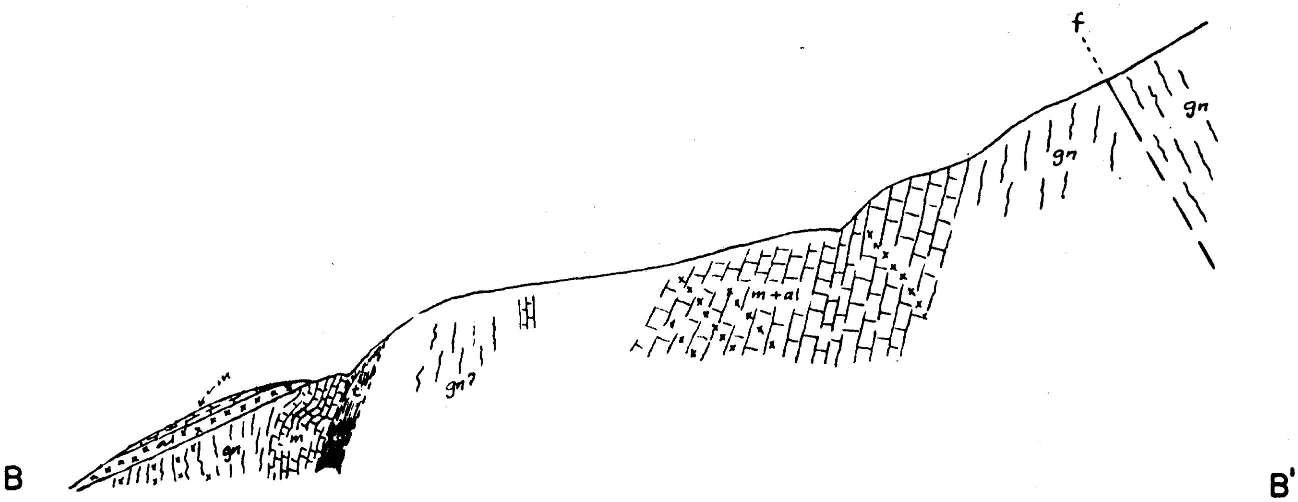


FIG. 6 GEOLOGIC SECTION B-B' AT STEEP CLIMB DEPOSIT, WILDHORSE MINE

Vertical and Horizontal Scale

0 50 100 150 feet

1.89 percent WO_3 for a strike length of 50 feet; 5 samples from an equal length of ore body in the southern portion averaged 2.25 percent WO_3. The two parts are separated by alaskite. Ore was mined by open pit methods and trucked down a newly built road to the mill at creek level. The ore body now (September, 1955) appears to be exhausted.

Hard to Find

The Hard to Find deposits are along the left fork of Wildhorse Creek about 1,000 feet above the confluence of the two forks and about one mile south of the camp site, at the northern base of Mustang Peak. Thedeposits (see map, Fig. 7) occur sporadically along the strike of a steeply dipping band of highly micaceous marble where alaskite dikes have invaded the marble and created tactite. Pale green actinolite and diopside are locally abundant in the marble. The trend of the line of outcrops and the strike of the marble is N. 15° W. The main structural feature is a broken anticline along the crest of which the alaskite dikes have cut both marble and gneiss. Mining has been done in a zone over 600 feet long. The thickness of the mineralized zone nowhere exceeds 5 feet. The associated tactite is the chlorite-garnet type, which includes chlorite, red garnet, pyrite, actinolite, scheelite, and molybdenite. Scheelite at the Hard to Find occurs in much finer grains than at the Steep Climb outcrop. Assays indicate that the Hard to Find ore should run about 1.0 percent WO_3. In the later work at these deposits, some high-grade scheelite, associated with vitreous quartz and accompanied by flakes of molybdenite, is reported to have been found in alaskite.

Beaver

The Beaver deposit (see map, Fig. 8) is on the east side of Wildhorse Creek about one mile downstream (north) from the mine camp. An impure marble band has been cut by alaskite with the resultant development of chlorite-garnet tactite sparsely mineralized with scheelite. Some tungsten-bearing tactite was mined from this deposit, but the grade was sub-commercial.

Pine Mouse and other deposits

High on the west side of Wildhorse Creek Valley about two miles north of the mine camp is the Pine Mouse deposit, which because of its apparent low grade and inaccessibility has not been mined. The tactite is the epidote type but includes some red garnet and feldspar in addition to epidote, scheelite, tremolite, quartz and calcite. The tactite occurs in thin scattered zones and the scheelite is fine-grained.

At the Pine Mouse gneissic inclusions within "alaskite" and migmatite are aligned and the gneissic structure in them has the same attitude as that of the country rock and the tactite bands. The major structural feature in the Pine Mouse-Steep Climb area is a broad northerly trending anticline which apparently has been thrust eastward over a steep, broken east limb and then cut by high-angle longitudinal faults.

