URANIUM, THORIUM, COLUMBIUM, AND RARE EARTH DEPOSITS IN THE SALMON REGION
LEHFi COUNTY, IDAHO

By

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IDAHO BUREAU OF MINES AND GEOLOGY
MOSCOX, IDAHO
In the past eight years deposits of uranium, thorium, columbium and the rare earth metals have been discovered in northern Lemhi County. These deposits of strategically valuable metals have now been explored sufficiently to allow an appraisal of their potential extent and value, as well as the gathering and interpretation of data which may lead to the formulation of guides to further exploration and development.

In view of the continued interest and activity in developing these properties, the Idaho Bureau of Mines and Geology asked Dr. J. L. Anderson, an economic geologist with a great fund of knowledge of Idaho ore deposits and their geologic environment, to investigate, during the summer of 1957, the new discoveries in the Salmon region. This Dr. Anderson did, with the results detailed by him in this comprehensive report which, we trust, will prove valuable to all those interested in the development of these deposits, as well as to those of scientific bent, curious about their origin.

E. F. Cook
Director
Idaho Bureau of Mines and Geology
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URANIUM, THORIUM, COLUMBIUM, AND RARE EARTH DEPOSITS IN THE
SALMON REGION, LEMHI COUNTY, IDAHO

by

Alfred L. Anderson

ABSTRACT

This report deals specifically with the uranium, the monazite and columbium-bearing rutile, and thorite-rare earth deposits in the Salmon region of Lemhi County, Idaho. These deposits were unknown prior to 1950 and have not been extensively explored. They appear to possess substantial reserves of thorium and rare earth metals as well as appreciable reserves of columbium and uranium.

The uranium deposits are widely scattered through the region with greatest concentration in the Gibbonsville area. They include lode deposits in metamorphosed sedimentary rocks, deposits in volcanic rocks, and deposits in lake beds. Those of greatest promise are in the metamorphosed sedimentary rocks and in the volcanics. As exploration has not extended below the oxidized zone, the known ore minerals are composed largely of autunite and torbernite, and locally also of uranophane. Reddish hematitic alteration along the lodes implies primary uranium mineralization below the zone of weathering.

The monazite and columbium-bearing rutile deposits are along a west-northwesterly trending belt a few miles west of North Fork. They represent a type of deposit recently recognized as belonging to the carbonatite group and are characterized by a concentration of rare earth elements, thorium, barium, titanium, calcium, phosphates, sulfates, iron, and carbonates. The deposits occur locally as structurally controlled replacements of crystalline limestone and gneissic and schistose rocks in the complex metamorphic border zone of the Idaho batholith. Most of the known deposits are small and show a sporadic and irregular distribution of minerals. The principal and most distinctive minerals are actinolite, allanite, monazite, apatite, barite, rutile, ilmenite, magnetite, and calcite. The rutile, which has a high columbium content, occurs only along a part of the mineral belt. The other minerals are present in variable amounts in all the deposits, with actinolite, monazite, locally allanite, and calcite generally dominant. The allanite contains a considerable amount of thorium; the monazite, only a minor amount, generally less than 1 percent. Most of the minerals are exceptionally coarse-grained. The coarse calcite, so distinctive of the deposits, is younger than most of the other minerals. The deposits were probably formed from carbonate-rich solutions which had their source in the Idaho batholith.

The thorite-rare earth deposits are confined to the Lemhi Pass region and a small area on and near Diamond Creek 6 to 8 miles north-northwest of Salmon. These deposits are contained in complex shear and fracture zones and in earlier gold-quartz veins and copper lodes. Most of the veins and lodes are in quartzitic phyllitic rocks of the Precambrian Belt series, but several near Diamond Creek cut the granitic rock of the Idaho batholith. Many of the deposits are small, but some are of considerable size and compose broad zones of
irregularly mineralized rock some tens of feet across. The deposits possess a considerable concentration of thorium and rare earth elements associated with silicon, phosphates, barium, potassium, calcium, iron, and sulfates. The principal minerals in approximate order of their deposition include thorite, locally allanite, monazite, xenotime(?), apatite, specular hematite, barite, potash feldspar, exceptionally calcite, and quartz. Unlike the minerals in the carbonatite deposits near North Fork, these minerals are mostly microscopic and, except for some of the specular hematite, barite, reddish feldspar, calcite, and quartz, cannot be detected by the unaided eye. The specularite and feldspar serve as the main markers of mineralization, but the radioactivity is the principal guide to ore. Most of the minerals have an irregular, sporadic, and commonly bunched distribution. The deposits are younger than the Idaho batholith and are believed to be associated genetically with late Cretaceous or early Tertiary magmatic activity.
INTRODUCTION

PURPOSE AND SCOPE

This report is written to provide factual data on the recently discovered uranium, thorium, columbium, and rare earth deposits in the Salmon region of eastern Lemhi County, Idaho. Since their discovery the deposits have attracted widespread interest and have prompted considerable demand for geologic information and an appraisal of their potential worth. To supply this information the Idaho Bureau of Mines and Geology had the writer examine the deposits and prepare a fairly detailed report of his findings.

On beginning the examination it quickly became apparent that the deposits fall into three distinctive groups. These include a group of uranium deposits, a group of monazite and columbium-bearing rutile deposits, and a group of thorite-rare earth deposits. In studying these three contrasting groups, particular attention was directed to their geologic relationships and mineralogic characteristics.

Because the mineralization characteristic of each of the groups shows a preferred geographic distribution, the study was largely confined to certain areas, especially true of the monazite-rutile and the thorite-rare earth deposits. Study of the former was limited to a single belt of mineralization extending from the Salmon River several miles below North Fork northwesterly to and beyond the Montana line. Study of the thorite-rare earth deposits was confined to two widely separated areas, the principal one in the Lemhi Pass region and the other, much smaller, in the vicinity of Diamond Creek 6 to 8 miles north-northwest of Salmon. Study of the uranium was not so restricted, for the deposits are widely scattered, with some concentration, however, in the Gibbonsville area.

PREVIOUS GEOLOGIC WORK

The major geologic features of the region are known through early work of Umpleby (1913), but data bearing directly on the deposits under consideration have accumulated only since 1950. The first studies directed to the uranium mineralization were instigated in 1949 by Vhay and Anderson each of whom prepared reports made available in 1950. Their work consisted of reconnaissance examinations for uranium chiefly outside the area of the present investigation. More comprehensive investigations by Trites and Tooker of both uranium and thorium were begun in 1950 in behalf of the Atomic Energy Commission, with the results published in 1953. Their work called attention to the thorite mineralization in the Lemhi Pass area, with descriptions of the several deposits then known, and also to the uranium mineralization in the Gibbonsville area. The thorium deposits were also investigated by Armstrong whose work was likewise published in 1953. The deposits of monazite below North Fork were not known until 1955 and were investigated the following year by Abbott of the Idaho Bureau of Mines and Geology and later by Kaiser of the United States Geological Survey. Kaiser's studies of these deposits have been more-detailed and have continued intermittently to the present. His findings have been made available in a preliminary open-file report issued in 1956. More recent publications by the writer
on the geology and mineral resources of the Salmon and Baker quadrangles have contained little data on radioactive deposits but have contributed to the body of knowledge on the regional geology.

The publications dealing directly and in part indirectly with the radioactive and rare earth deposits in the Salmon region are listed in the following bibliography.

**BIBLIOGRAPHY**


FIELDWORK

Work in the field consisted largely of examination of known deposits. The only surface mapping was confined to the Lemhi Pass area where most of the discoveries and locations were made after the appearance of early published reports. Because of the recent detailed mapping of the monazite-rutile belt by the U. S. Geological Survey, mapping there would have been needless duplication; consequently, only the deposits in that belt were examined with geologic observations confined to the immediate vicinity of the deposits. As the thorite-rare earth deposits in the Diamond Creek area are to be included in the mapping program of the North Fork quadrangle, they too were not mapped. The uranium deposits proved to be too widely scattered for surface mapping, although such mapping could have been carried out in the Gibbonsville area had time and base maps been available. Wherever feasible, maps were made of underground workings.

The greatest handicap to surface mapping was the lack of adequate base maps. For the Lemhi Pass study aerial photos were at hand for a part of the area and were used in mapping the Pattee Creek and lower Agency Creek drainages, but photos ordered to complete the coverage of the area were received too late for use in the field. These late-arriving photos were used, however, in compiling the base on which geologic data obtained in the field were later recorded.

The field studies were somewhat impeded by poor surface exposures. Except in the Gibbonsville area, most of the exploratory work has been confined to bulldozed cuts, many of which have failed to penetrate the overburden. In many cuts that have exposed the deposits, caved banks have obscured geologic relationships. However, the main problem is associated with the small amount of work on many of the properties, which in places is scarcely more than that at the time the locations were made.

Radioactive fallout from the atomic bomb tests in Nevada also proved to be a troublesome problem during the investigation of the uranium and thorium deposits with the scintillation counter. Following such tests the background readings were generally abnormally high; sage brush and shoes commonly gave higher readings than some of the lodes exposed in the cuts.

ACKNOWLEDGMENTS

The writer is deeply grateful to those who in one way or another rendered material assistance in the field. He is especially indebted to Mr. Russell Wood of the Molybdenum Corporation of America for his co-
operation and help on several visits to the Lee Buck property along the monazite-rutile belt below North Fork in 1954 and for his contribution to the thorite-rare earth studies in the Lemhi Pass area in 1957, particularly in making available the assay returns on samples of the thorite-rare earth ore he had collected. The writer also wishes to acknowledge his indebtedness to Messrs. H. R. Roberts, G. E. Shoup, C. K. McConnell, O. N. Gunderson, Wiley Evans, W. U. Lowe, Ed Sargent, C. E. Brown, Ralph Malloy, Fred Guderjohn, Jack Rucker, H. W. Coiner, Clif Edwards, and others; each of whom either accompanied the field party to specific properties, in many cases providing jeep transportation, or contributed maps, information, and other special services.

While in the field the writer was ably assisted by Mr. Bruce Brogoitti, student at the University of Idaho College of Mines. Mr. Brogoitti contributed immeasurably to the success of the field work. His willing cooperation and helpful assistance are gratefully acknowledged. The writer also had the companionship of his fifteen-year-old son, Alfred B. Anderson, who also performed many useful services for which acknowledgment is due.
The presence of uranium-bearing deposits in the Salmon region was not known until about 1950. Prior to this time there was little reason for interest in such deposits, but eventually the country-wide search for radioactive deposits led to consideration of the Salmon region as an area worthy of investigation. As a result of reconnaissance radiometric surveys carried on by the U. S. Geological Survey beginning in 1949 some of the gold- and lead-bearing lodes in the Gibbonsville area were found to contain small amounts of uranium minerals. The uranium disclosures there aroused some local interest and led eventually to the discovery of the Surprise deposit which so far remains the most important uranium find within the county. Interest in uranium spread to other parts of Lemhi County and considerable prospecting was carried on during 1953 and 1954 with some interesting strikes reported, including the El Toro on Dump Creek. Then early in 1955 came the much-publicized discovery of uranium along the main highway about 6 miles south of Salmon. The news of the discovery attracted a flood of prospectors and resulted in the location and filing of claims over much of the area of volcanic rocks and lake beds stretching for many miles along both sides of the Salmon and Lemhi Rivers. Nothing tangible resulted from this widespread activity and the excitement soon subsided.

Some prospecting has continued since, but most of the interest has been directed to a few surviving properties, including the Surprise near Gibbonsville, the El Toro on Dump Creek, the E-Dah-How, which initiated the excitement in 1955, and a property in Kriley Gulch about 11 miles below Salmon. Except for some drilling and bulldozing at and near the Surprise, the only active work during the summer of 1957 was at the E-Dah-How where an access road was built from the highway in preparation for underground exploration.

**TYPES OF DEPOSITS**

The uranium in the Salmon region has three modes of occurrence: (1) as lode deposits in metamorphosed sedimentary rocks, (2) as deposits in volcanic rocks, and (3) as deposits in lake beds. The first two contain the more notable concentrations of uranium. The deposits in the lake beds appear to have little immediate promise.

**LODE DEPOSITS IN METAMORPHOSED SEDIMENTARY ROCKS**

Distribution

The lode deposits in the metamorphosed sedimentary rocks, the first of the three types of uranium occurrences to be recognized in the Salmon region, are known only in the vicinity of Gibbonsville in the northern part of Lemhi County (Fig. 1). With one exception, the uranium was found in old mines formerly worked for gold. The exception is a subsequent discovery made during search for the source of radioactive float noted during earlier radiometric investigations. All these deposits are several miles west and northwest of Gibbonsville.
The lodes are along complex fissure and fracture zones in impure quartzitic and phyllitic rocks belonging to the Precambrian Belt series. These old metasedimentary rocks trend in a northwesterly direction, conforming with the prevailing regional trend and dip, for the most part in a northwesterly direction.

The zones of fractured and fissured rock that contain the gold-quartz veins and the apparently superposed uranium minerals strike in west-northwesterly directions, mainly N 70° E to N 80° W, exceptionally N 40° W, to N 60° W, and dip either northeast or southwest. The zones of broken rock range up to 30 or more feet across and have measured lengths underground of some hundreds of feet and probable lengths of several thousands of feet. These zones have sharply defined footwalls marked by thick bands of gouge, and less well-defined hanging walls. Through the remainder of the zone the more conspicuous fractures tend to parallel the prominent footwall break but there are many fractures or slips that extend across the zone, generally in north-northwesterly directions.

The fracture zones seem to have a preference for the phyllitic rocks; but they may leave the phyllites and enter the bordering, more massive, impure quartzites. The relations suggest that the faulting responsible for the fracture zones was in part directed along the beds of structurally weak phyllites. Some of the foliation, however, may have been induced by the faulting itself.

Mineralogy

The uranium minerals now visible are of secondary origin, formed or derived from some as yet undiscovered primary mineral, presumably pitchblende. These secondary minerals are contained in fractures in vein quartz and bordering rock, apparently added to an earlier lode filling of quartz with small but variable amounts of pyrite, gold, and locally galena and chalcopyrite. The galena at the Garm-Lamoreaux mine is radioactive, which indicates that it may contain associated pitchblende. The presence of widespread reddish hematitic alteration in and along the lodes, a type of alteration characteristically associated with primary uranium mineralization, further suggests that pitchblende or some other primary uranium mineral should appear in the lodes below the zone of weathering.

The secondary uranium minerals of current interest are identified as autunite and torbernite, the first an uranyl phosphate containing calcium \((Cu_3(PO_4)_2\cdot 10-12 H_2O)\), the second an uranyl phosphate containing copper \((Cu_2(PO_4)_2\cdot 8-12 H_2O)\). These two minerals are not always easy to distinguish from one another. Both have a pearly luster and tend to occur as small, flat, square, transparent crystals; the autunite, in shades of yellow to apple green; and the torbernite, from apple green to bright emerald green. Examined in ultraviolet (black) light, the autunite fluoresces a brilliant yellow to apple green whereas the torbernite fluoresces feebly faint green, if at all. In most of the deposits the mineral fluorescence is brilliant, suggesting that the usually dominant mineral is autunite, even though decidedly greenish in color. Both minerals occur as easily discernible crystals on fracture surfaces, commonly in small platy crystal aggregates.
Fig. 1. Map showing distribution of the uranium, thorite-rare earth, and monazite and columbium-bearing rutile deposits in the Salmon region, Lemhi County, Idaho.
Distribution of the uranium

The euhunite and torbernite show a decided preference for fractures in the vein quartz and the immediate bordering country rock, their distribution controlled entirely by porosity and permeability, which in turn depend on the extent to which the quartz and bordering rock were ruptured by renewed structural movements. Most of the quartz occurs above the prominent band of gouge along the footwall, either continuously as veins hundreds of feet long and several feet thick, with local bulges of greater thickness; or as irregular bunches through the fracture zone, with greater concentration along or close to the footwall. Much of the fracturing that occurred after quartz deposition was not in the quartz itself but in the structurally weaker bordering rock. Because of its greater strength and rigidity, the quartz tended to resist and shift the deformation to the adjacent rocks, the contact acting as an especially vulnerable spot for localizing the fracturing and uranium mineralization. In places the quartz itself was extensively fractured and under such circumstances became a favored site for mineralization. Localized fracturing also produced favorable zones for secondary uranium minerals in other parts of the fracture zone.

The uranium mineralization is mainly confined to the fractured quartz and rock above the footwall gouge, the gouge acting as a seal to prevent the uranium from entering the rocks below. Above, the uranium minerals have a rather spotty distribution, although at the Surprise they are well-distributed through a zone about 30 feet wide, showing greater concentration toward the footwall, particularly in and along bunches of quartz and in sheared rock with reddish hematite stains. In places some uranium has also entered into minor fractures in the gouge.