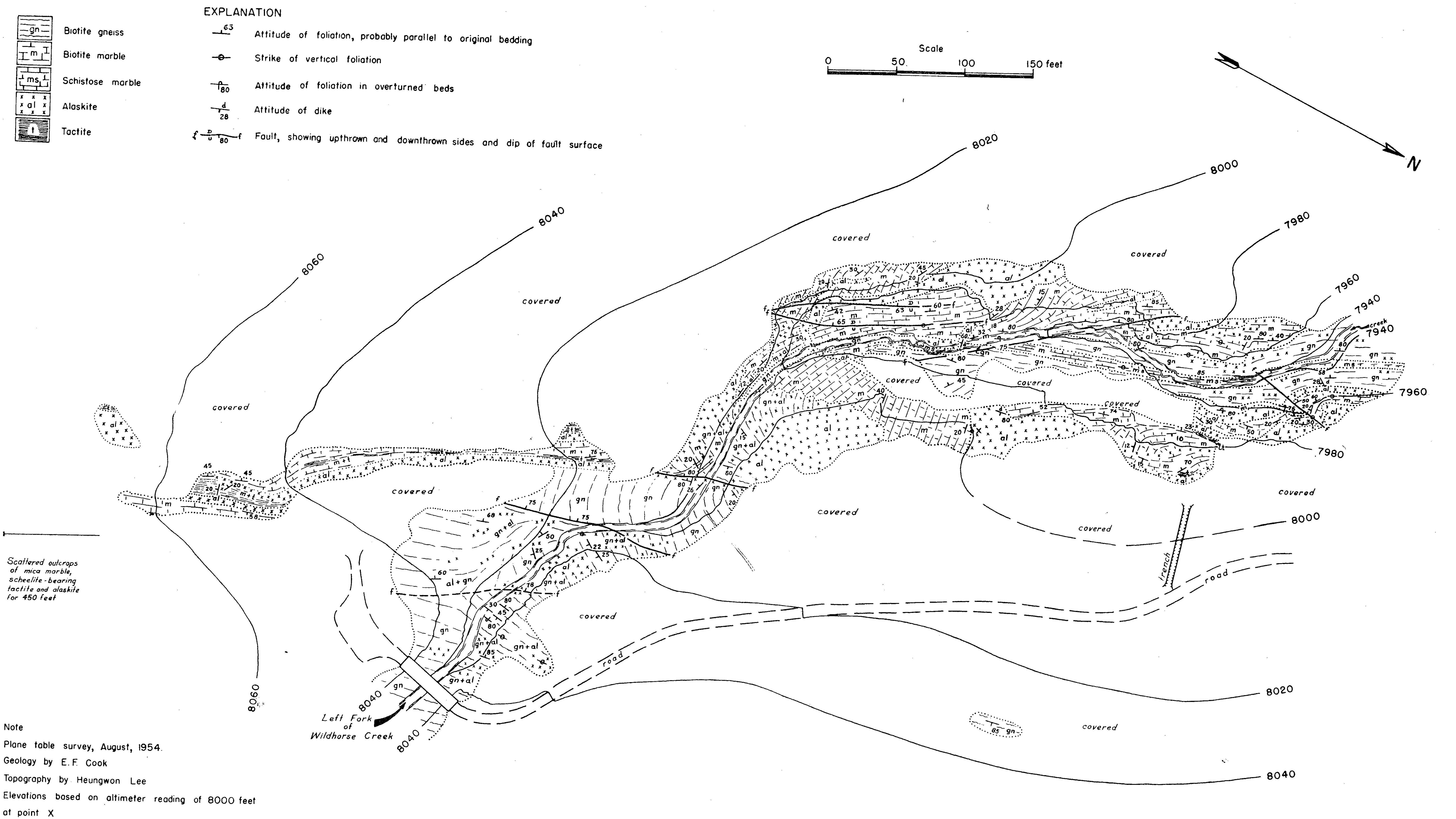


FIG. 7

GEOLOGIC MAP OF HARD TO FIND DEPOSITS, WILDHORSE MINE

ALTO DISTRICT, CUSTER COUNTY

EXPLANATION

gn	Biotite gneiss	m	Biotite marble	t	Tactite	al	Alaskite

Note:
Tape and compass survey, July, 1954
Elevations based on altimeter readings

. . . . Geological Contact

43 Attitude of Foliation

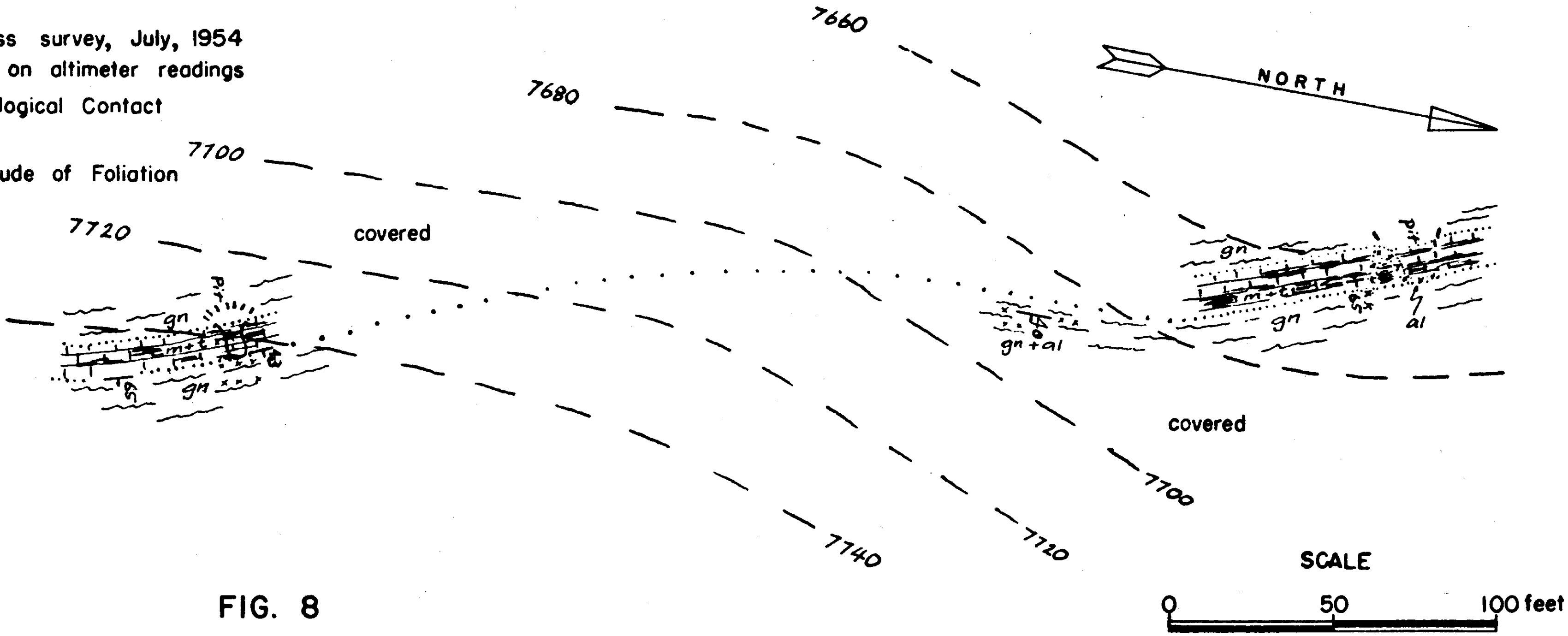


FIG. 8

GEOLOGIC MAP OF THE BEAVER DEPOSIT, WILDHORSE MINE
ALTO DISTRICT, CUSTER COUNTY

A few scattered occurrences of scheelite have been found along Boulder Creek, three to four miles north of the mine camp.

Outlook and guides to prospecting

The outlook is favorable for this area. The geology does not favor the discovery of large deposits of tungsten ore, but does favor the finding, by geologic means, of relatively small but profitable ore bodies. There is no reason to believe that the necessary alaskite-micaceous marble association is limited to the known deposits or that these deposits necessarily have shallow depth.

The guides are simple, the finding difficult because of vegetation and talus. Ore is found only in tactite; tactite is restricted to intersections of alaskite and impure marble; therefore tungsten should be sought at or near such intersections.

Summit Creek area

Phi Kappa Creek deposit (4a)

Tungsten is said to have been discovered as early as 1925 in ore from a copper prospect on Phi Kappa Creek. This property is in T. 6 N., R. 19 E. Custer County, on the east side of Phi Kappa Canyon about 1½ miles south of its junction with Big Lost River. The country rock is dark fractured argillite of the Ordovician Phi Kappa formation. Tactite as much as 50 feet wide has formed by local replacement of limy layers in the argillite. Fine-grained red garnet is the main constituent of the tactite, which also contains considerable diopside, some epidote, calcite and quartz. In places unaltered dark gray limestone grades along strike into massive garnet-epidote tactite. The beds strike a little west of north and dip about 65° east. Quartz monazite dikes and sills extending from a much larger body which lies to the north, penetrate the argillite but there appears to be no close spatial connection between such bodies and the occurrence of tactite. Although much of the tactite is barren, locally there is considerable fine-grained scheelite, especially along fractures. Umpleby, Westgate and Ross (1930, pp. 110, 206) were impressed by the differential alteration in the neighborhood of this deposit:

> "In the Phi Kappa deposit...a single bed of limestone about 6 feet wide has been almost completely transformed to lime-silicate minerals...for a distance of about 6,000 feet, whereas nearby shaleand quartzite beds are in most places but little altered...The intensely altered beds contain much garnet (grossularite) and lesser amounts of diopside, epidote, augite, calcite, quartz, magnetite, and prehnite. The sulphide minerals pyrite, chalcopyrite, galena, and a little sphalerite are scattered irregularly through the lime-silicate rock as bunches, lenses and isolated grains."

Little Falls Creek deposit (4b)

On the east side of Little Falls Creek about one-half mile north of the Trail Creek road is a scheelite prospect. The property is in section 17, T. 6 N., R. 19 E., Custer County, about 15 miles northeast of Ketchum.

The scheelite is found near a contact between quartz monzonite and rocks of the Ordovician Phi Kappa formation. The quartz monzonite is a white, resistant rock, medium-grained, consisting of feldspar, quartz, and scattered flakes of biotite; this is part of the same body which is exposed near the scheelite occurrence on Phi Kappa Creek and near a wolframite-bearing vein on Big Falls Creek. On Little Falls Creek the Phi Kappa formation consists largely of gray to black argillite with a little intercalated limestone and limy argillite.

The contact dips about 45° east (into the hill) and strikes about N. 40° W.; the bedding in the underlying argillite strikes N. 20° W. and dips only 20°-25° east. In other words the contact cuts obliquely across a portion of the Phi Kappa formation, bringing the quartz monzonite into contact with different beds at different points along the contact.

Two pits on the property have exposed scheelite. One of these, about 15 feet long, is at the contact; the other, smaller, is about 30 feet from the contact, in the Phi Kappa formation. At the contact pit the scheelite occurs mainly along fractures within the quartz monzonite. The rock has been bleached by hydrothermal solutions outward from these fractures up to three inches. The scheelite occurs in thin veinlets in the central parts of the bleached zones. These veinlets are composed of quartz, scheelite (up to 0.1 inch), and an unidentified black mineral which, according to D. Schmidt (personal communication), is radioactive. Schmidt suggests that the dark mineral may be samarskite or brannerite.

Four samples taken in the contact pit by government geologists gave the following results:

6 feet, horizontal, across northwest end...........1.55% WO_3

6 feet, vertical, at northeast corner............. 0.28% WO_3

6 feet, vertical, near southeast corner............0.15% WO_3

4 feet, vertical, on contact in middle of southwest side.... 0.94% WO_3

These samples show that the tungsten content decreases from the contact into the quartz monzonite. Although this contact is exposed for several hundred feet, scheelite has been found only at this one locality.

In the smaller pit, which is within the Phi Kappa formation, scheelite in fine specks and grains is found in a calcareous layer 2-3 feet thick which locally contains lenses of fine-grained biotite up to two feet wide. The scheelite is found on bedding planes and along fractures in this dark, iron-stained calcereous argillite; most of the scheelite fluoresces yellow, indicating relatively high molybdenum content. A little coarse-grained quartz accompanies the scheelite. Where scheelite occurs the rock does not effervesce; where the scheelite mineralization disappears along strike the argillite effervesces freely. In its mineralized portions the rock has been silicified, suggesting that the tungsten was introduced with siliceous solutions. Non-calcareous argillite between this mineralized bed and the quartz monzonite has been silicified but contains no scheelite. The scheelite deposition here, as in many other places, seems largely dependent on the existence of a calcareous bed in the argillite, as well as structure convenient for the migration of tungsten-bearing solutions or tungsten ions.

No tactite was seen in the two pits. At a small pit about 200 feet southwest of the scheelite locality, a 3-foot bed of recrystallized limestone has been locally and partially replaced by garnet-epidote tactite, which is greatly iron-stained by the oxidation of pyrite and chalcopyrite contained in it. No scheelite and no quartz were found in this isolated mass of tactite.

Meadowview mine (5a)

Scheelite and metallic sulphides are found in the Meadowview mine, near the headwaters of Fourth of July Creek, approximately in T. 8 N., R. 15 E., Custer County, about 23 miles southeast of Stanley. The mine is in marble and argillite, probably of the Carboniferous Milligen formation, not far from a contact with quartz monzonite of the Idaho batholith.

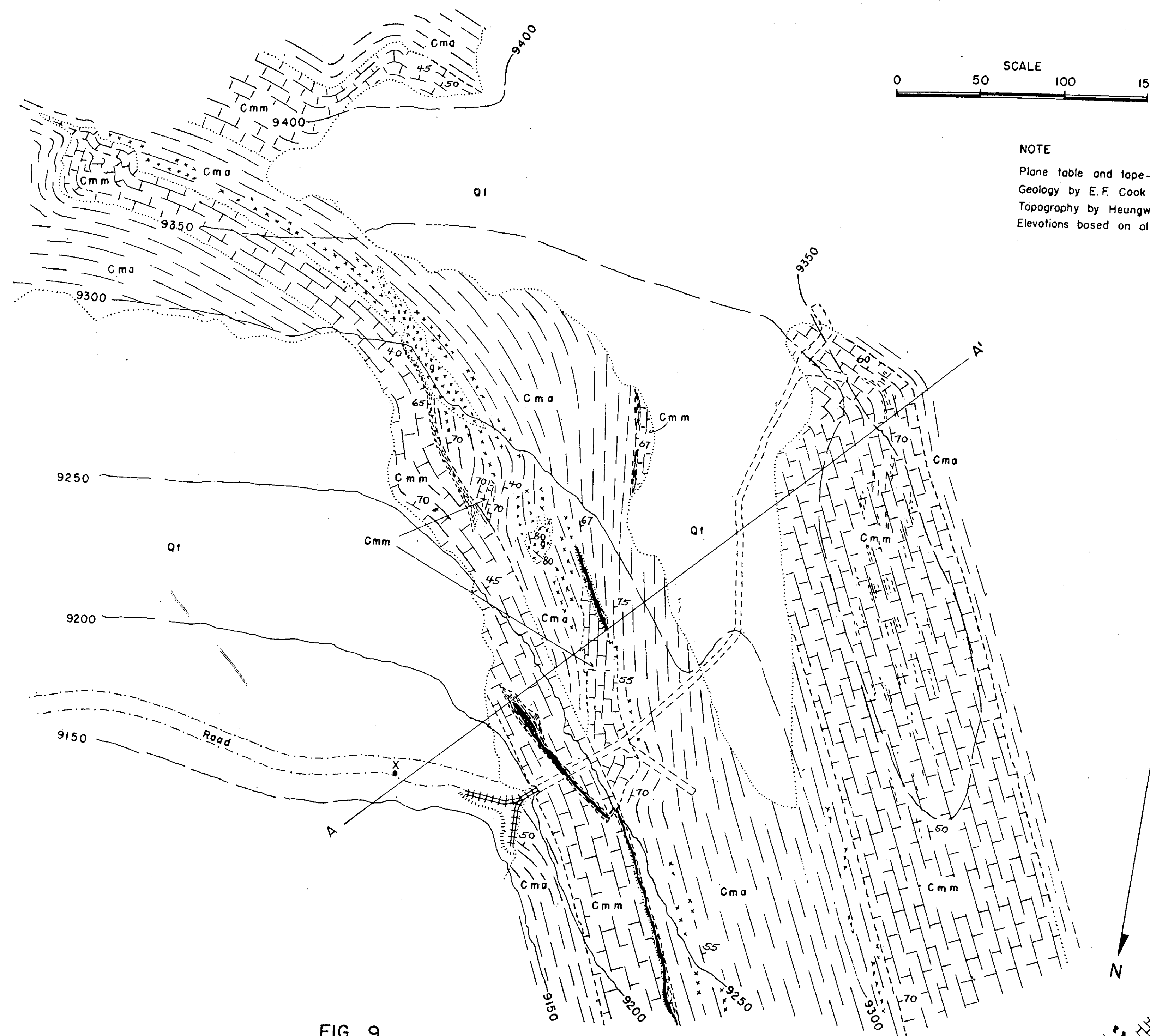
Two veins, both lenticular in plan (see map Fig. 9), have been explored by workings on a single level. The ore bodies, largely composed of pyrrhotite, chalcopyrite, and sphalerite, are replacements in the marble beds which lie between bands of argillite. Weighted assays of samples taken by D. M. E. A. geologists are as follows:

	WO_3	Zn	Ag
No. 1 vein - average width 3.9 feet,	0.27%	5.2%	0.28 oz./ton
No. 2 vein - average width 5.3 feet,	0.30%	7.2%	0.36 oz./ton

Neither dikes nor intrusive contacts appear to be closely associated with the ore. However, there is a general relationship of ore to the local formation of "contact" minerals and igneous-appearing rock. The marble near the veins has been altered to a light-colored tactite consisting of dippside, tremolite, wollastonite, vesuvianite, and a little

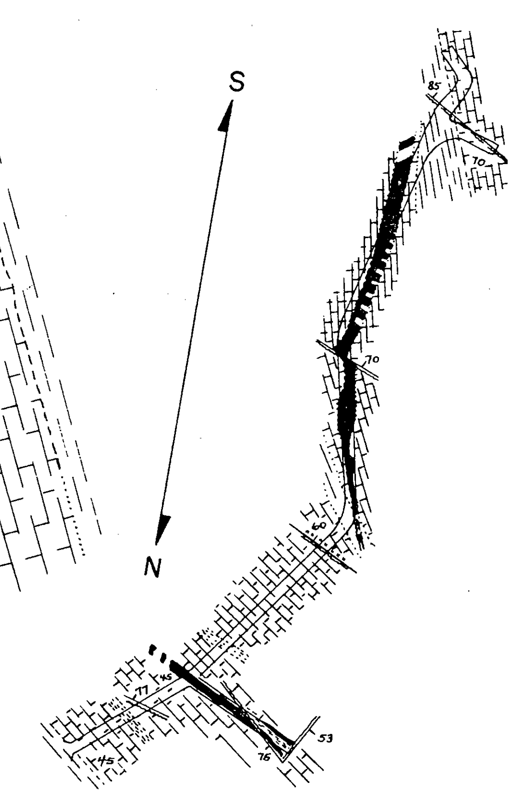
EXPLANATION

Qt	Talus	
Cma	Argillite	Milligen formation
Cmm	Marble	Milligen formation
g	Granitic rock	
	Tactite	
	Sulfide ore	
50	Attitude of bedding	
77	Fault, exposed underground	
?	Inferred fault, cross-section	
	Geologic contact, accurately located	
	Geologic contact, approximately located	



NOTE

Plane table and tape-compass surveys, July, 1954
Geology by E. F. Cook
Topography by Heungwon Lee
Elevations based on altimeter reading of 9170 feet at point



UNDERGROUND GEOLOGIC MAP

FIG. 9

SURFACE GEOLOGIC MAP OF THE MEADOWVIEW MINE
EAST FORK DISTRICT, CUSTER COUNTY

epidote. Small aplitic-pegmatitic dikes of probable replacement origin cut both marble and argillite on the ridge above the mine, and in this same locality the marble contains garnet, hornblende, tremolite, epidote and quartz; the calcite in the marble is coarser in the neighborhood of the dikes and the tactite than elsewhere. In the vicinity of the dikes the marble has been strongly silicified Although some of the replacement dikes cut marble, they appear thicker and more numerous in artillite; this may be due either to chemical affinity, the argillite being closer in composition to granite than is marble, or to the greater development of solution-guiding fractures in the argillite during deformation.

It seems that the formation of igneous-appearing dikes, the development of tactite and mineralization at the Meadowview mine all formed a single sequence of closely related events brought about by what may be called hydrothermal metamorphism. Hot rising solutions (or diffusion ions) guided by favorable structures, locally transformed argillite to granitic rock, and marble to tactite; then with declining temperature and change in character of the solutions, silica permeated marble and argillite outward from the newly formed dikes, and locally replaced the dikes themselves Perhaps coincident with this silicification was the deposition of the sulphides and scheelite in marble which had been partly replaced by "contact" minerals and which was therefore the most favorable host for the metals.

<u>Washington Basin deposit (5b)</u>

About two miles south of the Meadowview mine and separated from it by a ridge 9,500 to 10,500 feet in elevation is the abandoned mining camp of Washington Basin. Washington Basin is close to Washington Peak, at the head of one of the tributaries of upper Germania Creek. Scattered scheelite occurs in one of the principal veins of the camp, the geology of which has been described by Umpleby (1914, pp. 245-6):

> "...a thick series of sedimentary beds [has been] invaded by masses of porphyritic quartz monzonite. The sedimentary rocks include fine-grained quartzite overlain by dark-colored massive dolomitic limestone, which grades into a succession of alternating blue and white limestone and next into black slate..
>
> "The Empire vein or ledge strikes N. 25° E. and dips 55° S.E. It is entirely enclosed in the porphyritic granite [sic]... Its average width is about 30 feet---The vein material is coarse-grained bluish quartz and partly replaced quartz monzonite...In the southern part pyrrohtite, with about an equal amount of intermixed quartz and diopside, forms a band 15 to 20 feet wide next to the hanging wall. Thin sections of this material show clearly that the pyrrhotite replaces quartz monzonite the quartz of which remains. The feldspar and biotite crystals are completely transformed to pyrrhotite and diopside."