The uranium minerals are more widespread near the surface than at depth (Fig. 2). This distribution accords with the more extensive fracturing of the rocks near the surface as compared with depth. This more widespread fracturing has permitted the uranium to be carried outward for greater distances into the bordering rock. With depth the zone of mineralization should narrow and, near the water table, should not extend much beyond the borders of the bodies of quartz.

In some of the mine workings, minor concentrations of secondary uranium minerals appear on the lower walls of drifts, adits, and crosscuts, apparently as surficial incrustations made by water oozing from or trickling down over the surface of the rocks.

Tenor of the deposits

The deposits were not sampled during the present investigation. Some deposits obviously contain small concentrations of uranium minerals of workable grade but little tonnage. Other deposits contain so little uranium that sampling would not be justified, unless further work should uncover more abundant showings. The largest concentration of minerals observed so far are at the Surprise where 100,000 tons of ore averaging better than 0.1 percent U₃O₈ have been blocked out (Cook 1957, p. 1).
Origin of the deposits

The uranium minerals now exposed in the lodes are secondary and have been deposited by downward percolating ground waters. Such waters must have received their supply of uranium from some primary mineral, probably pitchblende, originally deposited in the lodes by mineral-bearing solutions from some deep magmatic source. When brought into the zone of weathering, the pitchblende is readily oxidised and taken into solution and, unless precipitated by contact with the proper combination of ions, is dissipated and lost. Locally the dissolved uranium formed insoluble compounds with dissolved calcium or copper and phosphates and was precipitated either as autunite in the presence of calcium ions or as torbernite in the presence of copper ions. The pitchblende or other primary uranium mineral has thus been removed from the upper parts of the lodes, the uranium remaining as insoluble secondary minerals. The pitchblende should make its appearance in the deeper part of the zone of weathering, and below the water table should probably be the only uranium mineral in the deposit. (Fig. 2).

Exploration has not yet gone below the zone of weathering, but the reddish iron staining on fractures in deeper parts of the lodes indicates original primary mineralization and suggests that primary uranium minerals will appear toward the bottom of the weathered zone.

As the reddish hematite coats fractures in the vein quartz as well as in the adjacent rocks, the primary uranium mineralization is younger than the gold-quartz mineralization; but whether the uranium was deposited during the final stages of the gold-quartz mineralization or was introduced much later from an unrelated source is something yet to be determined. The radioactive galena at the Garm-Lamoreaux suggests that the uranium may be a part of the gold-quartz mineralization; but the galena may have served as an effective precipitant of any uranium that might have been introduced later. If the gold-quartz and uranium mineralization are closely associated genetically, then they would be the product of early Tertiary metallization, for it was then that the gold-quartz veins of the region are believed to have formed. On the other hand, except for the difference in host, the uranium mineralization in the quartz lodes is essentially the same as in the Tertiary volcanic rocks. There thus may have been just one epoch of uranium mineralization, that of mid-Tertiary time, during which uranium-bearing solutions entered reopened fracture zones in the older rocks as well as in the younger fracture zones in the volcanics.

Properties

Garm-Lamoreaux

The Garm-Lamoreaux is about 5 miles west-southwest of Gibbonsville in Sec. 31, T. 26 N., R. 21 E., Boise meridian, on Allen Creek, a small tributary of Hughes Creek. It may be reached by a short road from Hughes Creek. The property is held by the Garm-Lamoreaux estate, locally managed by G. I. Hurley of Salmon, Idaho.

The mine is an old gold property which was developed by three adits a few hundred feet up the slope east of Allen Creek, with more recent work in a fourth adit just above creek level or about 295 feet below the older work-
<table>
<thead>
<tr>
<th>Uranium minerals</th>
<th>Typical vertical zonation in weathered veins</th>
<th>Color of uranium minerals</th>
</tr>
</thead>
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<tr>
<td>Uranophane with autunite and torbernite</td>
<td>Country rock</td>
<td>Apple green, greenish yellow, lemon yellow, canary yellow, orange yellow</td>
</tr>
<tr>
<td>Autunite and torbernite with uranophane</td>
<td>Fractures coated with secondary uranium minerals</td>
<td></td>
</tr>
<tr>
<td>Sooty pitchblende with autunite and torbernite</td>
<td>Red (hematite) alteration</td>
<td>Secondary minerals</td>
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<tr>
<td>Pitchblende</td>
<td>Lower limit of water table flotation</td>
<td>Primary minerals</td>
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<td>Black</td>
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**FIGURE 2 -- DIAGRAM SHOWING TYPICAL ZONAL RELATIONSHIPS OF URANIUM MINERALS IN WEATHERED VEINS**

Modified from Fig. 14, U.S. Geol. Survey Circular 220.
ings, especially along the zone of mineralization where the weakness is intensified. Much of the nearby rock may be classed as a phyllitic argillite with some intercalated quartzite. Rocks are poorly exposed on the surface and structural relations are obscure. In the mine workings the beds appear to have a rather flat dip.

Some small pieces of galena-bearing quartz were found on the dump at the third adit, but the ore was not seen in place. The only quartz visible underground composes a narrow, gently dipping vein in the face of the third adit. This vein contains no galena and is not radioactive. The uraniferous lead ore is reported to occur in lenses and thin stringers in the main fracture zone, but these occurrences were concealed by timbers and lagging or were beyond reach in workings blocked by caved ground. The only suggestion of uranium mineralization seen underground was the presence of some reddish hematite-stained rock.

The material on the dump indicates that the vein quartz contains some galena and pyrite and presumably gold. Some of the ore material on the dump also had sparsely scattered crystals of autunite and tobernite, but the main source of the radioactivity appears to be the galena. Selected specimens of the lead ore on the dump of the third adit are reported by Vhay (1950, p. 16) to contain as much as 0.11 percent uranium.

Moon

The Moon is about 3 miles northwest of Gibbonsville in Sec. 21, T. 26 N., R. 21 E., Boise meridian. It is located in what some call Doolittle Gulch and others call Placer or Fern Creek Gulch, a small tributary of the North Fork of the Salmon River. The old road up the Gulch was impassible in 1957, but the property might possibly be reached from the head of the gulch by way of the Volter-Granite Mountain road.

The Moon was originally discovered and located by Percy Anderson in 1924 and later was held by his estate. It is now owned by C. Walker Lyon of Salmon, Idaho. The workings comprise two open cuts and a 450-foot adit drift with a 60-foot winze and 387 feet of crosscuts. This work was done long before the discovery of the uranium. The adit was open in 1957 and was mapped (Fig. 3).

The underground work reveals a prominent shear or fracture zone more than 50 feet across in highly foliated phyllitic rocks of the Belt series. This fracture zone trends about N 68°W, dips 60° to 70° S/W, and contains several individually conspicuous slips with prominent bands of gouge and numerous minor fractures with thin seams of gouge. Most of the fractures extend in the direction of the fracture zone, but some of the minor ones strike obliquely across in a more northerly direction, exceptionally northeast (Fig. S).

The quartz vein, largely a replacement of the fractured phyllite, occupies about the center of the fracture zone and lies immediately above a thick band of gouge and broad zone of masher, gougy rock (Fig. 3). This vein is continuous for the full length of the adit and for much of its length forms the back and one or both walls of the adit. Additional seams and bunches of quartz also occur in foot and hanging wall zones. The
quartz preserves a few casts of pyrite; but in general it is free of metallic minerals, with only scattered patches of malachite to indicate the probable presence of chalcopyrite.

The quartz is extensively but not uniformly shattered and much of the secondary uranium mineralization is in the fractures of the bordering phyllitic rock, with lesser amounts in the quartz itself. In places, the fractured quartz and phyllite and small fractures in the gouge are stained or smeared by reddish hematite. In general the uranium mineralization is weak, with uranium minerals sparsely distributed and most conspicuous on the lower walls of the drifts and crosscuts (Fig. 3). The uranium minerals include both yellowish autunite and greenish torbernite, the latter in crystals generally less than 0.1 mm. across. There is also a nonfluorescent yellowish mineral, possibly uranophane (a uranium silicate); but the mineral is too finely crystalline for easy recognition.

**Surprise**

The Surprise is several thousand feet northwest of the Moon in a gulch referred to by some as Friedorf Gulch and by others as Doolittle Gulch. It is in the drainage of the first tributary of the North Fork of the Salmon River above the gulch in which the Moon is located. It is most conveniently reached by road up the gulch from the highway along the river; but, if this road is closed, it may be approached from above by a steep branch road from Granite Mountain.

The Surprise was discovered and located by C. C. Mathis and R. W. Dean in the early fifties, after they had tracked down and uncovered the source of torbernite-bearing quartz float which had been found more than half a mile northwest of the Moon workings. The previously unknown lode has been uncovered in several large bulldozed cuts on the upper slopes of the gulch and explored underground by an adit near gulch bottom. This adit, about 750 feet long with an additional 300 feet of crosscuts, is shown in Figure 4.

The bulldozer stripping and underground work has revealed a broad zone of complexly fissured and fractured phyllitic rock containing prominent fractures with broad bands of gouge, especially along the footwall. The fracture zone trends in a northwesterly direction; but the strike varies considerably from place to place, mostly from N 45° W to N 60° W. The strike of the principal fractures generally accords with the trend of the fracture zone; but many less prominent fractures or slips extend across in more north-northwesterly directions. Dips of the more prominent gouge-bordered fractures are generally 65° to 80° NE, but one prominent fracture along the footwall zone dips 80° SW (Fig. 4). The fracture zone as a whole appears to dip northeast and thus does not conform with the dip of the fracture zone at the Moon of which it is thought by some to be an extension.

The fracture zone contains irregular, sporadically distributed bunches of quartz, mostly just above the prominent band of gouge that marks the footwall zone. These bunches of quartz have been extensively fractured by later structural movements. This part of the fracture zone shows widespread reddish hematite stains, particularly of slip surfaces and, locally, relatively broad seams of iron along the upper side of the main band of gouge.
Fig. 2. Geologic map of the underground workings at the Moon property near Gibbonsville, Idaho.
Fig. 4. Geologic map of the underground workings at the Surprise property near Gibbonsville, Idaho.
The uranium mineralization is restricted to the fractured quartz and rock above the band of footwall gouge, stopping abruptly against the gouge, and extending far out into the sheared and fractured rock of the hanging wall zone, in most places as much as 30 feet from the footwall, locally even more (Fig. 4). The greater concentrations of uranium, however, are near the footwall, especially in and near bunches of fractured quartz and in the sheared rock showing reddish hematitic alteration.

The only uranium minerals in the present exposures are secondary. They include torbernite and autunite, mainly as small crystals up to an eighth of an inch square. These form conspicuous coatings on fracture surfaces. The torbernite crystals, mostly square transparent plates, are decidedly greenish and show an exceptionally brilliant greenish fluorescence. The walls of the underground workings fluoresce brightly under black light, with a brilliance more indicative of autunite than of torbernite. Small platy crystals of inferred autunite appear to have a pale greenish cast.

The Surprise appears to be rather abundantly mineralized. Secondary uranium minerals occur in the stripped cropings several hundred feet above the adit level and probably extend at least a short distance below the level. A 36-foot drill hole put down vertically 100 feet west of the Surprise adit portal during the later months of 1957 by the United Pacific Mining Corporation revealed a considerable increase of radioactivity at a depth of 284 feet with greatly increased intensity at still greater depths, where the drilling fluid changed from a white to a hematitic reddish color (Cliff Everett, personal communication). The depth reached by the drill should be well below the zone of weathering and the radioactivity that was encountered may come from the primary mineralization. Ore blocked out is reported to exceed 100,000 tons averaging better than 0.1 percent U3O8 (Cook 1957, p. 1).

DEPOSITS IN VOLCANIC ROCKS

Distribution

The uranium deposits in volcanic rocks are scattered over a wide area, their locations determined by the sporadic distribution of the volcanics. They are found on the north and south flanks of the Salmon Basin about 6 to 8 miles south and 11 to 12 miles north of Salmon; in a block of volcanics on D ump Creek, a mile or two below the lower end of Moose Creek basin; and in a patch of volcanics capping the lower mountains west of Gibbonsville (Fig. 1).

Geologic relations

The deposits are contained in flows and tuffs belonging to the Challis volcanic formation of Tertiary (Oligocene) age. The geologic details differ at each of the deposits: some of the deposits occur in massive silicic flows of probable quartz latitic composition; some in beds of consolidated ash or tuff; and some in flow-like bodies of welded tuff (ignimbrites).
The structural relations of the flows and intercalated tuffs are only partly known. In the exposures north and south of Salmon the volcanics strike northwest and dip northeast at moderate angles. The volcanics on Dump Creek also strike northwesterly and dip toward the east. The strike and dip of the flows and tuffs in the Gibbonsville area were not learned. A regional structural pattern cannot be formulated upon the limited data now available.

The volcanics have been broken by faults, some of considerable magnitude, but details are lacking. They have also been broken by many minor faults, some of which have localized uranium mineralization. Most of these smaller mineralized faults have had little displacement, just enough movement to produce weak or poorly defined fracture zones a few feet to several tens of feet across. These zones trend in northwesterly directions and generally dip northeast.

Types of deposits

The volcanics appear to contain two types of deposits, one as lode-like bodies along weak fracture zones in the flows and welded tuffs, the other as small, indefinite bodies in tuffaceous rocks containing woody or other vegetable debris. These two types are not directly related, for those confined to the fracture zones appear to be of hydrothermal origin, whereas those in the tuffs apparently represent concentrations of uranium leached from the tuff and precipitated by incorporated organic or tuffaceous matter.

Mineralogy

The uranium mineralization along the fracture zones in the volcanics is little different from that along the fracture zones in the older metamorphosed sedimentary rocks. The uranium minerals observed so far are secondary and include mostly yellowish autunite along with some torbernite and in places appreciable amounts of uranophane. The latter has a pale greenish-yellow color but, unlike the autunite and torbernite, has a fibrous or radial needle-like structure and is without appreciable fluorescence in ultraviolet light. It is a secondary silicate mineral and has the composition $Ca(UO_2)_3Si_2O_7·6H_2O$. Its finely fibrous or radiating needle-like crystal structure makes it easy to distinguish from the small, square, flat plates that characterize the autunite and torbernite. All three minerals may occur in the same deposit.

The presence of reddish hematitic alteration and reddish hematite stains along fractures suggests that the secondary uranium minerals derived their uranium from weathered, originally deposited primary minerals. Until the deposits are explored below the zone of weathering, the nature of these minerals, whether pitchblende or coffinite (primary uranium silicate), cannot be positively established.

No uranium minerals were observed in the radioactive concentrations in the tuffaceous rocks associated with vegetable debris. The radioactivity may emanate from minute blackish grains of uraninite or pitchblende or from some uranium-bearing organic complex.
Distribution of the uranium

The uranium minerals in the zones of weakly fractured rock occur as small, irregular coatings on fracture surfaces and as incomplete fillings of fractures and other small rock openings. Such coatings are patchy and irregular in outline and distribution. They are most conspicuous along the more porous and more readily permeable parts of the fracture zones, common-ly in zones a few feet wide with a less conspicuous and more meager dis-tribution across a much broader zone, in places more than 10 feet across. The greater concentration of uranium minerals is generally near or along the footwall of the fracture zones, exceptionally elsewhere in the zone of weak-ly fractured rock.

Tenor of the deposits

The deposits were not sampled and the tenor of the uranium ore can only be inferred. In some deposits inspection alone is sufficient to indicate that the concentration of uranium minerals is too low or that the deposit is too small for economic exploitation. In other deposits the uranium content may well exceed 0.1 percent U₃O₈ and may in some places confirm reported claims of 0.5 to 0.8 percent U₃O₈. The problem of these deposits is not so much the tenor of the ore as it is the quantity of ore. More effort should be expended to develop substantial tonnages of the better grade ore. So far there has not been enough work to establish any appreciable ore reserve.

Origin of the deposits

Like the deposits in the older sedimentary rocks, those along the zones of weakly fractured volcanics are also probably hydrothermal with the uranium brought upward in solution from deep magmatic sources and deposited as small grains of uraninite or pitchblende or possibly coffinite along the fracture channels. Subsequently the primary uranium minerals in the upper part of the fracture zones were broken down by weathering agencies and the liberated ura-nium was redeposited in the rock of the weathered zone as secondary uranyl phosphates and silicate (Fig. 2). As the uranium deposits are younger than the volcanics (Oligocene), they are no older than mid-Tertiary and are probably a product of magmatic activity of lower Miocene time.

The origin of the ill-defined deposits in unfractured tuffaceous rocks containing vegetable debris is notably different. The uranium is believed to have been dissolved from primary mineral dispersions in the tuffs and then deposited as the circulating waters came in contact with organic matter. The concentrations were apparently effected through the ability of the organic matter to convert the soluble uranyl ion carried by the water to a lower state of oxidation and cause its precipitation as uraninite or pitchblende or possibly as a stable urano-organic compound. The uranium concentrations are thus restricted to the vicinity of plant or wood debris in the tuffaceous beds.

Properties

Dot

The Dot claims are in the area of volcanic rocks west of Gibbonsville, a half mile or less northwest of the Surprise. The main deposit is exposed on
the crest of a ridge and has been explored by a large bulldozed cut which extends across the ridge. The claims were located by C. B. Jenkins and R. Van Eckout in 1955. The bulldozed cut was made in 1957.

The uranium deposit is in a ridge cap of volcanic rock about 40 feet thick, resting on Precambrian phyllites and quartzites. The volcanic rock is considerably weathered, but is a silicic flow, probably a quartz latite. It appears to have been cut by a weak zone of fractures which trends in a north-northwesterly direction.

At its widest part the mineralized zone is as much as 20 feet across. Some of the fractured rock within the zone has rather conspicuous scale-like and crystal incrustations of yellowish autunite and some greenish torbernite. Some fibrous uranophane was also observed on fracture surfaces. These secondary uranium minerals form rather widespread patches in the fractures and considerably decomposed rock. A drill hole put down during the late summer of 1957 disclosed that the uranium mineralization ceases within 14 feet of the surface.

E-Dah-How

The E-Dah-How is in the volcanic rocks 6 to 8 miles south of Salmon. This property has the distinction of having shipped the first uranium ore mined in the State of Idaho. It was here that uranium was discovered along the main highway (U. S. 93) 6 miles south of Salmon and it was this discovery that sparked the recent short-lived uranium boom in Lemhi County. Other discoveries were made more or less in line to the south for about a mile and a half. The various locations covered by four groups of claims have since been leased to the E-Dah-How Corporation of which W. W. Lowe and E. Sargent of Salmon, Idaho, are the owners or directing officials. The holdings include the Dona Lou group of 17 claims near the original discovery, the Mother Lode claim in the first sizable gulch south of Sevenmile Creek, the Ruth group of 11 claims on the ridge south of the Mother Lode claim, and the Lemhi group of 3 claims in the gulch below the Mother Lode. Large bulldozed cuts have been made on the No. 17 claim of the Dona Lou and on the Mother Lode, with smaller cuts on the Ruth and Lemhi claims. During the summer of 1957 a road was built from the main highway to the Mother Lode claim.

The uranium deposits are contained in welded tuffs. These tuffs are light-colored, well-compacted or cemented, and are composed of a third or more of biotite and andesine crystals and crystal fragments in fine matrices of minute to fairly coarse microspherulitic intergrowths of quartz and orthoclase, with some granular mosaics of orthoclase surrounding some of the coarser microspherulites. The andesine grains are unaltered, but the biotite, fresh in some places, is generally decomposed. Some scattered small clefs and fractures in the tuff contain chalcedonic fillings, others are filled or lined with tridymite and sanidine. Much of the tuff appears to have the composition of quartz latite.

Where mineralized, the tuffs are cut by weak systems of minor fractures and fine inconspicuous breccias, which appear to trend in northerly directions. These fractures and breccias are commonly cemented or stained by reddish hematite, forming for the most part a net of reddish stringers or in places reddish banded "ribbon" rock. The hematite bands are irregular,
measuring up to an inch thick; and they are composed of tiny, anastomosing veinlets rather than massive hematite. The uranium minerals are contained as small crystals or crystal aggregates in fractures and open clefts or vugs in the tuff. The uranium minerals include autunite, uranophane, and apparently some torbernite, the autunite predominating. The mineralizing solutions were apparently channelized along the zones of weak fractures and breccias, depositing hematite and some primary uranium mineral, which the weather has converted to autunite and other secondary minerals.

On the Dona Lou No. 17 claim the mineralized tuff is in a small landslip block of volcanics near the top of the ridge over looking the river. The beds in the block dip southwest at a low angle, which is opposite to the dip of the beds in place. Where exposed in the 10-foot high bank of the large bulldozed cut, the mineralized body is about 10 feet across. It shows a notable abundance of autunite along with lesser amounts of other secondary minerals. There has been little hematitic alteration.

At the Mother Lode the bulldozing has been across the lower nose of the ridge that separates the two forks of the gulch. This work cuts deeply into the nose and affords an excellent exposure of the bedded tuffs, which locally strike N 10°-15° W and dip 30° NE. The cut bank reveals much reddish, banded "ribbon" rock, the bands about parallel to the bedding and spaced several inches apart. The tuff shows weak fracturing and brecciation which have controlled the reddish-iron alteration and the distribution of uranium. Fracture trends are not clearly discernible. More prominent fractures that strike N 10° E and dip 30° SW cross the ridge to the north, but these fractures are not mineralized. The mineralized body in the cut is exposed for more than 8 feet vertically. High radiometric readings may be obtained along the cut in a northerly direction for about 100 feet.

The cuts on the Ruth group on the ridge south of the Mother Lode reveal little mineralization. The best exposure of mineralized rock is the outcrop on the knoll on top of the ridge.

The Lenhi claims are below but parallel to the Mother Lode. The exposure of mineralized rock is about 8 feet high and 6 feet wide.

El Toro

The El Toro group is in the canyon of Dump Creek a mile or more below the lower end of Moose Creek basin. The property may be reached by way of the Stormy Peak and Moose Creek roads and thence by foot or jeep from the lower end of the Moose Creek basin along a bulldozed jeep trail which in part descends rather steeply into the upper canyon of Dump Creek. The property is well down in the narrow rugged canyon. The deposit straddles a steep spur ridge several hundred feet above the creek bed.

The presence of uranium was known and attracted considerable attention in 1954, but little work was done to uncover the deposit until several years later. The property is now held by the Uranium Corporation of America, Inc. The development comprises two large bulldozed cuts, one just below the other on the north side of the spur ridge, and two small cuts, one across the crest of the ridge and the other just to the south.
The property is on a small mass of Challis volcanics which locally forms the lower wall of the canyon between metamorphic granite and gneiss on the west and impure quartzitic rocks on the east. The deposit is in a thick flow of pinkish, strikingly, porphyritic quartz latite, which has much an abundance of dark, smoky quartz phenocrysts and crystals of andesine, sanidine, and basaltic hornblende that it appears almost granular. The hornblende crystals are mostly decomposed to reddish and blackish alteration products; but the crystals of other minerals are clear; and those of quartz, the largest of the phenocrysts, are rounded and partly resorbed. The groundmass is composed of microlites of oligoclase and sanidine with minor amounts of glass. Apatite and magnetite are accessories.

The cuts on and just over the crest of the spur ridge reveal a broad zone of weakly fractured rock trending about N 60° W and dipping 48° NE. In the upper of the two large cuts on the north side of the ridg, the mineralized zone is about 16 feet across. As the large cut just below extends diagonally across the fracture zone, the mineralized body appears to be almost 40 feet wide, though actually it is much less.

The rock along the mineralized zone has been considerably altered. It has lost much of its original pinkish or reddish coloring, although the color has in part been restored by added patches, seams, and stains of reddish hematite, introduced with the uranium-bearing solutions. Otherwise, the rock has a dull, bleached appearance.

The uranium minerals are secondary and consist mainly of autunite, accompanied in places by a little greenish torbernite. The autunite occurs in part as fine, almost powdery incrustations on some of the rock. More generally it forms small crystals or crystal aggregates on and along fracture surfaces. These patches of autunite are yellowish to greenish yellow. The patches appear to be more plentiful in or near the footwall zone than farther out. A sample taken from a 17-foot channel along the lower cut is reported to have averaged 0.5 percent U3O8. Other samples over shorter lengths are reported to average even higher. Deeper work is needed before any considerable amounts of ore can be blocked out.

The volcanics across the canyon show evidence of extensive hydrothermal alteration. Subsequent weathering has colored the bleached rocks in shades of yellow, buff, red, and brown.

Wilcox

The Wilcox property is a short distance up a small gulch a few hundred yards south of Killey Gulch, about 12 miles north of Salmon and less than a mile east of the Salmon River. A short, steep road extends up the gulch from the highway (U. S. 93) to the property. According to location notices claims were staked in May, 1955, by Victor and Carl Hudson. Later the property was acquired by W. Wilcox, who initiated active exploration which continued through 1956.

The work on the property includes an adit about 150 feet long, an inclined shaft blocked by water within 60 feet of the surface, a number of cuts and bulldozed trenches, and three short adits in the gulch below the main workings.
The property covers an exposure of Challis volcanics which locally rests upon an uneven floor of dark-gray Precambrian quartzites, exposed in the lower part of the gulch. The volcanics in turn are overlain on the southwest by beds of conglomerate, sandstone, and shale belonging to the Tertiary Kenney formation and on the east by still younger beds of the Tertiary Geertson formation. The volcanic rocks locally strike northwesterly and dip about 35° NE. The Kenney and Geertson formations rest unconformably on the volcanics. The Kenney beds strike north-northwest and dip 8° E., and the Geertson beds strike about due east and dip 5° S. The volcanics are composed of flows and light-colored tuffaceous rocks. The basal flow appears to be a dark, grayish quartz latite, abundantly loaded with small fragmental inclusions of the underlying quartzite. Inclusions of both the quartz latite and quartzite appear in some of the beds of overlying tuff.

The main adit is driven northwest along the contact between a flow and overlying fine-grained tuff. The tuff beds strike about N 80° W and locally dip 50° NE. Some radioactivity (double background) was detected along the adit, but neither uranium mineralization nor reddish iron staining was observed.

The shaft, about 75 feet south of the adit portal, is inclined 38° E near the surface but changes to 36° a short distance below. The shaft is started in grayish volcanic rock but enters light-colored tuffaceous rocks lower down. Both rocks contain numerous quartzitic inclusions; the tuff also contains inclusions of the volcanic rock. Uranium minerals and hematite-stained rock were not observed.

The many cuts on the surrounding slopes, mostly in tuffaceous beds, reveal little radioactivity. The several short adits in the gulch some distance below the main adit and shaft also disclosed no significant amounts of radioactivity.

The lack of fractures, reddish iron stains, and visible secondary uranium minerals suggest that the local mineralization is not hydrothermal but that the radioactivity may be associated with plant and woody matter in the tuffaceous rocks which precipitated the uranium carried by circulating ground waters.

Other deposits

Other showings of uranium minerals in volcanic rocks are known in the area. These have generally been little explored and were not investigated. Some of these showings are in the volcanics west of Gibbonsville; others are in the volcanics across the river from the E-Dah-How, particularly on the high ridge between Williams and Perrean Creeks. Still others occur in the volcanics east of the Salmon Hot Springs. Some of these deposits may eventually prove as worthy of attention as those which have been described.
DEPOSITS IN LAKE BEDS

The several lake bed formations in the Salmon area also show evidence of radioactivity, especially where the beds contain woody or other incorporated organic matter. Lignites intercalated in these rock may possess even greater radioactivity; but the concentration of uranium is rather low, generally less than 0.01 percent and therefore much too low for present commercial interest.

The uranium concentrations in sedimentary beds with organic matter apparently came about because of the ability of the organic matter to reduce the soluble uranyl ion carried by the circulating ground waters to the lower state of oxidation and thus cause precipitation of the uranium as uraninite or pitchblende or as a stable urano-organo compound.
A. CANYON SETTING OF THE MONAZITE-RUTILE BELT

The rugged canyon terrain in which the monazite and columbium-bearing rutile deposits are located. Canyons in the foreground are carved by Spring Creek; those in the distant background by Squaw Creek and the Salmon River.

B. MONAZITE DEPOSIT

Prominent shear structure along which the principal monazite deposit on the Last Chance property is localized. The rock on the footwall is amphibolite; that on the hanging wall, gneiss.
MONAZITE AND COLUMBIUM-BEARING RUTILE DEPOSITS

LOCATION AND ACCESSIBILITY

The monazite and columbium-bearing rutile deposits are about 30 miles northwest of Salmon in the rugged canyon country carved by the Salmon River and its tributaries (Fig. 1 and Pl. 1, A). Most of the deposits are grouped along a belt about 1.5 miles wide and 18 miles long, beginning in the canyon across from the mouth of Dump Creek, about 2 miles below the town of North Fork, and extending in a northwesterly direction across the drainages of Sage, Indian, Papoose, Squaw, and Spring Creeks (Fig. 5) over the State line and at least as far as Woods Creek, a tributary of the Bitterroot River in Montana. The present study, however, is restricted to the 10 miles of the belt between Dump Creek and the State line, the area previously covered by Abbott and Kaiser. This area is contained in unsurveyed townships T. 24 N., R. 19 E.; T. 24 N., R. 20 E.; and the southern part of T. 25 N., R. 19 E., Boise meridian (Fig. 5).

The area is within easy reach of Salmon by paved highway (U. S. 93) as far as North Fork and from there by a gravelled forest road along the north side of the Salmon River Canyon. The canyon road, which extends down river far beyond the limits of the area, was surveyed for rebuilding during the summer of 1957 and was under construction during the latter part of the summer. Access roads extend up the valleys of Sage, Indian, Squaw, Papoose, and Spring Creeks and afford near approach to most of the deposits, most of which are on steep canyon slopes not easily reached except on foot or by jeep or truck with compound gears (Fig. 5). The Spring Creek road continues over the divide into Montana; the nearest rail transportation is at Darby, Montana, the terminus of a branch line of the Northern Pacific Railway, 60 miles north of North Fork on U. S. Highway 93.

HISTORY

Some crystals of monazite were noted by Trites and Tocker (1953, pp. 169-170) in a pegmatite during their examination of the area for radioactive minerals for the Atomic Energy Commission in 1950, but the monazite deposits with columbium-bearing rutile and other interesting minerals were not discovered until 1952. Their discovery came during building of access roads for logging operations. The discovery prompted widespread prospecting and led to the filing of many claims, mainly by four groups of owners.

During 1952 one group of claims on upper Spring Creek belonging to Oscar Westfall was leased to J. R. Simplot Company; but after considerable bulldozer work, which uncovered several mineral-bearing deposits with monazite, the lease was allowed to lapse. On learning of the presence of columbium-bearing rutile in some of the deposits, the Hobydiphenum Corporation of America leased an adjacent group of claims on upper Squaw Creek from Oscar Westfall. The Hobydiphenum Corporation of America built an access road to the deposits during the latter part of the summer in 1953 and carried on exploration work by drill and adit during the summer of 1954. This work failed to uncover promising quantities of rutile and the lease was dropped. The group of claims was then leased to the Union Carbide Corporation. After some exploratory work by drill and adit in 1956 at a site above that of the Hobydiphenum Corporation, the lease was allowed to lapse.
Some work, mostly by bulldozer, has been done on some of the properties since; but the only work of note in 1957 was the drilling carried on by the United Pacific Mining Corporation on several of the claims on Indian Creek belonging to the Kenneth White-Jim Hutchinson group, and the bulldozer work done by the owners of the Last Chance and adjacent groups of claims in the Salmon River Canyon across from the mouth of Dump Creek.

**GEOLoGIC SETTING**

*Stratigraphic features*

The deposits are within an area of intensely metamorphosed rocks composed largely of amphibolites, porphyroblastic gneisses, and schists, with subordinate quartzite and crystalline limestone. There are also small scantly distributed bodies of metadunite, pegmatite, and rhyolite. These rocks have been described in some detail by Abbott (1954, p.3-10) and Kaiser (1956), who regard the metamorphics as originally sedimentary, probably Beltian rocks, transformed by metasomatic metamorphism into their present form, supposedly by agencies and processes associated with the emplacement of the Idaho batholith.

The gneisses are the most widespread of the metamorphic rocks. They are composed of feldspar, quartz, and biotite with various accessories visible only under the microscope. They show considerable variation in mineral proportions, grain size, and texture. Much of the gneiss is strikingly porphyroblastic and contains large, sparse to abundantly distributed feldspar porphyroblasts up to an inch long. In much of the gneiss the porphyroblasts are so closely spaced that the rock resembles a typical augen gneiss, locally a coarse-grained granite with only minor traces of foliation.

The amphibolites are confined to the main belt of mineralization and along this belt are about as abundantly represented as the gneisses. These amphibolites are typically dark green, ranging from fine-to coarse-grained and from schistose to massive, all within the same outcrop. The amphibole composes from one-third to two-thirds of the rock; the remainder is largely considerably altered plagioclase. On the basis of textural and structural variations, Abbott (1954, p.8) has classed the amphibolites as hornblende-quartz-biotite schists, hornblende schists, actinolite schists, and nonfoliate rock of spotted or blotchy appearance containing a high percentage of hornblende and epidote plus feldspar, quartz, and mica. He describes these rocks as interbedded with the gneisses, their character in large part determined by the composition of the parent calcareous and dolomitic sedimentary rocks. Kaiser (1956) also believes in their original sedimentary character; but the present writer disagrees and recognizes the amphibolites as derived from igneous rocks of originally gabbroic composition. Where the gabbro has not been so extensively altered, it retains its massive character and most of its original minerals. Where it has been deformed by shearing, it has been changed to schist. Through metasomatic metamorphism it has also been impregnated by feldspar and converted to gneiss, including the conspicuously porphyroblastic "augen" gneiss. Thus, non-uniform shearing and metasomatic alteration appear to account for the textural, structural, and compositional variations shown by the rock.
Fig. 5. Map showing location of deposits along the monazite and columbium-bearing rutile belt, Lemhi County, Idaho.
Some thin beds of fine- to medium-grained crystalline limestone of bluish-gray color (buff on weathered surfaces) occur in the metamorphic complex, intercalated with the gneisses and schists of original sedimentary origin; but some of the limestone reported by Abbott and Kaiser is not of this kind but represents coarse-vein olivine associated with the monazite-rutile mineralisation. Such vein carbonates occur as lenses or layers in the foliated amphibolites, in the porphyroblastic and other gneisses, and in places in original beds of limestone.