Within recent years an exploration trench has been dug across the outcrop of the Empire vein in the western part of the camp. The width of the ledge in the trench is 50 feet, about 25 feet of which is massive pyrrhotite. The vein strikes N. 35° E. and dips 85° south The ledge contains some silicified limestone and, although this has not been converted to tactite, it contains a little scheelite. One 5-foot pyrrhotite band also contains some fine-grained disseminated scheelite.

<u>Thompson Creek deposit (6a)</u>

The Thompson Creek mine is about 10 miles northwest of Clayton, at an elevation of 6,600-6,900 feet near the headwaters of Thompson Creek, in section 33, T. 12 N., R. 16 E., Custer County. It is about 16 miles from Clayton by road.

The deposit was discovered by James Clutus in October, 1953, and it has been developed by the Salmon River Scheelite Corporation. Four hundred ninety-three tons of ore containing an average of 0.77 percent WO_3 have been mined and milled, with a recovery of 288 units of WO_3. The mining has been by open pit methods at the outcrop. During the summer and fall of 1955 an adit was being driven to intersect the ore zone at a depth of 300 feet below the outcrop.

The ore is found along a contact between rocks of the Carboniferous Wood River formation and a body of quartz monzonite which is probably an outlier of the Idaho batholith. This contact, which is exposed on the east side of Thompson Creek, 300-400 feet above the creek, strikes northerly and dips steeply eastward into the hill. The hanging wall of the ore zone is quartz monzonite. The contact is irregular and shows much evidence of faulting. The granitic rock has been hydrothermally altered (bleached) up to ten feet from the contact. Large pods of tactite, formed mainly by replacement of limy layers in the Wood River formation but partly at the expense of the granitic rock, are found in the contact zone. This tactite consists of fine-grained garnet, pyrite or pyrrhotite, and quartz. Although the scheelite is found in altered granite as well as tactite, the richer concentrations are in tactite which contains vitreous quartz and is therefore hard and resistant. White-fluorescing scheelite is the main ore mineral although yellow-fluorescing powellite coats fractures in the tactite. The actual ore width ranges from almost nothing to 6 feet, although the ore zone averages perhaps 20 feet in width for 800 feet along the contact; this zone contains pods of ore, much barren tactite and considerable unreplaced argillite and limestone. The footwall of the ore zone is siliceous argillite. The quartz monzonite body is wedge-shaped in plan and tapers out at the southern end of the mined area; this may control the limit of ore in that direction.

No geologic reason can be seen that would limit the downward extent to the ore zone. Thousands of tons of ore running above 0.5 percent WO_3 should be available. The necessity for underground mining and for selective mining will raise the cost above that of an open-pit operation.

Buckskin mine

The Buckskin mine is at an elevation of about 7,500 feet on a tributary to upper Thompson Creek about 9 miles northwest of Clayton in Custer County. It is about one mile southeast of the Thompson Creek mine and may be reached from Clayton by was of the Thompson Creek road.

The mineralized area (see map, Fig. 10) consists of a hill about a half-mile long which rises steeply to as much as 500-600 feet above the adjacent valleys. The hill consists largely of argillite of the Carboniferous Milligen formation. The argillite is dark, thin-bedded, and siliceous and contains thin bands of siliceous limestone. Both argillite and limestone have locally been converted to tactite. The tactite probably imparted the erosion resistance necessary for the formation of the hill. Quartz monzonite is exposed a quarter of a mile southeast and again about the same distance northwest of the mineralized area. At several points on the hill evidence of isoclinal folding of the argillite was seen.

The tactite, which forms several reef-like outcrops transverse to the strike of the rocks and differentially replaces beds outward from these reefs, consists largely of fine-grained red-brown vesuvianite and garnet, with subordinate diopside and vitreous quartz, and local pyrite. Alternating with tactite bands in the reefs are gray-green bands of silicified argillite, consisting mainly of quartz and diopside. Finely disseminated scheelite occurs in bands across the ridges parallel to the sedimentary bedding. In much of the sampling of the deposit this distribution has not been recognized and the samples were cut across the reefs instead of across the mineralized bands. This method of sampling gave a false picture of the mineralization.

The early development work at this property was carried on to explore a sphalerite-bearing quartz vein which crosscuts the argillite in the southern part of the hill. There are smaller, barren veins north of this which have similar orientation. They all are later than the period of tactite development and presumably later than the tungsten deposition, for no tungsten has been found in the veins.

Formation of tactite at the Buckskin mine has been controlled by the location of solution channelways. The best channelways available appear to have been some cross-fractures. Solutions rose along these channelways, replacing both argillite and limestone. Outward from those main channelways migration was along bedding planes and formation of tactite was controlled by chemical favorability and differential permeability. Even within the tactite ridges the chemical nature of the replaced rock determined where the bands of solid tactite would be, and this in turn directed the deposition of tungsten for, as has been explained in the discussion of the Wildhorse deposits, tungsten has a greater affinity for tactite than for any other host rock.

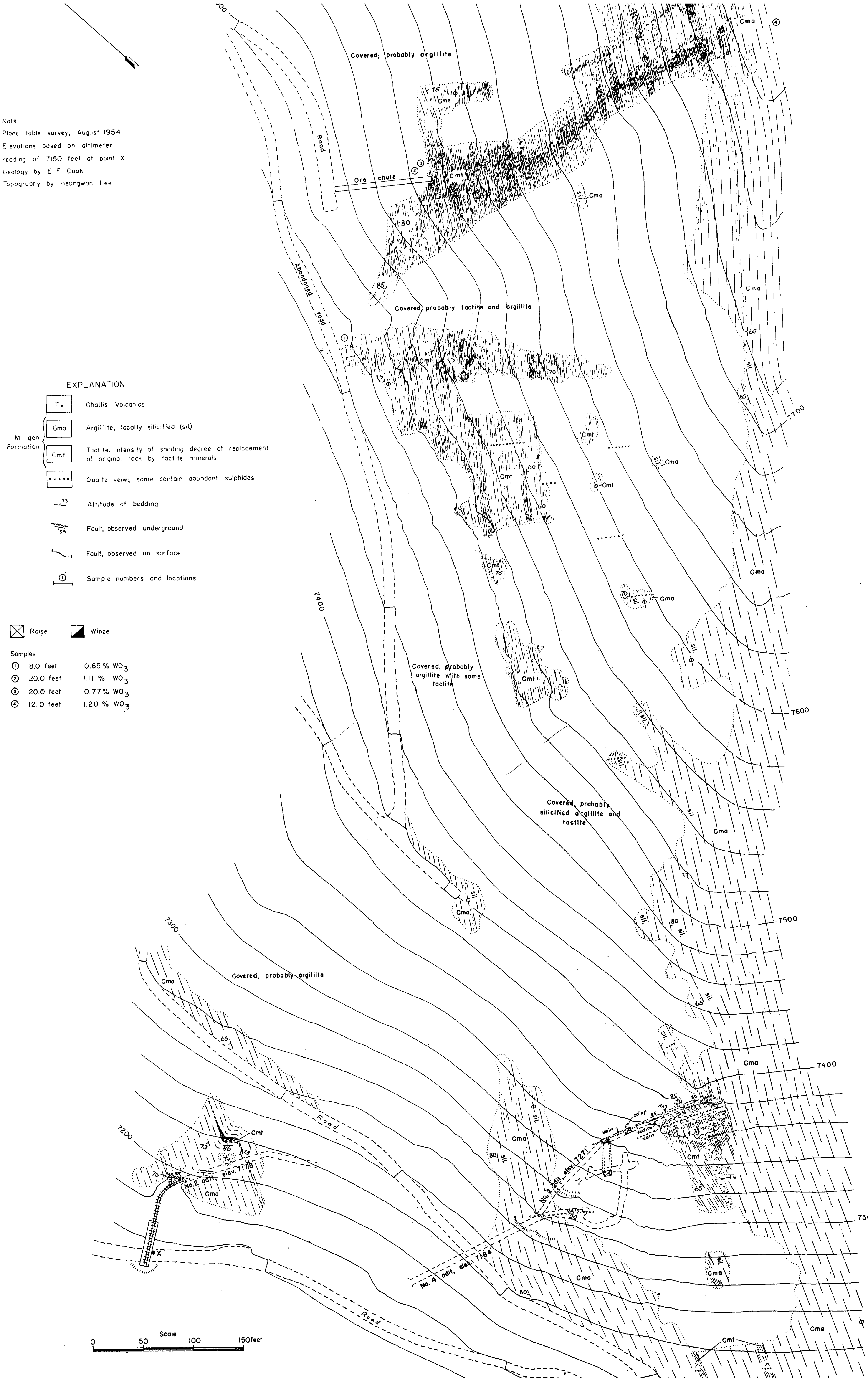


FIG. 10

GEOLOGIC MAP OF BUCKSKIN MINE

BAYHORSE DISTRICT, CUSTER COUNTY

At the Buckskin mine there is some evidence on the age of the mineralization. The mineralization is younger than the inclosing rocks (Carboniferous) and presumably younger than the nearby quartz monzonite (Cretaceous). The tactite is cut at the south end of the hill by a lamprophyre dike which is probably either Oligocene or Miocene in age. Better than this, however, is evidence which shows that the tactite was formed and extensively eroded before the deposition of the Challis (Oligocene) volcanics. In one place on the lower part of the southwest side of the mineralized hill is an erosional remnant, a small scab, of Challis volcanics. Apparently this hill, formed by differential erosion of strong and weak argillite, the strong argillite being that which possessed a reinforcing skeleton of tactite and silicified beds, existed prior to Challis volcanism. These Oligocene volcanics buried the hill, which has just recently been exhumed. Because the minerals in tactite are regarded as having formed at considerable depths, it is perhaps not an unreasonable guess to say that several thousand feet of rock had been eroded from this site before burial by the volcanic material. The mineralization is, therefore, probably late Cretaceous or Eocene in age.