The only other rocks of pertinent interest are a few small pegmatites rich in allanite along the southwest end of the mineral belt. Other pegmatites, metadiorabases, and rhyolites appear to have no bearing on the monazite-rutile mineralization.

**Structural features**

According to Kaiser (1956) these intensely metamorphosed rocks are separated from less-metamorphosed rocks on the northeast by a major thrust fault trending northwesterly across the Salmon River at the mouth of Dump Creek. To the northeast of the fault the quartzitic and phyllitic Belt rocks have been deformed into broad open folds of northwesterly trend. To the southwest of the fault the beds have been much more intensely and complexly deformed. In this highly metamorphosed and deformed terrain, the structure is interpreted by Kaiser as a large, complexly crumpled, overturned fold, a synclinorium, made up of many small to large isoclinally folded structures whose trends conform closely to those of the more open folds northeast of the major fault. He further points out that the complex crumpling is particularly marked in the amphibolitic zone along the central part of the synclinorium. This view is much the same as that presented by Abbott (1954, p. 12), who recognized the existence of a large synclinorium and attributed the structural complexity of the marbles (and amphibolites) to their position approximately astride the synclinorium axis.

The writer did not have the opportunity to familiarize himself with all the details of the complexly folded structures; but appreciating that the amphibolites are derived from igneous intrusive rocks rather than from calcareous sedimentary rocks, he proposes some structural modifications. The distribution of the metamorphosed intrusive rocks as well as the monazite-rutile deposits along the axis of the synclinorium suggests a special zone of structural weakness, a zone which yielded to intense deformation and facilitated intrusion of gabbroic magmas and later the metasomatic metamorphism associated with the emplacement of the Idaho batholith. This metasomatic metamorphism apparently spread through the sheared and crumpled rocks, converting the gabbro to the various amphibolites and in considerable part also into porphyroblastic rocks. Some of the shearing and crumpling may have occurred just prior to or even during some stages of the metamorphism, with the later shearing along the structurally weak zone also providing channels for the movement of the mineralizing solutions and for the deposition of monazite and other minerals (Pl. 1, B).

Faults and shear zones in the metamorphic complex are difficult to recognize or to interpret, largely because of almost complete obliteration during metamorphism and mineralization. Many faults may represent distributed shearing, preserved in the bands of schistose or more highly foliated zones of gneissic rock. Faults younger than the metamorphism and mineralization are readily detected by fractures, gouge, and offsets.
CHARACTER OF THE DEPOSITS

The deposits possess broadly tabular shapes and may be classed as replacement veins and lodes. They are, however, veins and lodes of an unusual type, characterized by an exceptional concentration of rare earth elements, thorium, titanium, columbium, phosphorus, calcium, barium, iron, and sulfur, and distinguished further by an abundance of carbonates, chiefly calcite. Although others have regarded the carbonates as representing beds of crystalline limestone or marble replaced by the monasite and associated minerals, the present study shows that much of the carbonate intimately associated with the mineralization is younger than the marble beds and indeed younger than the monasite and most of the other minerals. The carbonate is actually a late gneiss mineral and is as much a part of the mineralization as any of the other minerals. This vein carbonate is generally much more coarsely crystalline than that composing the beds of crystalline limestone.

The deposits possess all the compositional characteristics of the unique group known as carbonatites, differing from the type only in the apparent absence of usually associated, alkaline igneous rocks.

The metals of particular interest in these deposits are the rare earths contained in monasite and allanite, and columbium contained principally in the rutile. The rare earths are members of the cerium group.

STRATIGRAPHIC AND STRUCTURAL RELATIONSHIPS

The monasite and columbium-bearing rutile deposits are mainly within the zone of amphibolitic rocks and are contained in the massive and schistose amphibolites; in the porphyroblastic gneisses derived from the amphibolites and enclosing sedimentary rocks; and in thin beds of crystalline limestone. Contrary to previous reports in which the deposits are described as replacements of limestone or marble, many are outside the limestone or marble beds. Their occurrence appears to depend more on structural than on stratigraphic controls.

The belt of mineralization tends to conform with the zone of amphibolized rock and hence with the inferred zone of structural weakness, which, prior to metamorphism, had directed intrusion of gabbroic rocks later changed to amphibolites. This zone of structural weakness has influenced or localized mineralization over a distance not less than 18 miles, more than 10 of the miles in Lemhi County.

Within the belt of mineralization the individual deposits trend in northwesterly directions, in part approximating or coinciding with regional trends. Individual deposits possess strikes of N 80° W, N 60° W, N 30° W, and N 10° W. Deposits on the southwest side of the synclinorium dip northeast and those on the northeast side steeply southwest.

The deposits are structurally controlled, but the control is not always readily apparent. Some occur along well-defined zones of shearing, parallel to or conformable with the foliation or bedding of the enclosing rock and are bordered by sharply defined walls, unmarked by gouge (Pl. 1, B). Some cut the nonfoliate amphibolite and appear to be fissure
rather than shear-controlled. In many deposits the original control has been almost obliterated by the mineralization which, through replacement, has removed directive shears or fractures.

Stratigraphic along with structural controls have been advanced by Abbott (1954, p. 8-9) and Kaiser (1956) to explain the relations of the deposits, both stating that the beds of crystalline limestone have localized the mineralization, the deposits assuming the structural characteristics of the folded limestone beds. The relation of the mineralization to minor folding has received especial attention by Kaiser who suggests that the deposits are localized in crests and troughs of small folds, the actual location depending on a combination of a fault, a fold, and a bed of limestone.

MINERALOGY

Summary statement

The monazite and columbium-bearing rutile deposits contain an extraordinary assemblage of minerals, one quite typical of the carbonatite type of deposit, which is noted for its concentration of minerals containing rare earth elements, thorium, titanium, columbium, barium, phosphorus, calcium, and iron, and for its abundance of carbonates. The minerals containing these elements are prominently developed in the local deposits. The complete mineral list includes biotite, actinolite, glaucophane, garnet, allanite, monazite, apatite, barite, rutile, sphene, ilmenite, magnetite, calcite, and minor amounts of the sulfides, pyrite, pyrrhotite, and chalcopyrite. All of these minerals, except the glaucophane, sphene, garnet, and sulfides, are relatively though not uniformly abundant; and all, except the garnet, sphene, and apatite, are generally recognizable without the microscope. The minerals of most pertinent interest are the monazite and allanite, which contain the rare earth elements, and the columbium-bearing rutile. Other minerals also distinctive of the deposits are the actinolite, barite, apatite, ilmenite, magnetite, and calcite.

Descriptive features

Biotite

Biotite is not a conspicuous mineral in any of the deposits, but it is invariably present, in part as small grains inherited from the micaceous country rock and in part as much coarser grains up to a half inch in diameter deposited with the other lode minerals. It appears to be most abundant and most coarsely grained toward the northwest end of the mineralized belt. Like the inherited grains, some of the deposited biotite is penetrated and replaced by all the lode minerals; but some is a bit younger than and in part replaces actinolite which is otherwise the first of the introduced minerals. Some of the biotite is bleached and a little of it is chloritized.

Actinolite

Actinolite is one of the most abundant and in some deposits it is the most abundant mineral. It is present in all deposits, but it is not so plentiful along the southwestern end of the mineral belt as it is to the northwest where in some deposits it is the leading mineral.
In some deposits the actinolite is somewhat bleached and has a
dull, rather pale, greenish color; but in deposits where it remains un-
altered, its crystals are highly vitreous and dark green. Its most not-
able and characteristic feature, however, is its tendency to occur as
radial aggregates, generally of small size, less than one half inch in
diameter, otherwise as felted, essentially fibrous masses. However, in
some deposits, especially along Squaw Creek, the radial aggregates are
large, in part composed of slender needles up to 4 inches long.

The radial and felted actinolite replaces the host rock whether
crystalline limestone, amphibolite, gneiss, or mica schist, in part as
seamlike masses along fractures, especially in the limestone. Its aggre-
gates are penetrated and in part replaced by all the other minerals. Its
radial groups commonly occur as irregular remnants and as shadowy outlines
in the coarse calcite which is so characteristic of the deposits.

Glaucophane

Glaucophane has been found in only one deposit, on the east side of
Indian Creek. There it forms coarse black needle aggregates along frac-
tures in more or less massive actinolite, the aggregates penetrating in-
to and replacing the actinolite. Because of its black color, it is con-
spicuous in the deposit. Remnants of glaucophane are in places engulfed
in the calcite.

Garnet

Greenish garnet has been observed sparingly in one of the deposits at
the Silver King on upper Spring Creek where it was recognized as micro-
scopic grains with other silicates as remnants in coarse calcite.

Allanite

Allanite, a cerium-bearing epidote, is present in most, if not all the
deposits, in some as microscopic grains, in others as coarse grains easily
discernible by the unaided eye. Where visible, it has a rather dull, gray-
ish black appearance, showing marked resemblance to a blackish amphibole,
its somewhat flattish grains measuring up to a half inch long. Where es-
pecially abundant, it forms massive pods up to an inch thick and several
inches long, as well as scattered nests and small bunches and more widely
scattered grains generally closely associated with actinolite. In sev-
eral pegmatites at the southwest end of the mineral belt, it forms well-
shaped crystals up to two inches long.

The allanite is strongly radioactive and may contain much of the
thorium known to occur in the deposits. Allanite is a complex cerium-
bearing silicate of the epidote group which may be assigned the formula
(Ca,Co,Fe,Mn,Fe)3(Al,Fe)6(Fe,Fe,Mn)3(SiO4)3OH.

Microscopic study reveals that the allanite is older than and is re-
dered by crystals of monazite, in places in such a way as to make it ap-
pear as mantles on the monazite. It tends to form well-shaped crystals
which penetrate into and through the actinolite and biotite. Only remnants
of allanite appear in the barite and calcite.
Monazite

Monazite has the most widespread distribution of all the minerals, except calcite. It appears in every deposit, but more abundantly in some than in others. It occurs as crystals and small crystal aggregates which have a highly irregular distribution. It is discernible in most deposits without the microscope but the microscope usually reveals its presence where it cannot be detected by the eye alone. The crystals and grains range from microscopic sizes to a half inch long. Most of the monazite has a honey-brown color; but in some deposits the grains are reddish brown and at the Roberts property, in part, decidedly reddish.

Most of the monazite, a rare earth phosphate \((\text{Ce}, \text{La}, \text{Th})\text{PO}_4\), is weakly radioactive and in general contains less than one percent thorium. Most of the thorium in the deposits was apparently taken up by the somewhat earlier allanite.

Like the allanite, the monazite tends to develop as well-shaped crystals and these crystals tend to impress their outlines against the actinolite and allanite. In some of the crystal aggregates, the monazite contains remanent inclusions or shadow outlines of the allanite. Its crystal borders are generally preserved in contact with the calcite, but exceptions occur. Its rounded or corroded grains may occur as inclusions in calcite as well as in apatite and barite.

Apatite

Apatite is notably abundant in the deposits, but the microscope is necessary to detect its presence. It may occur as scattered, more or less barrel-shaped crystals but perhaps more commonly as groups of crystals which tend to form granular aggregates scattered here and there through the deposits. These aggregates may hold small remanent inclusions of monazite, but in general the apatite tends to clear itself of earlier minerals. Aggregates may be penetrated by calcite and the apatite may appear as remanent masses within the calcite.

Barite

Barite is another abundant mineral, but without the microscope its presence may be easily overlooked. Its distribution within the deposits is irregular. In places it forms coarsely crystalline aggregates which are readily recognized by the unaided eye. More generally its presence is obscured by the more abundant calcite, but the weight of the material may be a clue to its presence. The barite shows up with the microscope, generally as granular aggregates interstitial to the minerals that have been described. Like the other minerals, its distribution is somewhat sporadic with the crystal or granular aggregates occurring as irregular, scattered patches through the deposits. These patches tend to be remarkably free of other minerals; but some remnants of actinolite and monazite may remain, the latter usually as small ovoid grains. Where the barite and apatite occur together, the barite tends to penetrate into, corrode, and engulf the apatite. With calcite the relations are reversed, the barite occurring as irregular, island-like remnants in the calcite grains.
Calcite

Calcite, one of the most distinctive minerals, occurs in appreciable to large amounts in every deposit. This calcite is generally coarsely granular, the grains in places measuring up to one-half inch long, and is not to be confused with the bluish-gray, fine- to medium-grained crystalline limestone in which some of the deposits occur. The calcite is white to pale buff and weathers brownish. Most of it appears to be a ferriferous variety and, although some of it resembles siderite superficially, it reacts vigorously with cold acid.

The calcite offers strong contrast to the crystalline limestone, especially where it occurs as irregular seams cutting and penetrating the limestone. Such seams and masses generally retain remnant inclusions of the limestone, visible microscopically. The calcite may also retain remnant inclusions of all the minerals that have been described, preserving shadowy outlines of some of them which are even visible to the unaided eye. The calcite, however, does remarkably well in clearing itself of the minerals which it replaces. Its relations to the rutile, ilmenite, and magnetite are somewhat obscure and have not been completely determined.

Rutile

Rutile appears to be present along most of the mineral belt, but the columbium-bearing variety is apparently restricted to the deposits from Indian Creek northwestward, reaching its greatest development in the Squaw Creek area. Toward the southwest end of the belt the rutile apparently does not contain columbium.

Most of the rutile occurs as lumps or granules, some up to an inch or two in diameter and some as pods up to several inches long. The rutile is generally without crystal form and that which is columbium-bearing occurs chiefly as dark, steel-gray, granular masses. This rutile may be distinguished from the ilmenite and magnetite by its higher luster or more shiny appearance. Its metallic appearance reflects its high columbium content, reported by Kaiser to range from 4 to 10 percent columbium metal and by chemists of the Molybdenum Corporation of America 45 to 48 percent columbium oxide (Russell Good, oral communication). Because of its high columbium content, the rutile is generally opaque in thin sections and cannot be distinguished from the ilmenite and magnetite. The rutile that contains no columbium possesses an adamantine rather than a metallic luster and is further distinguished by its more normal, somewhat reddish color.

Its spatial relations indicate that the rutile is one of the younger minerals. It generally appears in the more central parts of the deposits, usually with the calcite, although granules may occur outward in the actinolite. These granules penetrate into and out through the other minerals, except possibly the calcite. Its relations to the calcite are not entirely clear; but in places where the granules have been broken, the fragments appear to have been cemented by the calcite.

Ilmenite

Ilmenite is conspicuously abundant in some of the deposits on the Roberts property, but elsewhere is a minor mineral and in some places may be lacking. It shows some tendency to assume its crystal form, but it also
occurs as lumps and grains. Its color is black but its luster is not so shiny as that of the rutile and in contrast appears rather dull. It also tends toward a platy development, which further distinguishes it from the rutile. It probably shows a greater resemblance to the allanite in color and luster than to any other mineral. Its grains are generally rather small; but in one of the deposits on the Roberts property the crystals approach giant size, measuring up to 8 inches long and 4 inches wide. The ilmenite contains a small amount of columbium, probably less than one percent.

Like the rutile, the ilmenite penetrates and replaces silicates; but as some of its broken grains are cemented by coarse calcite, it is not quite so young as the calcite gangue.

Sphene

Sphene is another of the scant minerals and was observed as microscopic grains in some of the ilmenite-rich fillings at the Roberts property. Its grains are mostly along or against some of the larger grains of ilmenite, the relation suggesting that the sphene crystallized ahead of the ilmenite and was then in part replaced by the ilmenite.

Magnetite

Magnetite is present in all deposits but generally in little more than accessory amounts. Its grains and crystals are generally small and occur as disseminations, less commonly as fine, granular streaks, and small irregular veinlets. The magnetite appears to be more closely associated with and more abundantly disseminated through the carbonates than with or through the other minerals. That some of the magnetite is younger than the carbonates is evident from the few veinlets that cut the carbonates, but the relations of some of the disseminated grains in both the calcite and other minerals suggest that some may be older than the calcite.

Sulfides

The sulfides are scant accessories and generally occur as rather widely disseminated grains, exceptionally as coarse aggregates. They may occur irregularly through the deposits but are generally most abundant in or with the calcite. The most common or abundant sulfide is pyrite, in part as cubic crystals up to one-eighth inch square; but chalcopyrite and pyrrhotite also occur in some deposits. In one deposit on Squaw Creek, a small pocket of sulfides was uncovered containing coarse grains of pyrite, pyrrhotite, and chalcopyrite, which replace actinolite and calcite.

Thorite

Thorite has been reported by Kaiser in deposits along the central and southwestern part of the mineral belt, particularly in a small area on Squaw Creek, at Noname Gulch, and on the south side of the Salmon River opposite Noname Gulch, occurring therein as reddish-brown grains 1 mm. or less in diameter. These areas were not examined by the writer. The deposits are apparently not those which contain the monazite and rutile but belong to the thorite-rare earth group prominently developed at Lemhi Pass and in the Diamond Creek area.
Data on mineral relationships included with the mineral descriptions make it evident that the minerals were formed in an orderly succession, silicates ahead of phosphates, phosphates ahead of sulfates, sulfates ahead of oxides, oxides ahead of carbonates, and carbonates ahead of sul-
fides. This order may be regarded as a normal succession, but the exact position of some of the individual minerals in the succession has been obscured through absence of adequately defined contact relations. This lack is particularly true of garnet and the oxide minerals.

From evidence of replacement and other relationships the sequence from earliest to latest minerals appears to be biotite, actinolite, biotite, glaucophane(?), garnet(?), allanite, monazite, apatite, berite, rutile(?), sphene(?), ilmenite(?), calcite, magnetite, pyrite, pyrrhotite, and chalcopyrite. Question marks are affixed to those minerals whose relations with respect to adjacent minerals are not definitely known or precisely fixed. The glaucophane, for example, is known to penetrate and replace actinolite; but it was not observed in contact with biotite, allanite, and monazite. It is known to be older than the calcite. The greenish garnet is older than the monazite, but it was not observed in contact with the actinolite or other silicate minerals. The order of the iron and titanium oxides has not been definitely established. These oxide minerals are rather closely associated and in part may be nearly contemporaneous. It is known that the sphene is somewhat older than the ilmenite. It is also known that some of the magnetite is older and that some is younger than the calcite. The oxides and carbonates seem closely grouped.

DISTRIBUTION OF THE RARE EARTH AND COLUMBIUM-BEARING MINERALS

The distribution of the rare earth minerals, allanite and monazite, and the columbium-bearing rutile within the deposits is not predictable. These as well as many of the associated minerals have a highly irregular distribution. Only the actinolite and calcite maintain some regular degree of persistence, but even the quantity and proportions of these minerals vary considerably from place to place. The rare earth minerals and the rutile typically form grains, granules, and small irregular aggregates in the silicate-carbonate bodies. Usually just a few aggregates of these minerals are visible at any one place. Their distribution is for the most part bunchy or sporadic.

Allanite and monazite occur in variable amounts in all deposits, locally in shoots of appreciable size. The columbium-bearing rutile has its greatest concentration in the deposits on upper Squaw Creek, but apparently occurs in most, if not all, deposits from Indian Creek northwestward to and beyond Spring Creek, its distribution invariably spotty.

The radioactivity and thus the thorium content of the deposits vary widely. The radioactivity is only a few times higher than average where monazite is the chief rare earth mineral, but is considerably higher where allanite is present.

SIZE OF THE DEPOSITS

The individual deposits are characteristically small, rarely more than a foot or two across, exceptionally as much as 8 feet, and generally cannot
be traced for more than a few tens of feet, mainly because of limited exploration. Where the overburden is not too concealing, some of the deposits have been traced for some hundreds of feet, even for a thousand feet or more; but the more important minerals are distributed irregularly along them, largely confined to small shoots, exceptionally as much as 40 or 50 feet long.

In relatively broad zones of schistose rock, the mineralization may spread sparingly through much of the zone with greatest concentration of minerals in small, irregularly distributed veins mostly less than a foot thick. There may be several of these veins, one about parallel to the other, each of no great length or depth. The zones may also contain sporadically distributed bunches or pockets of minerals with monazite or rutile. Such distribution of minerals appears to characterize the deposits explored by the Molybdenum Corporation of America on upper Squaw Creek. Such a tone of mineralization may be regarded as a relatively large, low-grade lode.

**Tenor of the Deposits**

No sampling was done during the present investigation, but the few and generally inadequate exposures give the impression of a fair concentration of rare earth minerals and locally also of columbium-bearing rutile. This impression is partly confirmed by the sampling done by Abbott in his investigation several years earlier when some of his samples were found to contain up to 20 percent or more of combined rare earth oxides and thorium. His best analysis across 3 feet of a deposit on the Monazite Queen gave 21 percent rare earth oxides plus thorium; but two other samples from other parts of the same deposit gave 15 percent rare earth oxides and thorium across 3.5 feet, and 2.15 percent of the oxides across 10 feet. A grab sample from the fresh muck pile at the Silver King contained 14.6 percent rare earth metals and thorium, whereas a cut sample 5 feet long contained 17.7 percent of these oxides. A 2-foot sample across another body near the creek on the same property contained 4.46 percent rare earth oxides and thorium. The highest value was obtained at the Roberts property where a 2.5-foot sample across the principal deposit carried 21.5 percent combined rare earth and thorium oxides; whereas another sample of the same width at another spot contained 14.5 percent of these same oxides. Samples taken at other deposits along the mineral belt contained from less than one percent up to several percent combined rare earth and thorium oxides. The percentage expressed in all the analyses probably represents mostly rare earth oxides as the thorium content of the monazite is generally less than 1 percent. If considerable allanite is included in the sample, the thorium content may be somewhat higher. The allanite may account for the low phosphate content of some of the richer rare earth samples.

The deposits were not sampled for columbium by Abbott and the results of such sampling by others is not available for publication. From eye appraisal of some of the small high-grade shoots the columbium content could locally exceed 5 percent and even 10 percent. Mining-width samples might run several percent columbium for limited distances and samples across 20 or 30 feet of a mineralized schistose zone might run a little better than one-half percent columbium. The problem is one of finding a sizable reserve.
Both Abbott and Kaiser regard the deposits as products of metamorphic differentiation. Abbott (1954, p. 22) favors the view that the rare earth elements had their source in clastic grains in the argillaceous and arenaceous sediments of the Belt series and that during regional metamorphism the minerals containing the rare earths were dissociated and the rare earth ions forced to migrate into a more compatible environment consisting of beds of phosphatic limestone, where the ions combined with the lime and phosphorus of the limestone to form porphyroblastic grains of monazite. Kaiser (1956) considers metamorphic segregation more plausible than hydrothermal action and postulates that during metamorphism solutions permeated the rocks and carried appreciable though probably small proportions of the rare elements, either introduced along with the solutions from an unknown source or taken up selectively from the rocks themselves, and that these elements were concentrated under favorable environmental conditions involving a combination of a limestone and a certain structural setting, the stratigraphic and structural controls restricting the deposits to their present position.

Contrary to the views held by Abbott and Kaiser, the writer believes that the Belt rocks could not have supplied the unique ingredient of these deposits. The association and concentration of elements are so much like those found in and characteristic of carbonatites of undisputed igneous origin that a genesis other than through igneous agencies seems most improbable and would be a most unusual coincidence. Thus the writer believes that the rare earths, barium, columbium, titanium, and other substance were introduced by highly mobile fluids from some deep, probably magmatic source, possibly the root region of the Idaho batholith. This source may earlier have provided copious "granitizing fluids", enriched in potash, which soaked through the Belt rocks and transformed them into porphyroblastic gneisses and other types of metamorphic rocks. The mineralizing fluids enriched in the rare earths, titanium, columbium, phosphorus, barium, carbonates, and other constituents entered not long after the metamorphism and deposited their load of materials along structurally favorable channelways.

The minerals of these deposits show an orderly sequence of formation, one probably controlled by declining temperatures and changing chemical composition. As in the high-temperature hydrothermal deposits, the silicates were the first to form, presumably when temperatures were highest; and the carbonates and sulfides last, after temperatures had declined to more moderate levels. The sequence can be regarded as more or less typically hydrothermal and the deposits as hypothermal, occurring as hypothermal replacements in carbonate and other rocks. They should, perhaps, be classed as carbonatite veins and lodes.

OUTLOOK

The district contains a notable concentration of rare earth minerals and columbium-bearing rutile, but the exploitation of these deposits must await further development and more favorable marketing conditions. At present the rare earths cannot be expected to compete against the huge, already developed, rich carbonatite deposits in the Mountain Pass district of California. Should a larger market develop for the cerium group of rare earth metals, these deposits could have competitive possibilities. In the
meantime they should be more thoroughly explored and developed, and search should be carried on for as yet undiscovered deposits. More work is needed in order to evaluate the deposits properly and to establish sizable reserves. Economic exploitation cannot be considered until more is known of the available supply of rare earths. From the relatively little work that has been done, the district appears to contain a potentially valuable reserve of rare earth metals, available for commercial utilization, if and when economic factors justify.

The deposits with columbium-bearing rutile should be given special consideration because of the multiplicity of metals. Not only may such deposits be a potential source of columbium but also of the rare earth metals. This combination of metals should add considerably to the value of the deposits, should attention be directed to the recovery of all metals. Although sizable deposits rich in rutile have not been found, the search should not be discontinued. The possibility that the richer concentrations, especially those in zones of schistose rocks, may be contained and form essential parts of much larger lower-grade deposits should receive some consideration. Marketing problems may also plague the utilization of the rutile. Unless a sizable reserve of rutile should be demonstrated, it is not likely that the district can compete against the Brazilian deposits recently announced to contain major world reserves of columbium.

PROPERTIES

Monazite Queen

The Monazite Queen, the most northwesterly of the properties within the area (Fig. 5), is near the headwaters of the east fork of Spring Creek, very close to the Idaho-Montana line, actually near the heads of steep rugged gullies just under the ridge or drainage divide that carries the State line (Pl. 1, A). It can be reached most conveniently by driving to the summit of the divide on the Spring Creek road and then descending the slope on foot. The property is about a mile east of the Spring Creek road.

The claims comprising the Monazite Queen are owned by Oscar Westfall of North Fork. The work on the property is reported to comprise two prospect holes about 300 feet apart (Abbott, p. 13).

Because of the difficulty of finding the deposit unguided, the property was not visited and the description which follows has been adapted from the one given by Abbott (p. 13). The deposits are enclosed in schists which locally strike about N 35° W and dip 60° NE. In the lower, more southerly cut the immediate hanging wall of the deposit is a barren, white quartz vein about 2.5 feet thick containing schist inclusions. Beneath the vein are about 3 feet of calcite with rather large grains of actinolite and monazite, bordered below by schist with small seams and lenses of calcite. Monazite is present in the seams and stringers of calcite in the underlying schist as well as in the vein above. According to Abbott a sample across 10 feet of the schist and vein contained 2.16 percent combined rare earth and thorium oxides and 1.01 percent phosphate.

In the upper prospect pit the carbonate vein is 3.5 feet thick and, in addition to monazite and some pyrite, contains small, black, exceedingly shiny grains, presumably rutile. Above the vein is a 3-foot zone of highly
oxidized and disintegrated, originally schistose material with abundant well-formed crystals of monazite. A sample across the 3.5-foot carbonate vein contained 1.05 percent combined rare earth and thorium oxides and 1.04 percent phosphate, whereas the oxidized material above contained 21.0 percent rare earth and thorium oxides and 8.5 percent phosphate.

**Silver King**

The Silver King is near the head of the most easterly branch of Spring Creek, about 5 miles from the Salmon River (Fig. 5). This property, also owned by Oscar A. Westfall, comprises a group of 15 claims covering monazite deposits near creek level and on the upper slope separating Spring Creek from Squaw Creek (Pl. 1, A). Those on the upper slope are some 300 to 400 feet above the creek and about a fourth of a mile to the east. The deposits may be reached by an unimproved road which in 1957 was barely passable as far as the first workings near the creek and, impassable from there on because of fallen timber.

The claims were among the first of those located in the district and in 1952 were leased to J. R. Simplot Company, after which they were extensively prospected by bulldozer trenching. Several monazite deposits were uncovered, but the work was abandoned and the lease allowed to expire. Exploration was resumed several years later but much of this never work was in an adit near creek level and in further bulldozing to enlarge some of the cuts made in 1952.

The deposits are within the main belt of mineralization; but the belt locally seems to be largely devoid of amphibolitic rocks and is characterized by complexly folded beds of marble, mica schist, and gneiss. The trend of the deposits does not appear to conform with that of the belt itself; but the individual deposits trend obliquely across the belt in more northerly directions and, exceptionally, directly across in a northeasterly direction.

The deposits are no longer well-exposed near the creek and the only monazite observed was in a cut above the adit. The early cuts are reported (Abbott, p. 14) to have exposed a narrow zone of monazite-bearing lime silicate rock along the north bank of the gully. Although the mineralized rock was not then adequately exposed, it was thought that the trend of the body was N 45° E and the dip, 65° SE. The original marble had been almost entirely replaced by honey-colored monazite and by much lesser amounts of actinolite and ilmenite (rutile?). The monazite-rich body measured 1.5 feet thick and was enclosed in deeply weathered biotite schist. A 2-foot sample cut across the monazite zone into the bordering schist walls is reported to have contained 4.46 percent rare earth and thorium oxides and 2.14 percent phosphate (Abbott, p. 14). A probable continuation of the deposit was also reported in the floor of a bulldozed cut about 500 feet to the northeast on the other side of the gulch and about 75 feet higher than the first exposure. The showing is said to consist of blue marble with scattered grains of actinolite and barite but with no visible crystals of monazite. The strike of the body at this point is given as N 55° E.

The work on the upper slope east of the creek consists of four large bulldozed benches arranged en echelon, one closely above the other and tied together by bulldozed ramps. The lower cut reveals nothing but highly weathered schist and gneiss, but the cut above has uncovered three beds
of closely folded, strongly altered, but unmineralized marble enclosed in mica schist. Some monazite is reported in the marble along the floor of the ramp connecting the second and third benches, the quantity of monazite increasing in abundance near the floor of the third bench and becoming especially abundant in the exposures on the third bench itself. On this bench the mineralization has been exposed for more than 300 feet, with bodies of carbonates up to 8 feet thick.

The mineralization on the third as well as on the other benches appears to be confined to beds of bluish-gray marble, but in places the marble seems to be missing. At one place near the northeast end of the third bench the marble, which locally trends nearly due north and dips 65° W, shows little evidence of mineralization other than some small grains of monazite. About 25 feet to the west along the same bank, a zone about 5 feet across is composed almost entirely of actinolite, biotite, and quartz, the strike there being N 10° W and the dip, 70° SW. About 25 feet beyond this point is another zone some 8 feet wide, composed of marble or calcite rock which projects out into the cut. The strike and dip of this body is much the same as of one which is 50 feet to the east, but the mineralization is much more impressive and is represented by 5 feet of carbonate rock heavily impregnated with large honey-colored crystals of monazite. A sample across 5 feet of this rock taken by Abbott contained 17.7 percent combined rare earth oxides and thorium, and a grab sample from the same pile obtained from the last blast made on the exposure contained 14.8 percent rare earth and thorium oxides. This high monazite-bearing deposit has been uncovered for a length of 50 feet.

The minerals exposed in the upper benches appear to be largely, if not entirely, a replacement of bluish, crystalline limestone, but the minerals have a spotty distribution. The crystalline limestone or marble has been replaced rather extensively by coarsely crystalline calcite and in places by abundant actinolite and appreciable amounts of coarsely crystalline biotite. Monazite crystals up to a half inch long are locally abundant and rutile occurs sparingly in granules up to a half inch in diameter. In addition to the minerals just mentioned, the microscope also confirms the presence of variable but generally appreciable amounts of barite and minor amounts of green garnet, magnetite, pyrite, and quartz. The coarse calcite, generally the most abundant mineral in the mineralized rock, is younger than and shows considerable replacement of the actinolite, biotite, allanite, monazite, and barite.

**Lee Buck**

The Lee Buck group of claims, the property of Oscar A. Westfall, Lee Ash, and E. R. Hagel, is on tributaries of Squaw Creek 3 to 5 miles from the Salmon River (Fig. 5). The property is accessible by road, but the final few hundred yards are too steep for motor vehicles without compound gears. This group of claims was leased May 5, 1953, to the Molybdenum Corporation of America. Work began soon thereafter on an access road from the main creek to the principal deposits on an upper tributary in preparation for surface trenching, drilling, and underground work which was largely carried on during the summer and autumn of 1954. When this work was completed the Molybdenum Corporation relinquished its lease. Later a lease was granted to the Union Carbide Corporation and in 1956 exploration was started on deposits a short distance above those investigated by the Molybdenum Corporation. After completing a short adit and drift and some drilling, operations were suspended and the property has since been idle.
The property comprises about 12 claims. The work of the Molybdenum Corporation of America was confined to deposits on the Lee Buck No. 3 claim and that of the Union Carbide to deposits on the Lee Buck No. 4. The work done underground by the Molybdenum Corporation comprises a crosscut driven northerly for about 65 feet and a 55-foot drift driven westerly about 25 feet from the face of the crosscut. The amount of drilling done was not learned. The work by Union Carbide consists of a crosscut 55 feet long driven northeasterly with a 55-foot drift carried southeasterly 35 feet from the face of the crosscut. The amount or extent of any drill work was not learned.