About 150 tons of material from the main reef was taken for a mill test late in 1954. The mill heads assayed 0.13 percent WO_3 and there was no recovery. By selective mining better grade material could be produced from this deposit. A 70-foot adit was driven in late 1954 to explore the main reef.

Springfield mine (7)

The Springfield mine is on the west fork of Springfield Creek, a tributary of Pistol Creek, about 7 miles south of Stibnite in Valley County. It is in section 28, T. 17 N., R. 9 E. Mining of scheelite-bearing talus was begun by the Bradley Mining Company in 1953 and about 20,000 tons of talus bearing 0.4 percent WO_3 was mined and milled but the recovery was poor. Since that time an additional 10,000 tons of bedrock ore assaying 0.3-0.35 percent WO_3 have been mined and milled. The deposit is nearing exhaustion. During 1953 and 1954, 3,625 units of WO_3 were recovered from this operation; during this time about 25 men were employed at the mine.

The ore body is a mass of scheelite-bearing pyrrhotite entirely inclosed in quartz monzonite of the Idaho batholith. The scheelite was found in certain zones in the pyrrhotite but whether or not this reflected sedimentary structure was not determined, there being no remnants of any rock other than the quartz monzonite.

Yellow Pine mine (8)

The Yellow Pine mine near the town of Stibnite in Valley County was the largest source of tungsten ore in the United States from 1942 to 1944. It is now closed.

In January, 1941, in the course of microscopic study of a drill-core specimen from the Yellow Pine mine, which at that time was an antimony property, D. W. White of the U. S. Geological Survey discovered scheelite. As a result of this discovery, tungsten ore was produced from August, 1941, until July, 1945, at which time the ore body was exhausted. A total of 831,829 units of WO_3, worth more than $52,000,000 at the present price, were contained in the tungsten concentrates produced during this period. The ore averaged 1.645 percent WO_3. Cooper (1951, p. 151) gives an informative picture of the geology of this deposit:

> "The main ore bodies occur along the Meadow Creek fault, a shear zone as much as several hundred feet wide cutting... quartz monzonite /of the Idaho batholith/. The ore bodies are localized by changes in strike or dip of the main fault zone and by intersecting subsidiary faults associated with these changes. The tungsten-antimony ore body at the Yellow Pine mine has the general shape of a flat upright funnel flaring to its widest diameter at the surface and tapering to a narrow neck...
>
> "Metallization took place in three stages, with intervening periods of fracturing. The first stage is represented by extensive replacements by gold-bearing pyrite and arsenopyrite, the second by less extensive replacement by scheelite within the gold ore bodies, and the third and final stage by replacements by stibnite and silver, localized in part by the same fractures that localized the scheelite."

Aplite, according to Cooper, is very abundant in the Yellow Pine mine. It is found in small irregular dikes and stringers; locally the coarser phases grade into pegmatite. Away from the ore deposits aplite is less abundant. Cooper (p. 172) believes that the three stages of mineralization are genetically related and that all are Tertiary in age, perhaps connected in origin with the Tertiary igneous activity which is manifested by dikes in the Yellow Pine mine.

Quartz Creek deposit (9)

About two miles northeast of the town of Yellow Pine in Valley County is a quartz vein containing scheelite. The property is about 1½ miles above the mouth of Quartz Creek and may be reached only by trail. Talus below the outcrop was pladered in 1953 by E. F. Kissinger, discoverer of the mine, who recovered (by tabling) 5 tons of 10-15 percent WO_3 and 800 pounds of 60 percent WO_3 concentrates. The mine was not visited during the present investigation.

Profile Gap deposit (10)

A few hundred feet north of the Wilson mine in Profile Gap, on the road between Yellow Pine and Big Creek, is a band of peculiar "tactite" which contains scheelite and is reported to average 0.5 percent WO_3. The bulldozer cuts which have exposed this "tactite" are about 400-500 yards southwest of the highway through the Gap and at an elevation of 8,000 feet, probably in sections 24, T. 20 N., R. 8 E.

The scheelite-bearing zone strikes a little east of north and dips steeply. It is inclosed between granitic rocks and is cut by lamprophyre and quartz latite porphyry dikes. The scheelite seems to be sporadically distributed in a band of dense green rock which is locally called tactite, although it resembles no other tactite seen during this investigation. The rock has a structure of braided or anastomosing shears and consists of lenticles of calcite in irregular stringers of zoisite, clinozoisite, vesuvianite, fluorite, and quartz. To the south this "greenstone" grades into a hard green altered tuffaceous conglomerate which in turn gives way to fine-grained, greenish-gray granitic rock which has been mapped as part of the Idaho batholith by Shenon (Shenon and Ross, 1936, Fig. 3). The greenstone band is a discontinuous and in reality consists of a line of lenses up to 35 feet wide, locally the greenstone contains some pyrite or pyrrhotite, chalcopyrite, and molybdenite. A grab sample from a scheelite-bearing zone within one of the greenstone lenses assayed 0.24 percent WO_3.

Smith Creek deposit (11b)

High on the south side of the valley of Smith Creek about 4 miles northwest of the town of Big Creek in northern Valley County is a poorly exposed scheelite deposit. At the base of a cliff are boulders containing large scattered crystals of scheelite in an amphibole tactite containing tremolite-actinolite, calcite, muscovite and some pyrite or pyrrhotite as well as a little garnet. On the hill above this talus, a sequence of siliceous argillite and thin-banded argillaceous quartzite, is exposed, striking N. 25°-45° W. and dipping 40-80° east. Limy bands in the argillite have been partially converted to amphibole-garnet tactite. No scheelite was found in the tactite in place; the proveniance of the talus boulders is unknown. Quartz monzonite of the Idaho batholith is exposed a short distance below the boulders, and it may well be that a valuable tungsten deposit lies concealed at the contact between the argillite and the granitic rock.

Croy Creek deposit (15)

Sporadic low-grade scheelite deposits have been found near the border of a large outlier of the Idaho batholith about 11 miles southwest of Hailey, just north of the eastern end of the Hailey Gold Belt. Most of these occurrences are in section 4, T. 1 N., R. 17 E., Blaine County.

Biotite quartz monzonite has in this area intruded a metasedimentary sequence of argillite, quartzite, and recrystallized limestone of the Pennsylvanian Wood River formation. These metasediments have not been greatly disturbed by the intrusion, for they have a rather uniform attitude throughout the area of tungsten outcrops, striking north to N. 20° W. and dipping an average of 60° west. Metamorphism near the contact has been mild, consisting in silicification of the shale and sandstone, as well as recrystallization and local development of garnet and epidote in the limestone, especially in layers parallel to bedding.

Both the quartz monzonite and the metasedimentary rocks have been cut by later alaskite dikes containing pink feldspar and local segregations of quartz and pegmatitic quartz-feldspar.

The garnet-epidote rock developed locally where the quartz monzonite has truncated limestone layers in the metasedimentary series contains scheelite only near the alaskite dikes (described as aplite by Anderson and Wagner 1946b, p. 6). In addition scattered grains of scheelite are found in silicified bands, some of which parallel and some of which transect the limestone bedding, containing diopside, plagioclase, epidote, and quartz. Although the formation of tactite appears to have accompanied the intrusion of quartz monzonite, the tungsten and silica-bearing solutions were introduced with the later "alaskite" dikes.

Although some of the rock is reported to assay 0.5 percent WO_3, there seems little hope of developing commercial tonnage.

<u>Mackay area (16)</u>

Phoenix mine (16a)

The Phoenix mine, on a ridge near the head of Mammoth Canyon, about three miles west of Mackay in Custer County, contains powellite mineralization concentrated along shear zones (see map, Fig. 11). The mine is in the contact zone of the White Knob stock and an adit cuts granite of the stock, recrystallized limestone or marble, and red-brown garnet, tactite, as well as a rhyolite dike 30-50 feet thick.