The Lee Buck is the site of several columbium-bearing rutile-monazite deposits, all of them on tributaries west of the main creek. These are within the main belt of deformation and amphibolitic alteration, and apparently also within the area of most extensive rutile mineralization. Some of the deposits are in thin beds of marble, but others are within schistose or siliceous rocks. They all appear to conform in trend and dip with the foliation of the enclosing rock, but most of them have been bared for only short distances, so that the structural and stratigraphic picture is not wholly complete. In all exposures the minerals have a rather spotty distribution, with local areas containing considerable concentrations of rutile and other minerals. Coarsely crystalline actinolite and calcite with rutile and alalanite are the most abundant minerals of these deposits.

The deposits on the Lee Buck No. 4 claim, explored by the Union Carbide Corporation in 1956, are the most northerly of the deposits and are at the very end of the access road which was extended beyond the workings of the Molybdenum Corporation by Union Carbide. These deposits are exposed in several small cuts on the outcrop and by crosscut and drift a short distance under the outcrop. The deposit is contained in a thin bed of bluish-gray crystalline limestone which strikes N 85° W and dips about 55° SSW, about parallel to the steep slope bordering the gulch. The outcrop relations suggest two such beds about 10 feet apart. The beds of crystalline limestone, which measure up to several feet thick, have been sheared or fractured and the introduced minerals occur in part as thin, irregular bands, veinlets, and stringers in and along the fractures. These introduced minerals include very coarse-grained actinolite and calcite; variable but locally abundant amounts of monazite, rutile, and barite; and minor amounts of apatite, magnetite, ilmenite, and pyrite. In the drift and crosscut a short distance under the surface exposures, the shear or slip zone is prominently developed but shows little evidence of mineralization. Some thin bands of calcite appear along the drift but there is no clearly recognizable vein. A few pieces of rock on the dump contain some small grains of monazite and rutile. Apparently little attempt has been made to trace the course of the deposit or to determine its length.

The deposits on the Lee Buck No. 3 claim explored by the Molybdenum Corporation lie several hundred yards southeast and several hundred feet below but apparently not in line with the deposits on the No. 4 claim. The deposits were once well-exposed in a long bank cut across the outcrop and in some smaller cuts above, but caving of the banks as well as slide material from above have so well covered them that they are unavailable for detailed study. The exposures suggest a rather broad zone of mineralization, composed of a principal vein several feet thick, closely bordered by several small parallel veins a foot or two thick. The general zone appears to trend N 70°-75° NW and dip 75° SW, and may measure 8 feet or more across. The veins are in
schist and tend to swell and pinch abruptly, occurring in part as pods, lenses, and irregular bunches of vein materials. Although several of these veins appear on the surface, only one was cut in the underground workings just a short distance below. Where exposed by the crosscut the vein is about two feet thick; but, although shearing is fairly prominent along the drift, the vein is discontinuous and the mineralization spotty though locally rich.

The deposits on the Lee Buck No. 3 claim are apparently not in marble, but are enclosed in schist and gneiss. The most conspicuous minerals are actinolite, calcite, and rutile; but allanite is also abundant and there are appreciable amounts of monazite, apatite, barite, magnetite, and pyrite, and locally minor amounts of pyrrhotite and chalcopyrite. The actinolite is exceptionally coarse-grained and commonly forms coarse, radial aggregates composed of slender crystals as much as two inches long. The calcite is also coarse and in places forms grains more than a half-inch long. The rutile likewise forms coarse granules and small pods up to two inches long. The allanite generally occurs with the actinolite and forms dull, dark greenish-black, discontinuous seams up to a half-inch thick. Monazite is not conspicuous but is visible in places to the unaided eye. Most of the other minerals, except the magnetite and sulfides, are best recognized with the microscope, although the presence of barite may be inferred from the weight of the ore material. The actinolite and coarse carbonate are persistently distributed, but the others have a more sporadic distribution. In places the rutile forms small shoots of relatively rich ore.

Because of the spotty distribution of the minerals, more attention might be directed to the broad zone of mineralization rather than to the individually small but rich veins within the zone. There is a possibility that the entire zone of mineralization might comprise a relatively large, low-grade deposit.

Other deposits on a tributary farther down Squaw Creek were not visited; but from descriptions given by Abbott (1954, p. 15) a carbonate body striking N 70° W and dipping 75° SW, has been exposed for more than 100 feet. This deposit is composed of coarsely crystalline calcite, with barite and rutile and minor amounts of monazite.

Roberts

The Roberts property is on the steep slope north of the Salmon River about 3.5 miles below the Indianola Ranger Station (Fig. 5). The deposits are some distance up the slope and can be reached from the main road along the river by poorly marked trails which start their ascent along the floors of steep gulches and then switch to the side walls where more moderate grades may be used. These trails leave the road a few hundred yards northeast of the buildings on the Thomas Wend ranch.

The property is reported to comprise seven claims belonging to H. R. and Helen M. Roberts, originally located in 1946 with amended locations in 1955 and 1957. The work on the property consists of a number of small cuts, mostly along the outcrops of several of the deposits.

The deposits are off to one side of the main belt of mineralization, nearly a mile southwest of the deposits on Papoose Creek aligned along the axis of the belt. They are just over the ridge separating Squaw Creek from
the Salmon River, directly opposite the mouth of Popoose Creek. They are contained in schistose and gneissic rocks and, unlike the deposits along the main belt which dip southwest, they dip in northeasterly directions. These deposits are particularly notable for their high concentration of monazite and ilmenite, with the monazite locally in relatively large, high-grade shoots. The deposits also contain abundant calcite, variable but locally abundant ilmenite and actinolite, appreciable amounts of apatite and barite, and minor amounts of allanite, magnetite, pyrite, and chalcopyrite.

The main monazite deposit is the most westerly one and has been traced across the ridge and down the north slope for nearly a thousand feet. It has been exposed in a number of shallow cuts, beginning at the crest of the ridge and continuing northerly to the gulch bottom. For part of the distance the deposit forms a low ledge extending diagonally across the slope. The deposit strikes N 50° W and dips 50°-60° NE. It lies between a hanging wall of augen gneiss and a footwall of biotite schist. At the crest of the ridge the deposit is about three feet thick and in the main exposure below from two to three feet thick. Except at the bottom of the gulch, monazite is invariably present. In the main cuts midway up the slope it is concentrated as a massive band about six inches thick just under the hanging wall, with further occurrence as scattered crystals through a 2-foot carbonate zone below, and as fewer grains in the underlying schistose footwall. This rich concentration of monazite is exposed for about 40 feet along the strike, but the monazite mineralization continues less abundantly as scattered grains to the crest of the ridge. Other minerals along the deposit include considerable actinolite and some allanite, apatite, barite, ilmenite, and magnetite. The ilmenite is most conspicuous in the most northwesterly cut near the gulch bottom. The monazite crystals are coarse and are reddish brown. A sample taken at the main exposure midway up the slope across 3.5 feet of the deposit is reported by Abbott (1954, p. 18) to contain 21.5 percent rare earth and thorium oxides and 11.6 percent phosphate. A check sample at nearly the same place contained 14 percent combined rare earth oxides and thoria.

At the east side of the same ridge on the Jack Pot No. 5 claim and more or less closely aligned with the deposit on the west, is another exposure, which has been prospected by a cut, with a face about ten feet high. This exposure shows ilmenite and carbonate almost exclusively. The deposit strikes about N 55° W, dips steeply northeast, and may be traced above the cut for more than 100 feet, measuring up to eight feet thick in the cut and decreasing to three feet about 80 feet beyond the cut. The deposit is contained in biotite schist and appears to be a replacement of the schist. Locally the deposit cuts the schistosity at a small angle.

In the cut the deposit is composed largely of ilmenite with remnants of schist, actinolite, and calcite. The ilmenite occurs abundantly as nests, pods, and granules in the deposit, the crystals and masses measuring up to eight inches in diameter. Beyond the cut where the actinolite is much more abundant, it becomes the dominant mineral, accompanied by some granules of ilmenite up to two inches in diameter, and by some crystals of monazite up to a half-inch long. Microscopic studies reveal some apatite, allanite, and sphene as well as minor amounts of magnetite and pyrite. The mineralization is reported to extend southeastward down the slope below the cut for a hundred yards, mostly concealed by a mantle of disintegrated schist. High concentrations of reddish monazite are reported in places.
Other deposits of monazite occur on the second ridge to the east of the above deposits. The one lowest on the ridge is on the Jack Pot No. 4 claim, several hundred feet above the road and a little less than one-fourth mile northeast of the ranch house. This deposit is exposed in a small cut just off the crest of the ridge and appears as a podlike mass enclosed in gneiss. This pod is about four feet across at the surface but virtually pinches out a few feet below, at first glance giving the impression that it represents the over-turned amygdaline bottom of a replaced bed of marble. The deposit strikes N 60° W, dips about 55° NE, and is in line with a small outcrop exposed a few tens of feet away on the crest of the ridge. This deposit, however, does not appear to be a replaced bed of crystalline limestone but is structurally controlled and is directed along a small fissure from below and then by a more steeply dipping hanging wall fracture which has caused an abrupt enlargement of the body. Below the enlargement, the vein is but two or three inches thick. The deposit contains considerable actinolite; small blobs and scattered pods of ilmenite up to several inches thick, and 6 inches long; here and there crystals of reddish monazite; and the usual coarse calcite with some magnetite and pyrite.

A second deposit on the same claim is exposed about 50 feet northeast of the one described above. This deposit is not aligned with the other. A part of the outcrop has been blasted; but otherwise no work has been done to explore the deposit, which may be traced along the surface for about 20 feet. The deposit is one to two feet thick, strikes N 55° W, and dips steeply northeast. The most conspicuous mineral in the deposit is monazite which occurs as coarse, reddish crystals and in such quantity as to give the deposit a pronounced reddish color. Associated with the abundant monazite are a little actinolite, much calcite, and a little barite and magnetite.

A little higher on the same ridge on the Jack Pot No. 3 claim is another deposit exposed along a shallow cut about four feet long. This deposit also strikes N 55° W and dips steeply northwest into the ridge. It is contained in and replaces fractured, reddish-colored augen gneiss and has scattered grains and granules of ilmenite, mostly less than one-half inch in diameter, as well as scattered small crystals of reddish monazite.

Cardinal

The property of the Cardinal Mining Company, comprising claims located by Kenneth White and Jessie Hutchinson, is on Papoose Creek, a tributary of Squaw Creek, about 2.5 miles upstream from the Salmon River (Fig. 5). Most of the deposits are on the ridge separating Papoose Creek from Squaw Creek. Considerable work has been done by the bulldozer in numerous cuts on the slope bordering Papoose Creek; but the most noteworthy deposit is near the crest of the ridge, above the ground covered by the bulldozer.

The only deposit given more than cursory examination is the one near the crest of the ridge. The position of this deposit, the first to be discovered on the property, is marked by a prominent quartz vein which forms the hanging wall of the deposit. The vein of white "bull" quartz forms a conspicuous ledge which for part of its length rises boldly above the surface. It attains a maximum width of about 30 feet in the immediate vicinity of the main deposit and then decreases abruptly along the strike in both directions. This vein has no genetic relation to the monazite mineralization;
but inasmuch as it forms the hanging wall of the deposit, it provides a marker which clearly traces the course of mineralisation and hence assists in tracing the monazite deposit. The quartz vein has incorporated some remnants of the underlying monazite and associated minerals and is, therefore, definitely younger than the monazite mineralization.

The quartz vein and the deposit beneath strike about N 40° W and dip about 40° SW. This strike carries the deposit to the crest of the ridge not far north of the main exposure, but the mineralization is much less impressive. The monazite deposit has been uncovered in one fairly large out and in several smaller ones. The deposit is several feet thick, perhaps as much as five feet; but its length cannot be definitely established without further exploration. It is reported that carbonate rock may be traced discontinuously along the strike of the deposit for a half-mile or more. The rock under the deposit is gneiss, but there is no certainty that the deposit itself replaces a bed of crystalline limestone. The structural relationships indicate that the monazite-bearing solutions took advantage of a zone or shear or other structural weakness, possibly localized in and by the limestone; and that later the quartz vein was directed along the same zone of weakness, controlled more directly by superimposed fissuring.

The deposit contains abundant actinolite and in places coarse calcite and moderate amounts of barite, monazite, allanite, and magnetite, and some rutile. In places the deposit is composed almost entirely of actinolite with a scattering of monazite, magnetite, barite, and allanite grains. The actinolite exhibits fine rosette-like or radial intergrowths. The monazite has an irregular distribution, occurring as scattered crystals up to one-half inch long and as groups or clusters of crystals, with transition to massive aggregates. Most of the crystals have a reddish-brown color. Small nests of coarse crystalline barite may be distinguished without the microscope. All minerals tend to show an irregular or sporadic distribution. A sample cut by Abbott (1954, p. 17) across 13 inches of the vein material contained 3.84 percent combined rare earth and thorium oxides and 1.71 percent phosphate.

Cuts between the ridge and Papoose Creek were visited, but little information was obtained from them. Lower cuts reveal narrow zones of reddish-stained gneissic rock, but no minerals characteristic of the monazite mineralization were observed.

Radiant

The principal claims of the Radiant Mining Company, originally located by Reese Eaker and Wiley Evans, are along both sides of Indian Creek about 1.5 miles above the Indianola Ranger Station (Fig. 3). Monazite deposits are exposed on the slopes on both sides of the creek, but the most noteworthy deposit is near the top of the ridge west of the creek and about 500 feet above. Those on the east side are at somewhat lower levels. The deposits can be reached only on foot from the Indian Creek road. The deposit near the top of the ridge, however, was approached from the Papoose Creek side during the summer of 1957 while it was being drilled by the United Pacific Mining Corporation. The work on the property is
limited to a few small cuts and several drill holes put down during 1957.

Not less than six monazite deposits are known on the property: at least four of them are east of the creek. Some of these deposits are in beds of crystalline limestone; but others are in amphibolized gabbros and in schists and gneisses. The deposits do not accord altogether in strike and dip nor does the individual deposit maintain a fixed direction. All deposits, however, trend in a general northwesterly direction.

The main deposit on the high ridge west of the creek is in a bed of medium-grained, bluish-gray limestone one to two feet thick enclosed between walls of mica schist. A small quartz vein forms the immediate hanging wall of the deposit. The deposit and the host rocks strike about N 60° W and dip about 45° SE. Both can be traced at intervals for at least one-half mile. At the main showing, the limestone is largely replaced by actinolite and coarse calcite; but these minerals are accompanied by appreciable amounts of allanite, brownish and reddish monazite, and barite, as well as by rather widely scattered granules of rutile and crystals of magnetite and pyrite. Microscopic studies also reveal considerable amounts of apatite and some biotite, the latter as grains inherited from the schist and as grains deposited with or just after the actinolite. Most of the minerals are coarse-grained; the actinolite, allanite, and monazite form crystals up to one-half inch long. Locally allanite and monazite are especially abundant.

More crystalline limestone or carbonate rock is reported one-fourth mile beyond the northwest end of the deposit mentioned above, near the headwaters of a western tributary of Cow Creek (Abbott 1954, p. 19). The limestone, which is not exposed continuously, strikes N 75° W and dips 50° SE. The bed is reported to be about 1.5 feet thick, where exposed in small prospect holes, contains irregularly disseminated honey-colored monazite along with some barite, actinolite, and ilmenite or rutile.

The deposits east of the creek are exposed in small prospect cuts. The one nearest the creek is more than one hundred feet vertically up the slope just under the crest of a spur ridge on the north side of a fairly prominent gulch. The vein, which measures up to 10 inches thick, strikes N 60° W and dips steeply southwest. It lies between walls of sheared amphibolized gabbro and is exposed for less than 10 feet. In the face of the cut the vein is less than two inches thick. The filling is largely coarse crystalline calcite, the crystals measuring up to one-half inch in length, cut by irregular stringers and veinlets of magnetite, and by scattered granules and pods of ilmenite as much as 1.5 inches thick and four inches long. Only minor amounts of actinolite and monazite occur with the carbonate. Some quartz has infiltrated the deposit but is nowhere conspicuous.

The second vein is exposed in the steep floor of the gulch several hundred yards east of the deposit on the spur ridge. This vein is 10 to 12 inches thick and lies within a shear zone four feet thick in massive gabbroic rock, somewhat gneissic and imregnated with small feldspar porphyroblasts along one of the walls. The vein appears to strike N 80° W and dip almost vertically. It is composed of coarse calcite with variable amounts of actinolite, barite, rutile, magnetite, monazite, and glaucocone, the last-named as black needle-like aggregates cutting and replacing actinolite along fractures. The black ore minerals, including rutile, are conspicuously abundant. As in the other deposit a minor amount of quartz has filtered into the filling.
The third deposit is on the ridge south of the gulch some dis-
tance southeast and considerably higher than the one in the gulch bottom. The
deposit is contained in a bed of crystalline limestone about two feet thick and is composed of coarsely crystalline calcite along with abundant actinolite, barite, and considerable monazite and allanite. This deposit also contains minor amounts of ilmenite or rutil, and magnetite.

The fourth vein is near the top of the main ridge a short distance north of the head of the gulch. The vein is less than 10 inches thick and is contained in schist. It consists largely of actinolite and monazite with only minor calcite and ilmenite. The actinolite forms rather coarsely crystalline aggregates and is in part replaced by monazite crystals ranging up to one-half inch long.

The Radiant Mining Company also has claims on the north side of the Salmon River Canyon opposite the mouths of Dump and Moose Creeks, but these were not examined.

Last Chance

The Last Chance is on the upper canyon slope of the Salmon River across from the mouth of Dump Creek at the southeast end of the monazite belt (Fig. 5). The property may be reached by jeep by making use of the logging roads up Sage Creek and then of a newly bulldozed trail that descends part way down the upper canyon slope.

The property comprises 12 claims and is owned by C. E. Brown of Hanson, Idaho, Ralph Malloy of North Fork, and two other associates. All work so far has been confined to the surface and consists of one large and a number of smaller bulldozed cuts or banks. Much of this work was done during the summer of 1957.

The property has a variety of deposits, most of which contain mona-
zite or other rare earth minerals. These deposits include shear zone deposits and pegmatites, in part in amphibolized gabbroic rock and in part in schistose and gneissic rocks, including some very coarse-grained, granite-like rock. Except for the monazite and allanite these deposits bear little mineralogic resemblance to the deposits along the rest of the mineralized belt.

The main exposure is the one highest on the slope on the Last Chance No. 9 claim. A large bulldozed bank reveals a broad zone of complexly sheared rock extending up the steep canyon slope (Pl. 1, B). This mineralized zone strikes N 10° W and dips about 55° NE. The footwall of the shear zone is a weakly foliated, nearly massive, dark-gray, medium-grained, amphibolized gabbroic rock containing fairly conspicuous grains of biotite. The microscope reveals that the rock is more than half composed of uralitic amphibole; is about one-third labradorite; contains much biotite, in part large crystals; and has appreciable amounts of clinzoisite, epidote, apatite, and an undetermined, brownish mineral (possibly altered sphene); as well as a little accessory monazite and quartz. Immediately above the footwall are three to four feet of highly fractured schistose rock, with some gouge seams, overlain by about three feet of somewhat gneissic granular rock resembling a fine- to medium-grained sandstone. The sandstone-type rock, however, is highly feldspathic. It is in turn overlain by a broad zone of irregularly sheared schistose rock.
The shear zone is sporadically mineralized. Much of the mineralization is concentrated in or near the footwall. In places the shear zone contains thin seams or pods of quartz, locally with scant amounts of chalcopyrite. There are also small nests of a black unidentified mineral, and scattered small granules of reddish rutile and blackish ilmenite. The deposit also contains notable concentrations of brownish monazite. Some of the monazite forms essentially compact seams up to an inch thick. Some also occurs as bunchlike clusters. The microscope reveals other minerals including abundant albite and quartz (which form the sandstone-like rock) and variable amounts of barite, calcite, biotite, and magnetite. The deposit shows spotty radioactivity.

A few hundred yards southwest of the deposit just described, along the crest of a minor ridge on the Last Chance No. 2 claim, is another small occurrence of monazite, uncovered in a small shallow cut. The deposit, in a sandstone-like rock about a foot thick between walls of schist, strikes about N 20° W, and dips 70° S1. The mineralized rock, although resembling a weathered sandstone, shows slight gneissic banding and contains streaks, zones, and pods of compact, granular, pale reddish-brown monazite up to one-half inch thick. The microscopic studies disclose that the rock is composed of granular quartz and albite, the latter predominating, replaced by small to large crystals of monazite and scattered crystals of magnetite, the whole in places cut by thin, irregular veins of coarsely crystalline quartz. Small fractures cutting the deposit are in places coated or filled by black crystals of tourmaline.

Also on the No. 2 claim but eastward across the gulch from the monazite showing is an allanite-bearing pegmatite one to two feet thick, adjacent to a white quartz vein. This pegmatite has been exposed in a small cut and may be traced for about 10 feet up the slope. It contains abundant, well-shaped crystals of allanite to two inches long in a coarse matrix of pinkish feldspar, biotite, and quartz. The allanite is highly radioactive and presumably has a relatively high thorium content.

Another allanite-bearing pegmatite has also been uncovered in a shallow cut on a small spur ridge on the Last Chance No. 10 claim, just south and below the No. 9 on which the main mineral showing is exposed. The pegmatite is a foot or two wide, and like the other, is composed nearly half of allanite in crystals averaging more than an inch long, associated with pink feldspar, quartz, and biotite.

Several hundred yards south of this second pegmatite and on the same No. 10 claim is a radioactive body of rock quite unlike the other deposits. The mineralization here is in a mass of coarsely granitized rock which is spotted with pinkish or pale reddish feldspar. This spotted rock is strongly radioactive. It contains biotitized areas (unreplaced remnants of a biotite-bearing rock) between the feldspar crystals which are composed of andesine. The biotite-rich areas examined microscopically were found to be composed of abundant allanite, epidote, chlorite, and possibly some thorite with blackish decomposition products. There are also minor amounts of zircon or xenotime, monazite and quartz. The allanite appears to be the leading mineral.
Another body of radioactive granitized rock is exposed along the gulch bottom on the Last Chance No. 1 claim. It has been uncovered in a bulldozed bank made on the lower nose of the ridge between the forks of the gulch. The rock in the bank has been conspicuously sheared along a zone of N 60° E trend and 30° NW dip. The rock along the shear zone is a very coarse-grained, granitized rock with crystals of biotite and feldspar up to one-half inch long. This rock contains large reddish spots, in places up to an inch in diameter. Such rock is strongly radioactive. The reddish, spotted rock is a foot or more thick and may be traced for several tens of feet. The bordering rock is mucked and generally highly schistose. The microscope reveals large grains of microcline, replacing a quartzose matrix, also grains of muscovite or coarse sericite, small to large crystals of biotite, scattered crystals of monazite, and some partly decomposed blackish grains which could be thorite. Just up the west fork of the gulch is a pegmatite with abundant black tourmaline crystals up to one inch in diameter and as much as five inches long.

The mineralized, granitized rock does not resemble the deposits characteristic of the monazite-rutile belt. On the contrary their mineralization is much more like that of the thorite-rare earth deposits in the Diamond Creek area to be described later in the report. The Last Chance property apparently covers an intersection or intermingling of two contrasting, unrelated types of mineralization.

Salmon River Uranium Development Company

The property of the Salmon River Uranium Development Company is on the lower slope of the canyon between the Last Chance group of claims and the river, directly across from the mouth of Dump Creek (Fig. 5). The work comprises a series of bulldozed cuts and switchbacks on the steep canyon slope. Deep outcrops extend across a mineralized zone which strikes N 30° W and dips 30° NW. This zone is exposed in the two uppermost banks and is composed of schistose, quartzitic, and calcareous rock, sheared parallel to the schistosity. Two small calcite veins lie along the shear zone. One is almost one foot and the other is about two feet thick. Neither vein appears to contain any minerals of interest, although the larger of the two contains a considerable amount of quartz. Parts of the shear zone give rather high radiometric readings, but when the rock is removed for testing it fails to excite the counter.
A. LEMHI PASS

The relatively low area comprising Lemhi Pass and the higher Beaverheads with its broad summit surface in the background. The road descending from the higher Beaverhead summit is the U.S. Forest Service road which joins the Agency Creek road at the Pass. Scattered bulldozed cuts are on thorite showings.

B. BEAVERHEAD RANGE

The abrupt cleavage-and fault-controlled escarpment that separates the lower mountainous terrain from the higher, broad-summitted Beaverhead Range. The steep, rugged, tree-darkened canyon that incises the frontal slope is occupied by Flume Creek. The bulldozed cuts are along or across thorite-rare earth deposits on the Lucky Horseshoe, Sparky, Skylark, and Buffalo properties.
THORITE-RARE EARTH DEPOSITS

GENERAL DISTRIBUTION

The thorite-rare earth deposits are centered in several widely separated parts of Lemhi County, the main center in the Lemhi Pass region about 26 miles airline southeast of Salmon, the others in the Diamond Creek area six to eight miles airline north-northwest of Salmon and at and near the extreme southeast end of the monazite-rutile belt several miles below North Fork (Fig. 1). Each of these areas represents a special locus of thorite mineralization and each comprises a distinct geographic entity with no intervening deposits to link one area with another. Despite their isolated groupings, the mineralization in each is much the same, with due allowance for differences in geologic environments.

The deposits in the Lemhi area have a fairly widespread distribution, but those in the Diamond Creek area are very much restricted. Except for the deposits at the last Chance, those near the southeast end of the monazite-rutile belt were not examined and are not described. Their distribution, too, seems quite restricted.

DEPOSITS IN THE LEMHI PASS AREA

Location and accessibility

The Lemhi Pass area is taken to include all the region between the Lemhi River and the Continental Divide drained by Agency Creek and its tributaries, by lower Pattee Creek and its more southerly tributaries, and by the headwaters of Yearian Creek (Fig. 6). Actually the area extends eastward beyond the Continental Divide for a considerable distance into Montana, but the study is restricted to the Idaho part of the area. The deposits show somewhat greater concentration in the vicinity of Lemhi Pass but otherwise are scattered widely over the area (Pl. 2).

The area mapped covers about 70 square miles, bounded approximately by parallels 44° 56’ and 45° 00’ north latitude and meridians 113° 27’ and 113° 40’ west longitude. This area is contained within T6s. 19 N., R. 24 E. and R. 25 E. and in part within T6s. 18 N., R. 24 E. and R. 25 E., Boise meridian. Much of this area covers the western slope of the Beaverhead Range from the Lemhi River to the summit or Continental Divide (Pl. 2).

The western edge of the area is within easy reach of Salmon over State Highway 28 which follows the Lemhi Valley from Salmon to its head and thence continues on to Idaho Falls. About 20 miles from Salmon, a graded and partly gravelled road leaves the highway at Tendoy, the only settlement in the area, and extends up Agency Creek across Lemhi Pass into Montana and provides access to most of the deposits within the Agency Creek drainage (Fig. 6). At Lemhi Pass an unimproved road extending southward along the Continental Divide permits approach to deposits along the crest of the Range. Poorly improved roads also give access to deposits on or near lower Flume Creek and to deposits in the upper drainage of Agency Creek to and beyond the Copper Queen mine. Many deposits on the upper slopes are without roads, but may be reached by jeep or on foot.
An unimproved road also extends up Pattee Creek and Poison Gulch and provides access to deposits within that part of the area. This road leaves the Agency Creek road about a mile out of Tendoy (Fig. 6). Many deposits in this part of the area are also off the road and can be reached only on foot or by jeep.

Lemhi Pass may also be reached by the Warm Spring road, a recently improved forest road, which starts up Warm Spring Creek in the northwest corner of the map area (Fig. 6), reaches the summit of the Beaverhead Range near the head of Pattee Creek, and then closely follows the Continental Divide around the head of Flume Creek to Lemhi Pass (Fig. 6 and Pl. 2, A). This road provides an easier ascent to the Pass during the open summer season than does the Agency Creek road which is notably steep above Horseshoe Bend Creek.

Geologic Setting

Main Features

The deposits in the Lemhi Pass area are contained in broadly folded and faulted metamorphosed sedimentary rocks belonging to the Precambrian Belt series. These rocks are intruded or cut by scattered small dioritic and lamprophyric dikes of uncertain but probable late Cretaceous or Early Tertiary age. On the lower slopes and on the crest of the Range at Lemhi Pass these older rocks are partly blanketed by volcanic rocks, probably the Challis lavas of Oligocene (?) age. Closer to the Lemhi River, the volcanic and older rocks pass beneath Tertiary lake beds. All rocks are covered largely by terrace gravels and alluvium of Quaternary age.

Stratigraphy

Belt series (Precambrian)

The rocks of the Belt series are far more widespread than those of the other formations. They underlie more than two-thirds of the mapped area and are almost continuously exposed east of the Lemhi River, except in the lower mountainous country in the northwestern part of the district and across the mid-part of the Agency Creek drainage (Fig. 6).

The series locally is composed largely of moderately metamorphosed quartzitic rocks, subordinately of phylites. The quartzites are mostly rather dark and are for the most part somewhat micaceous, showing prominent jointing and generally a cleavage or foliation that is more conspicuous than the bedding. Because of the jointing and cleavage, the rock offers little resistance to the weather and breaks down into fragments which mantle and effectively conceal the underlying rock. Consequently, outcrops of the bedded rocks are rare and are confined largely to the steeper canyon walls of Flume and Horseshoe Bend Creeks (Pl. 2, B).

The phylites are restricted in distribution, and because of the thick mantle of surface debris, are rarely visible on the surface. The most notable zone of phylites extends along the base of a prominent southwest-facing slope which forms a conspicuous part of the higher Beaverhead Range about a mile above the mouth of Flume Creek (Pl. 2, B). This escarpment-like slope continues northwestward above the head of Poison Gulch and southeastward almost to Lemhi Pass. The phylites are dark gray to green, are prominently foliated, and are composed largely of quartz and
Fig. 6. Geologic map of the Lemhi Pass area showing distribution of the thorite-rare earth deposits.
fine grains of biotite or chlorite. The phyllite is most generally observed in bulldozed cuts made across mineralized zones.

The Challis volcanics are pertinent only because they cover the older Belt rocks that contain the thorite-rare earth deposits. The volcanics apparently accumulated on a surface of considerable relief, carved by streams entirely independent of those of the present day. Except where these volcanics filled the larger and deeper valleys, they have been mostly stripped off by subsequent erosion and those that remain are erosional remnants of this formerly more extensive cover.

The largest remnant forms an irregular band through the middle of the district, apparently occupying one of the older and deeper valleys. This remnant enters the upper Cow Creek drainage from Tertiary Creek and extends in a generally northerly direction across Agency Creek into the Pattee Creek drainage, reaching its greatest spread along the north of Agency Creek (Fig. 6). Another large area extends northward across lower Pattee Creek to and beyond the north boundary of the district. Remnant patches also occur on the Continental Divide just south of Lemhi Pass (Fig. 6).

Unlike the older rocks, the volcanics are well-exposed on the surface and generally have impressive outcrops. They are composed of both flows and pyroclastics. The latter, mostly as bedded tuffs, make up the larger part of the formation. The flows include both dark- and light-color-ed varieties and are probably represented by andesites, basalts, and latites. The tuffs are light-colored and generally rather fine-grained.

In many places the volcanics are underlain by a basal conglomerate.

The Tertiary lake beds overspread the volcanics in the northwestern part of the area and the Belt rocks farther south (Fig. 6). They apparently comprise several unconformable formations, but no attempt was made to differentiate between them or to work out their structural relations. The lake bed formations are composed of light-colored, chiefly fine-grained, rather well-indurated shales with intercalated beds of sandstone, bentonite, and, in places, volcanic ash.

The terrace gravels are conspicuous along the east side of the Lemhi River flood plain and along the middle course of Agency Creek, especially between Sharrow and the Copper Queen road turn-off. The terrace gravels also extend about a mile up Plume Creek (Fig. 6).

The gravels are composed largely of quartzitic pebbles with some local admixtures of vein quartz, phyllite, and volcanic rocks. The gravels in the terrace bordering the Lemhi River, however, have a more varied composition, containing pebbles from more distant sources. Some of the gravels in the terrace gravels along Agency Creek are composed of granitic rock. No granite is known in place within many miles of the Lemhi Pass area and thus the pebbles could not have been derived from local sources. They are, perhaps, an inheritance from an older, more extensive, probably Tertiary, drainage system.
Recent alluvium is prominently developed only along the flood plain of the Lemhi River, where it forms a band parallel to the river about a mile wide from the mouth of McDevitt Creek, 1.5 miles south of Tendoy, northward beyond the area (Fig. 5). Southward, where the river has cut through quartzitic Belt rocks instead of Tertiary lake beds, the band of alluvium is much narrower. Mapable strips of alluvium also extend about three miles up Pattee Creek and more than 1.5 miles up Agency Creek. Further up Agency Creek the alluvial strip is in general too narrow to show on the map, except locally across areas of tuffaceous rocks.

The alluvium is gravelly with admixed sands and has about the same composition as the terrace gravels. Much of it is probably reworked terrace gravel.