Some scheelite can be found in an old pit on the surface, a pit which exposes a mass of coarse, black, red-brown and olive-gray garnet. Some scheelite was found also on joints in the bleached rhyolite dike. Most of the scheelite, however, is concentrated along northeast-trending shear zones in tactite. The shear zones strike northeast and dip steeply northwest; the inclosing marble and tactite strike northeast but dip a little more flatly to the northwest.

The scheelite partially fills cavities in massive garnet and is not associated with quartz as is the scheelite of many other deposits. Some molybdenite is associated with the scheelite; the molybdenite fills fractures in the tactite. The garnet is intensely fractured, the scheelite much less so. Although good assays are reported from this mine, the restriction of ore to relatively narrow shear zones

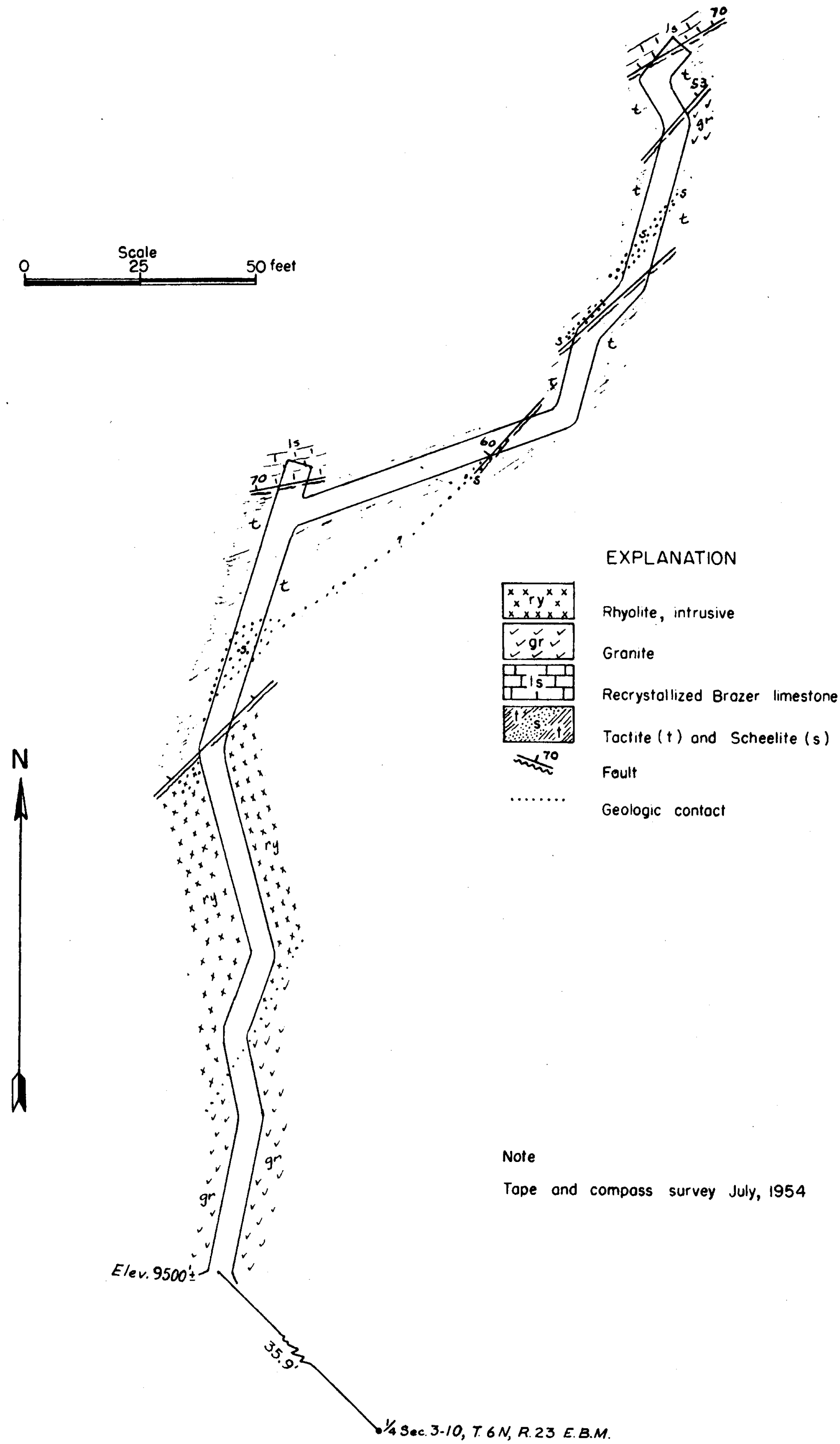


FIG. 11

UNDERGROUND GEOLOGIC MAP OF THE PHOENIX MINE

ALDER CREEK DISTRICT, CUSTER COUNTY

will make mining costs high.

All the mines in and adjacent to the White Knob intrusive are in T. 6 N., R. 23 E., Custer County.

Empire mine (16b)

A carload of tungsten ore was shipped in 1942 from the Empire mine, the most productive and best-known of the Mackay mines, situated high on the hill just about two miles west of Mackay. The tungsten ore came from a winze stope below the 1,000 level; the winze is now flooded but the 1,000 level is open and accessible. The average assay of four samples from the tungsten ore awaiting shipment and the assay of the carload are given below (from Farwell and Full, 1944, p. 11):

	Ounces/ton		Percent	
	Au	Ag	Cu	WO_3
Four samples	0.24	1.75	3.28	4.28
Carload (55.425 tons)	0.105	1.35	2.45	2.08

Only the tungsten content was paid for by Metals Reserve Corporation and no further shipments were made.

Farwell and Full describe the ore of the Empire mine as follows:

"The hypogene copper ores are composed of garnet, diopside, and other lime silicates that carry disseminations and sponge-like aggregates of metallic minerals. Chalcopyrite is the principal sulphide and is accompanied by pyrite, pyrrhotite, calcite, and quartz. Magnetite, fluorite, scheelite, molybdenite, sphalerite, specularite, and rare bornite are less widely distributed... Scheelite is present in the copper ores in minable amount in only a few places."

Vaught mine (16c)

On Cliff Creek, about 500 feet north of the creek and 200 feet above creek level, a few hundred yards above the road from Mackay (and about three miles southwest of Mackay) are some old workings known as the Vaught mine. The workings, which extend over 200 feet into the hillside, explore a contact zone between granite and limestone. Powellite is rather abundant in the mine, and the bright yellow fluorescence gives a false sense of the amount of tungsten present. Two samples of tungsten-bearing tactite taken by the author assayed as follows:

Width	WO_3	Mo
42"	0.08	0.044%
36"	0.30%	0.049%

Broken garnet tactite up to five feet thick contains small yellow-fluorescing powdery powellite grains. The granite is soft and bleached and has some powellite on fractures. Although the limestone is fractured, it does not contain powellite.

The U. S. Geological Survey sampled this mine with the following results:

Width	WO_3
60"	0.16%
51"	0.12%

Hanni mine (16d)

Eleven tons of scheelite ore were mined in November 1953 from a point near the portal of a short adit high on a steep slope at the head of Cliff Creek. The shipment assayed 1.60 percent WO_3 but no more ore has been found. The prospect is in a tactite band about 20 feet wide which forms the transition between granite and silicified limestone. Yellow-fluorescing scheelite or powellite occurs together with pale garnet on cross fractures which trend east-west and dip 85 degrees south. The marble and the contact strike N. 25° W. and dip 55° west. A sample was taken across 2.5 feet of fine-grained hard vitreous gray-green tactite on the surface near the main adit. This sample assayed 0.13 percent WO_3. Microscopic examination revealed that this "tactite" consists largely of plagioclase feldspar, magnetite, and quartz; it is evidently highly altered granite rather than metamorphosed limestone.

Copper Queen mine (16e)

At the head of the east fork of Navarro Creek, about 4 miles northwest of Mackay, are the Copper Queen workings. These are on a marble-granite contact which strikes north and dips 45-65 degrees east, as does the marble. In places 3-8 feet of tactite has formed along the contact and scheelite is reported to occur in the tactite.

North Fork of Wood River deposit (17)

About 12 miles north of Ketchum in section 25, T. 6 N., R. 16 E. is a scheelite deposit in a tactite zone between quartz diorite porphyry and impure limestone. The deposit outcrops on the southern slope of Boulder Peak about 800 feet above Boulder Creek, which is tributary to the North Fork of Wood River. There is considerable epidote but not much garnet in the tactite, which has an average width of perhaps three feet and can be traced 50 to 75 feet along strike (H. Powers, personal communication). Samples are reported to assay between 0.5 and 1.0 percent WO_3.

Other occurrences

Scheelite has been reprted from several mining districts of Idaho County. In 1877 scheelite was identified by Benjamin Silliman in a specimen of gold quartz from the Charity vein in the Warren district. Since that time scheelite has been reported from several of the gold-bearing veins of the Warren area. Scheelite in grains and small masses disseminated in quartz has been found near Newsome in the Ten Mile district, about 12 miles northwest of Elk City (Shannon 1926, p. 470). Scheelite and wolframite are reported from several mines at Buffalo Hump (Kerr 1946, p. 122).

Powellite was first described as a new mineral from its occurrence in the Seven Devils mining district in Adams County. The tungsten deposits of this district have been discussed in another publication (Cook 1954).

A reported scheelite property on Logan Creek about 3 miles southwest of the town of Big Creek in northern Valley County was examined during this investigation. A body of white quartz over 80 feet wide is exposed. Scheelite and molybdenite are contained in specimens presumably from this property but none was found during the examination.

A. L. Anderson (personal communication) in 1942 found some scheelite in a quartz vein at the U. P. mine a few miles northwest of Salmon City in Lemhi County; some of the scheelite is in micaceous wall rock. The grade was estimated at 0.2 percent WO_3 or less.

Harry McClure of Custer reports finding scheelite at several localities in Custer County. He has specimens from near the junction of West Fork and Yankee Fork (near the town of Bonanza) which are composed of fine-grained epidote-garnet-quartz tactite containing disseminated scheelite. These specimens are from a "lime dike" in granitic rock. McClure has also found scheelite on Copper Creek in section 19, T. 11 N., R. 14 E., about 5 miles northeast of Stanley; specimens from this locality show powellite in recrystallized limestone. McClure further reports finding scheelite on a contact between the Idaho batholith and the Wood River formation on Peach Creek about 2 miles above its mouth (4 miles east of Sunbeam Dam) and again along a granite-limestone contact about 2 miles south of the Livingston mine in T. 9 N., R. 16 E.

A deposit of molybdenite and scheelite near the head of Little Boulder Creek about 6 miles south of the Livingston mine has been reported.

In the south end of the Horseshoe group of claims north of the Empire mine near Mackay, a copper-lead prospect being explored in 1954 had disseminated scheelite in the face of a new drift.

Scheelite has been reported in an "iron dike" near a hot spring on Big Smoky Creek about two miles east of Soldier Ranger Station in northern Camas County.

BLACK TUNGSTEN DEPOSITS

Lava Creek district (1)

Both powellite and huebnerite have been found in the Lava Creek district, neither in commercial quantities. The huebnerite occurrence is described by Anderson (1929, p. 68-69):

> "The Wolframite prospect, containing huebnerite as its ore mineral and curiously named after the iron tungstate, wolframite, lies near the very summit of Blizzard Mountain at an elevation of approximately 9,350 feet. The outcrop is about 200 yards northwest of the triangulation monument on Blizzard and on the crest of the ridge over-looking the head of Lava Creek...
>
> "The tungsten occurs in a greatly brecciated zone at the contact of...Miocene (?) granite and...Mississippian limestone and quartzite and is in part in granite and part in sediment. Apparently the movement has followed very closely the intrusive contact and has brecciated both the invading rock as well as the invaded rock. The zone of brecciation extends N. 30° E. and dips steeply to the northwest. The vein ranges from two feet to five feet in width and is made up of veinlets and bunches of quartz in the crushed igneous and sedimentary rock. The granite shows intense hydrothermal alteration and has much sericite and a little chlorite in it. The fragments of rock are in the main crusted by quartz crystals which point inward toward a well-defined median plane with drusy surface. Vugs lined with inward-projecting quartz crystals are very numerous and quite characteristic of the vein filling. The huebnerite occurs in scattered platy aggregates and isolated plates in the coarse-textured quartz...
>
> "Development has not been extensive...Little of the huebnerite is to be seen in the manganese-stained rock and fresh specimens of either the huebnerite or its oxide, tungstite, are difficult to find. Apparently, the lode has been only lightly mineralized, and judging from development efforts is not considered promising."

The Wolframite prospect is in the south central part of section 13, T. 2 N., R. 23 E., Butte County.

Big Falls Creek deposit (4c)

An occurrence of wolframite in quartz is found near the junction of Big Falls and Summit creeks, about 14 miles northeast of Ketchum.

The quartz constitutes a flat-lying vein averaging perhaps 6 feet in thickness. It has been explored by surface pits and by an adit 140 feet long. The vein is in dark, iron-stained argillite of the Phi Kappa formation a few tens of feet above its contact with a pale gray quartz monzonite body which outcrops on both sides of Summit Creek. The quartz vein is variable in width (0-8 feet) and contains some argillite inclusions. The wolframite occurs in sporadic concentrations of bladed crystals; cavities and coarsely crystalline quartz are associated with the wolframite. The ore is spotty and would have to be selectively mined.

McRae mine

The McRae Tungsten Corporation operates a mine about 5 miles northwest of the town of Big Creek at an elevation of about 8,000 feet. The ore minerals are huebnerite and scheelite in a 2:1 ratio. Ore has been taken from two groups of claims, known as the Red Bluff and the Snowbird. About 400 tons had been mined and milled at the property by August 1954. The millheads have averaged 0.98 percent WO_3.

The Snowbird was discovered in 1942, mined in 1944, then was dormant until about 1952, at which time mining was recommenced. Surface assays average 1.75 percent WO_3 over widths of four to nine feet. The vein quartz exposed in the adit contains local segregations of coarse sericite or muscovite as well as scattered pyrite and fluorite.

The vein at the Red Bluff property is in granitic rock which contains aligned phyllitic and quartzitic inclusions; these inclusions have gradational contacts with the granite which locally contains foliated muscovite. The vein material itself is banded because of phyllitic inclusions. Some post-mineral faulting has produced clayey gouge especially on the hanging wall. The vein, which dips steeply east and strikes N. 12° W., contains, in addition to quartz and huebnerite, some rhodonite, pyrite, and minor sphalerite, galena, and chalcopyrite. Pyrite was noticed also in the phyllite inclusions and the nearby granite. The Red Bluff deposit was discovered in 1952, drilled and developed 1952-54; the only production is about 30 tons mined in early 1954.

Two deposits south of the Red Bluff have not been mined. One of these, the "upper south side outcrop" is a lens of replacement quartz cross-cutting quartzite. Within the quartz body are several bands of ore which lie parallel to the bedding in the surrounding quartzite; ore deposition was apparently controlled by differences in the nature of the replaced rock. The quartz lens averages five feet in thickness and the bands of ore assay 0.37 to 2.87 percent WO_3. The second deposit, known as the "middle south side outcrop," 10 feet in maximum width, is similar except that it is enclosed in igneous rock, granite on the east, dacite on the west. The two ore zones in this quartz lens assay 0.03 to 1.98 percent WO_3 and again are parallel to the general bedding in the nearby quartzite.

Whitehawk Basin deposit (12a)

In Whitehawk Basin west of Bear Valley in southeast Valley County are some huebnerite deposits (A. E. Chambers, personal communication) assaying as high as 30 percent WO_3 but found only in thin quartz veinlets and stringers in bleached granite. The veinlets follow fractures which strike north to N. 70° E. In the same area are many pegmatites and many small barren quartz veins. The pegmatites, according to Chambers, seem to bear no relation to the ore.

Deadwood Reservoir deposits (12b)

Wolframite occurs as reddish to brownish cleavable masses disseminated in quartz at the Horsefly prospect and as very black indistinct friable material in vuggy quartz coated with a thin layer of chalcedonic silica in specimens from the Merry Blue mine, both in the Deadwood Basin (Shannon 1926, p. 467).

According to Kerr (1946, p. 120) these mines are 4 miles northeast of Deadwood Dam. The vein at the Merry Blue mine has been explored by 1,000 feet of workings; the vein is about 2 feet thick and was once mined for gold.

Ima mine (13a)

The geology of the Ima mine has been ably presented by Callaghan and Lemmon (1941) and Anderson (1948). The following brief discussion is taken almost entirely from their papers.

The Ima mine, owned by the Bradley Mining Company, is in section 23 of T. 14 N., R. 23 E., on the north side of Patterson Creek, a mile upstream (east) from the small settlement of Patterson, on the east side of Pahsimeroi Valley. Patterson is 68 miles southeast of Salmon and 56 miles north of Mackay by road. Tungsten was discovered at the Ima mine in 1903 in veins which had previously been prospected for silver and gold. Two shipments of tungsten ore were made in 1913 and shipments were made sporadically until 1936, in which year steady production started and has continued with few interruptions to the present time.

In the vicinity of the Ima pre-Cambrian quartzite of the Belt series has been folded into a northwesterly trending anticline. The Ima vein zone has a northwesterly trend, parallel to the trend of the arch in the quartzite.

The veins fill a complex group of fractures in quartzite near the borders of a granite body that does not crop out but is exposed in underground workings. Anderson has presented evidence that this granite formed through granitization of the quartzite and he believes that it represents an early intense type of wall-rock alteration, with the sulfide and tungsten mineralization occurring as later and cooler phases of the same process.

The vein filling is mainly quartz, which incloses fluorite, orthoclase, rhodochrosite, huebnerite, pyrite, tetrahedrite, molydenite, and minor amounts of other minerals. The minerals other than quartz have a rude zonal arrangement with reference to the granite. Huebnerite occurs mainly in the wider parts of the veins, and ore shoots are confined to the relatively large veins close to the granite.

The ore mined has an average content (1954) of 0.5 to 0.7 percent WO_3. Ninety men are employed at the property and the daily production is 180 tons.

Beverly Ann property (13b)

Adjoining the Ima property on the north is the Beverly Ann Group of claims. The principal showing is a lenticular quartz-huebnerite vein striking N. 15° W. and dipping 55° north. This vein, which is in bleached quartzite, has a maximum width of about 16 inches and has pinched out in the face of a 35-foot adit driven to explore it. The vein is not banded; in other words, there has been none of the recurrent fracturing during mineralization which is evident in the rich veins of the Ima mine. The grade of the vein material is good (perhaps 2 percent WO_3) but the vein is narrow and discontinuous.

Soldier Mountain deposit (14)

According to Shannon (1926, p. 468):

> "Ferberite occurs in three narrow parallel quartz veins one to 10 centimeters wide and about 50 cm. apart in trachyte or syenite porphyry on Corral Creek near Soldier Mountain in Camas County. The rock is light colored with prominent white phenocrysts which are completely kaolinized in the vicinity of the mine. The ferberite fills fractures in the brecciated rock and occurs as drusy crystals lining open spaces."

The country rock is probably nearer to quartz monzonite in composition, because it forms part of the Idaho batholith. The single vein currently being mined contains ferberite in a quartz filling between breccia fragments in a narrow fracture zone which strikes N. 55° E. and dips 50° north and is one of a set of fractures with similar attitude which cut the rock of the batholith in this area. The vein, which has an average width of approximately 1½ inches, has been explored by an adit about 200 feet long. The ferberite is concentrated near the borders of the vein and in bands around breccia fragments of highly altered quartz monzonite. The quartz is chalcedonic. The deposit apparently formed under epithermal conditions.

In 1953 the present operator of the property, Charles Ford, shipped 10,630 pounds of hand-sorted ore containing 3.28 percent WO_3. In 1943 1.304 tons of 9 percent ore were shipped.

SUGGESTIONS TO PROSPECTORS

MINERAL LIGHT AND ACID BOTTLE

Ultra-violet rays cause certain minerals to glow or fluoresce. Ultra-violet lamps, commonly called mineral lights or black lamps, are the most useful tool in prospecting for these minerals. Both scheelite and powellite fluoresce brilliantly; even minor amounts of these minerals can be detected by means of the lamp. Without the mineral light scheelite is difficult to locate because it may resemble certain worthless gangue minerals and because it commonly occurs in small grains and crystals.

Pure scheelite fluoresces bluish white. A golden yellow fluorescence indicates the presence of some impurity, commonly molybdenum. Some profitable mines are operating on deposits of yellow-fluorescing scheelite, where the amount of included molybdenum is small. The included molybdenum may, on the other hand, be so great as to render the deposit valueless; in any deposit of yellow-fluorescing scheelite (powellite) samples should be assayed for both tungsten and molybdenum.

Care must be taken that fluorescent calcite not be mistaken for scheelite. Although most calcite is not fluorescent, some of it is. Most fluorescent calcite fluoresces pink but some may fluoresce bluish white or pale yellow according to the impurities contained within it. In order to make sure that a white or yellow-fluorescing mineral is not calcite, a small, tightly stoppered bottle of dilute hydrochloric acid (obtainable at any drug store as muriatic acid) should be carried by the prospector. If the mineral, after being dried, fizzes or effervesces vigorously under a drop of acid, it is calcite and not scheelite or powellite. Most fluorescent calcite forms thin soft coatings on rock surfaces and can easily be distinguished from hard, crystalline scheelite; but some fluorescent calcite is found in disseminated specks and may closely resemble the more finely disseminated forms of scheelite and powellite.

Another possible source of error in using the ultra-violet lamp arises from the fact that scheelite quite commonly is deposited in narrow fractures in the inclosing rock. If, as frequently happens, the rock chances to break along this fracture after mineralization a wall studded with scheelite crystals will glow under the prospector's lamp, perhaps causing him to gain a false impression of the value of the deposit. An attempt should be made to determine the orientation and extent of the deposit before estimating its value.

WHERE TO LOOK

For "contact" deposits

A knowledge of the geology of "contact" deposits will serve to narrow down areas favorable for prospecting. Contact tungsten deposits are found only in areas where limy sedimentary or metamorphic rocks are in contact with granitic rock. The invaded rock may be limestone, marble, calcareous argillite or calcareous shale; the granitic body may be a batholith, a stock, or a dike. Almost all contact deposits are in tactite, a rock composed of distinctive green, red, white and colorless minerals such as epidote, actinolite, chlorite, garnet, tremolite, diopside, and quartz. Thus the search can be quickly narrowed to portions of limy beds which have been converted to tactite near granitic bodies. Then the mineral light is brought into play.

For vein deposits

Tungsten veins are quartz veins and they are generally in or near granitic rocks. The dark tungsten minerals are recognized by their tabular form, red brown to black color, and high specific gravity. Scheelite in quartz may be difficult to recognize without the mineral light. Panning streams for tungsten minerals is an excellent way to search for both vein and contact deposits.

In the Idaho Tungsten belt

Since there is a zonal distribution of most of the known Idaho scheelite deposits, it would seem logical to expect a greater chance of finding new tungsten deposits somewhere near the axis of this tungsten belt than elsewhere.

OUTLOOK

A NEW TUNGSTEN PROVINCE

Over the past 15 years Idaho has been one of the leading tungsten producing states of the union. Largely because of the Yellow Pine mine Idaho accounted for about 40 percent of the domestic tungsten production in 1942-44. Almost all of the Idaho tungsten production has been from two mines, the Yellow Pine and the Ima. Significant discoveries in the past two years have not only broadened the area of tungsten production in Idaho but promise to restore some of the annual output lost with the exhaustion of the Yellow Pine ore body. Tungsten ore has been shipped from at least 9 of the properties mentioned in this report; three mines which produced ore for the first time during the past two years have now yielded nearly a half million dollars in tungsten concentrates. Production figures of tungsten mines in this region are as follows:

Mine	Production period	Tons ore milled or shipped	Units WO_3 Produced	Value at the present price
Yellow Pine	1941-45	611,285	835,681	$52,647,903
	1950-52	337,311	12,417	782,271
Ima	1935-44	239,532	87,064	5,485,032
	1945-55	413,824*	170,480*	10,740,240
Springfield	1953-54 (Talus)	14,300	3,573	225,099
	1955 (Ore)	10,863	2,315	145,845
Wildhorse	1954-55	3,800	3,360	211,680
McRae	1953-54	922	954	60,102
Thompson Creek	1954	493	288	18,144
Empire	1942	55	114	7,182
Soldier Mountain	1942, 1952	7	29	1,838
Hanni	1954	11	18	1,109

*Includes 11,662 tons of tailings remilled, from which 565 units of WO_3 were recovered.

The Yellow Pine mine had two periods during which tungsten was produced. The figures for the 1941-45 period represent the production from the main ore body. During the 1950-52 period, various low grade materials were processed and some tungsten was recovered as a by-product from the antimony-gold ore. The Ima figures for the 1935-44 period are an estimate gathered from various sources by the present owners. The 1945-55 figures are actual production. During initial operations at the Springfield, talus was processed. The tonnage milled during this period is not accurately known, but the figure given in the table is an estimate provided by the mine manager. The Wildhorse totals do not include production subsequent to September, 1955. Finally, it should be emphasized that the values based on the present price are for comparison purposes only; the Yellow Pine and Ima mines have returned far less than the values indicated because much or all (in the case of the Yellow Pine) of their production came at periods of lower prices.

By virtue of the discoveries made within the past few years, it is not only apparent that south-central Ieaho constitutes a tungsten province, in the metallogenic sense, but that, under present conditions, a considerable increase in Idaho's mineral output could be expected from increased tungsten production in this area. The Ima is a profitable mine with a good future. The Wildhorse and McRae mines are small but good mines with a future dependent on development of additional reserves. The Thompson Creek property could develop into a good mine. The Quartz Creek, the White Bluff, and the Buckskin all have promise. The Empire should still have tungsten ore in it and may have a lot. Furthermore, there are almost certainly tungsten deposits still to be found in this region.

THE ECONOMIC PICTURE

During the past few years, all domestically mined tungsten has been purchased by the U. S. Government at $63 per short ton unit (20 pounds) of contained WO_3. This tungsten purchase program came to an end in June, 1956 when the government stockpile reached three million units. Because the world market price of tungsten is about $34 per unit, many of the nation's tungsten mines, including the new mines in south-central Idaho, faced the prspect of closing. However, soon after the government stopped buying tungsten, stop-gap legislation to continue the domestic purchase program of tungsten was approved by the Senate Interior Committee. Under the new program an additional 1¼ million units of tungsten will be purchased at $55 and small producers (1000 units per year or less) will get a bonus rate of $63 per unit. Both Houses of Congress are expected to pass the measure. The outlook section above, written with the $63 price in mind, would have been considerably less rosy, based on the world market price.

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