Structure

Because of poor surface exposures, the structure of the older quartzitic rocks is difficult to work out and data obtained during the brief study, when much of the time was given to the thorite deposits, are too meager for full understanding of structural relationships. The limited data indicate that the older rocks are folded and faulted and further that they are marked by a conspicuous cleavage, which in places is more prominent than any other structural feature. The younger volcanic rocks have also been somewhat disturbed by structural movements.

The local trend of the Belt strata tends to conform with the regional northwesterly trend; but there are a few places where the beds bear northeast, possibly because of structural interruptions induced by faulting. In the northeastern part of the area where the rocks are more advantageously exposed in and along the canyons of Flume and Horseshoe Bend Creeks and tributaries of Pattee Creek, the beds strike N 30°-50° W and dip 25°-70° NE. Southwestward, the exposures are poor and the only strike and dip measurement is near the lake bed contact about 2.5 miles east of Tendoy. There the beds strike about N 60° W and dip 45° SW. Whether the change in the direction of dip implies a broad anticlinal structure of northwesterly trend cannot be demonstrated until many more structural data are obtained from nearby and intervening areas. The relations along the main part of the Range in the northeastern part of the area suggest that the rocks there comprise the southwest flank of a broad syncline, somewhat overturned toward the northeast.

The flows and tuffs of the Challis volcanics also trend northwest and are tilted in a northeasterly direction at angles up to 22°. The significance of this trend and dip is not yet understood, but the trend conforms to the regional pattern.

Topographic relationships suggest that the older rocks are considerably faulted, in part, perhaps, by faults of appreciable magnitude. The presence of these faults, however, cannot be entirely verified without additional detailed field work. Evidence other than topographic suggests the presence of a fault of major magnitude along the zone of phyllitic rocks at the base of the escarpment-like slope which extends from the vicinity of Lemhi Pass northwestward to about the middle
course of Pattee Creek (Pl. 2, B). Along this zone the phyllites strike about N 60° W and dip about 30° SW, whereas the more massive quartzites northeast of the phyllites strike about N 30° W and dip about 30° NE. Drift folds in the phyllites near Flume Creek suggest upward or reverse movement. This fault has apparently carried the phyllites over the more massive quartzites and has been instrumental in localizing some of the thorite-rare earth mineralization.

Numerous faults and shear zones, most of minor magnitude, are amply indicated by the widespread thorite-rare earth mineralization. Most of the fracture and shear zones which have directed the mineralization trend in northwesterly directions, commonly N 60°-70° W, and dip steeply southwest, less commonly northeast. A few mineralized zones along the Continental Divide differ from the others and strike east-northeast.

Most of the older rock shows a prominent cleavage, more noticeable in some places than the bedding and strong enough in many places to be reflected in the topography as cleavage-controlled dip slopes. The cleavage control is strongly manifested in the slopes near the Copper Queen and Wonder mines and in the escarpment-like slope extending northwest from Lemhi Pass (Pl. 2, B). The cleavage that controls this slope strikes N 60° W and dips about 45° SW, whereas the bedding along the same front strikes N 30°-60° W and dips about 25° NE (Fig. 6). This cleavage is of regional extent and may be recognized along the entire northwestern end of the Beaverhead Range.

History

The Lemhi Pass area has long been known for its copper mineralization, but it was not until the radiometric surveys by Vhay in 1949 and by Trites and Toker in 1950 that some of the deposits were found to contain thorium. After these findings became known, there was a marked surge of interest in the area and within the next several years much of the available land had been staked. The staking of claims continued into the summer of 1957.

Some adit work was carried on at the Buffalo mine in 1953 or earlier and at the Wonder mine in 1954, the latter under joint sponsorship of the Federal Government and private enterprise. This work further intensified prospecting and filing of claims, but the exploration thereafter was chiefly by bulldozer, especially during 1956. Interest in the area remained high during 1957. By then most of the properties, totaling some hundreds of claims, had been acquired by D. B. Lewis.

Character of the deposits

Although these deposits are regarded primarily as thorite deposits, they contain a considerable concentration of rare earth metals, principally of the cerium group but including also a small amount of yttrium. There is at present as much interest in the rare earth metals as in thorite and any utilization program should regard the deposits as sources of both thorium and rare earths.

These deposits have been characterized as thorium-rich, blackened fracture zones and veins containing thorite (Cook 1957, p. 3). This characterization typifies most of the recently discovered deposits, which are replacement veins and lodes along complex shear and fracture zones; but in
some of the first recognized thorium-bearing deposits the thorite is
an introduction into earlier quartz veins and copper-bearing lodes.
These associations prompted Sharp and Cavender (1953, p. 1555) to clas-
sify the deposits into four types of quartz veins according to the prin-
cipal mineral constituents. This classification included (1) veins con-
taining copper-bearing sulfides; (2) veins containing hematite; (3) veins
containing barite, hematite, and thorite; and (4) veins containing copper-
bearing sulfides and thorite. Most of the deposits discovered during the late
wave of prospecting are not associated with the earlier quartz and
copper-bearing deposits but occur along independent zones of shearing and
fracturing.

Because of their mineral associations and structural relations, these
deposits may be classed as hydrothermal veins and lodes composed of a
unique group of minerals which in part are more characteristic of igneous
rocks and pegmatites than of veins.

Structural relations

The thorite-rare earth deposits are distributed along a broad zone
about six miles wide which crosses the area in a southeasterly direction.
This zone emerges from beneath the cover of volcanics and lake beds just
north of Pattee Creek and continues its southeasterly course across the
Continental Divide for a considerable distance into Montana. Its north-
east boundary passes about a mile north of the mouth of Poison Gulch and
crosses the Continental Divide a short distance north of Lemhi Pass. The
southwest boundary crosses Agency Creek not far below the mouth of Cow
Creek and continues southeast to include unmapped and unstudied deposits
near the head of Yearing Creek.

Within this broad belt of mineralization the deposits are contained
along individual shear and fracture zones whose trend for the most part ac-
cord with that of the broad belt. Except for a few deposits along or close
to the Continental Divide, the individual shear and fracture zones trend
about N 60° W, in some places close to N 70° W, and less commonly about N
30° W. These zones generally dip steeply southwest, but a few dip northeast.
The deposits near the Continental Divide which do not conform with this
northwesterly trend bear in a east-northeasterly direction.

Most of the shear and fracture zones are relatively broad. Some are
no more than a few feet across; but most are much wider and may measure
40 to 60 feet, exceptionally 120 feet, across. The mineralization, how-
ever, rarely extends through the full width of the zone. These shear and
fracture zones possess considerable length, measureable in hundreds and in
some cases in several thousands of feet; but the mineralization along them
is sporadic, and individual deposits may have a comparatively short length,
less than 100 feet.

The older quartz and copper-bearing lodes and veins are controlled
by earlier shearing and fissuring and where these deposits were reopened
by later structural movements, thorite and associated minerals were added
to them. The later fracturing was generally confined to the limits of
the earlier filling and is not so extensive as that characteristic of the
independent shear and fracture zones.
Mineralogy

Summary statement

The deposits possess a unique assemblage of minerals, for the thortite is invariably accompanied by specular hematite, monazite, barite, feldspar, and quartz, and generally also by one or more of such minerals as sericite, allanite, apatite, xenotime(?), calcite, magnetite, and pyrite. Biotite may also be added to the assemblage, although much of it appears to be an inheritance from the phyllitic and quartzitic country rock.

Few of these minerals are recognizable without the petrographic microscope. Those that are include specular hematite; feldspar, calcite, and quartz; but the others, thorite, barite, allanite, and pyrite, except on occasion, are not distinguishable by the unaided eye. The microscope is essential for mineral identification and must be used for each deposit in which the complete list of minerals is desired.

As most of the deposits are exposed in surface cuts, the minerals mentioned above are generally found with abundant hydrous iron oxides, mostly yellowish-brown goethite, less commonly blackish manganese oxides. In some deposits the secondary iron oxides occur as dense, compact seams and masses, in others, as minute disseminations, giving the vein matter a brownish jasperoid appearance.

Descriptive features

Some of the biotite may have been introduced along with the biotite other minerals, probably at the very beginning of the mineralization; but much, if not all, has apparently been inherited from the country rock. It occurs rather sparingly under the microscope, usually in the aggregates of thorite, monazite, and specular hematite. All grains are small and most are somewhat bleached, almost completely so in places. They are irregular in outline and are commonly cut off or penetrated by crystals of specular hematite and by any accompanying thorite and monazite. Locally the biotite is penetrated and replaced by allanite. The biotite generally disappears in the aggregates of barite, feldspar, and quartz, occurring therein only as minor remnant inclusions.

Sericite occurs in some deposits, usually as microscopic grains difficult to distinguish from the bleached biotite. It is a sparse mineral and is nowhere noticeable, except at the Cago No. 12, where some of the coarser grains in the more marly parts of the deposit may be observed by the unaided eye. This sericite occurs mainly as minor, very thin, non-persistent seams in the quartzose material invaded by the thorite and associated minerals. It is penetrated and replaced by those minerals.

Thorite, the main source of thorium in the deposits and responsible for much of the radioactivity, is an essential constituent of all but one of the deposits examined microscopically. Its presence in the deposits is generally inferred from the radioactivity, for its crystals or grains are rarely distinguishable without the microscope. In some deposits small reddish grains or colorations suggest thorite, but only at the Cago No. 12 may the grains be detected by the eye alone and then with some difficulty because of partial concealment by intimately associated specular hematite and brownish, hydrated iron oxides.
Under the microscope the thorite appears as short square prisms with reddish-orange border zones, the coloration extending through all but the center of the otherwise colorless crystals. The thorite is thus largely recognized by its reddish-orange decomposition products.

The thorite shows a marked preference for the micaceous zones and the company of the monazite and specularite hematite. Its grains are commonly contained within and sheltered by aggregates of specularite and associated monazite. It generally occurs as scattered crystals, but in some places the crystals occur in clusters and may be so grouped as to form small granular aggregates. The always closely associated monazite locally may occur as mantles on the thorite, but more generally it occurs separately. The thorite and closely associated monazite and specular hematite impregnate and replace the sheared and fractured rock. They are the earliest minerals and are commonly held as remanent inclusions within grains and aggregates of barite, feldspar, and quartz.

Allanite ((Ca,Ce,Th)₂(Al,Fe,Mg)₉Si₈O₂₆(CH)), also a source of thorium and the rare earths, was observed only at the Lucky Horseshoe on lower Flume Creek and at several of the adjacent properties. It is apparently the principal radioactive mineral and the source of most of the rare earth metals at the main deposit at the Lucky Horseshoe where it occurs with some monazite and specularite but apparently not with thorite.

At the Lucky Horseshoe, the allanite occurs rather abundantly throughout much of the broad zone of sheared phyllite, showing greater concentration in some parts of the shear zone than in others. It may be recognized without the microscope by the dark-gray "hornblendic" appearance it imparts to zones within the phyllitic rock. Its crystals penetrate and replace the quartz and micaceous minerals of the phyllite and are in turn penetrated by monazite and specular hematite.

Monazite, essentially (Ce,La,Th)PO₄ but with subordinate amounts of other rare earth elements, apparently including some yttrium, appears in all lode material examined microscopically. It is generally present in considerably greater quantities than the thorite and probably contributes quite materially to the radioactivity of the deposits. Its grains are generally small, like those of the thorite, and cannot be discerned by the unaided eye. It usually forms small but well-shaped crystals, where not in contact with or engulphed within grains of barite, feldspar and quartz. If the monazite is contained in these minerals the outlines are inclined to be irregular and it appears commonly as small remanent inclusions.

Apatite is not an abundant mineral in these deposits and is visible in only a few. It occurs as microscopic crystals, which in some deposits are long, almost needle-like; and in others, short and tabular. Some of the latter closely resemble the barite grains but differ from them in possessing distinct cross partings.

The apatite is closely associated with the monazite and thorite. It has not been found in the barite, calcite, or feldspar, except as remanent inclusions.
Xenotime (YPO₄) may occur sparingly in some of the deposits, closely associated with monazite and thorite; and, if present, may account in part for the small yttrium content of some of the deposits. Its presence is suspected because of the sparse occurrence of zircon-like grains which show parallel extinction and in this respect differ from the grains of closely associated monazite.

Specularite, which is as much a part of the mineralization as the thorite, is one of the most distinctive minerals and one that may be recognized without the use of the microscope. Although in places its grains are of microscopic size, the black color they impart to the lode filling is enough to indicate their presence. More generally the micaceous-like grains are large enough to be seen and in some places they are notably coarse. Although the specular hematite is present in all deposits, it is not uniformly distributed but tends to occur in streaks, nests, or pockets. Its presence is usually indicative of high radioactivity.

The fine-grained specularite is invariably closely associated with thorite, allanite, and monazite; the coarse-grained specularite may also be accompanied by thorite and monazite. In some deposits there appear to be two generations of specular hematite; one fine-grained and accompanied by thorite and monazite; and the other coarse-grained, with or without thorite and monazite. In some deposits the crystals of the coarser specularite penetrate the areas containing the finer-grained hematite. The thorite accompanying the younger generation of coarse specularite also forms relatively large crystals. In some places the coarsely crystalline specularite is completely free of thorite.

Magnetite occurs sparingly in some deposits, usually with specularite and particularly in deposits containing calcite. Its crystals are microscopic. Its relations to the specular hematite and to other minerals are not fully determined.

Barite (BaSO₄) is a widespread and relatively abundant mineral. In a few deposits it is coarsely crystalline and is readily recognized by the unaided eye, but in most deposits its grains are small and can be observed only with the microscope. Its presence otherwise may be inferred from the heavy weight it lends to the material in which it occurs.

The microscope reveals that barite occurs in nearly all the deposits. It may show up under the microscope as scattered grains, but more generally as granular aggregates. These grain and grain aggregates penetrate irregularly into the thorite-monazite-specularite areas and may engulf and hold these minerals as inclusions. In such penetrations the barite tends to clear itself of the invaded minerals and the only evidence that such minerals were present may be scattered remnant inclusions. In some deposits the development of the barite aggregates has given the filling a spotted, mottled appearance, with resemblance to a partly granitized rock.

Like specular hematite, feldspar is about as much a part of the mineralisation as thorite; and because of its easy recognition, has some value as an indicator mineral. Inasmuch as the feldspar has a reddish or pinkish color, its presence is easily detected, although individually its grains are small and recognizable or discernible.
only with the microscope. Fortunately the grains occur as massive aggregates and thus appear as conspicuous reddish or pinkish bands and irregular masses in the deposit. The feldspar is not in general abundantly distributed, but it is sporadically visible in small but variable amounts in nearly every deposit.

The feldspar appears to be composed entirely of microcline which shows good albite twinning but generally imperfect or poorly defined plaid structure. Microcline was apparently introduced into the deposit after the deposition of barite and earlier minerals, for its grain aggregates commonly penetrate into and through the barite and the thorite-monazite specularite mosaics, removing these minerals or retaining only remnant inclusions of them. Because of the tendency of the feldspar aggregates to clear themselves of the earlier invaded minerals, they occur as breccia-like fragments in a dark, hematite-thorite matrix and appear to the unaided eye as fragments cemented by the hematite and associated minerals. Such is not the case, although at the main deposit on Pattee Creek a pseudobrecchia of the feldspar has been fractured and cemented by a second generation of the more coarsely crystalline specularite and thorite.

Calcite was noted in several deposits along Pattee Creek and in one deposit on Agency Creek. This calcite is the one formed during the primary mineralization and does not refer to that recently deposited in fractures by circulating ground waters. In the few deposits in which this primary calcite does occur it is notably abundant and forms lenticular seams or veins up to several inches thick, usually in close association with the barite.

The calcite is coarsely crystalline and appears to be free of iron. Its relation to the other minerals is much like that of barite and feldspar, but it also contains patches and remnant inclusions of barite and feldspar, as well as other minerals. It is definitely a late mineral of the deposit but not as late as the quartz.

Pyrite is a very minor constituent of the deposits and has been noted as widely scattered crystals in the carbonate in the deposit on upper Agency Creek and much more abundantly as disseminations in the Sage deposit on the slope bordering lower Agency Creek. It is possible that some of the hydrous iron oxides found abundantly in the oxidized parts of the deposits elsewhere in the region had their source in pyrite.

Excluding the quartz inherited from earlier vein fillings and hence not directly related to the thorite mineralization, there remains a quartz which is related to and does form an essential part of the thorite mineralization. Minor but variable amounts of this quartz occur in all deposits, abundant enough to be visible but generally not abundant enough to be conspicuous.

It commonly fills fractures that cut indiscriminately through all the other minerals. Its role, however, is not restricted to fracture filling, for the microscope reveals that it has also "soaked" into and has replaced the other minerals including the late carbonate. This quartz is relatively coarse-grained as compared with the inherited quartz from earlier fillings and country rock and shows pronounced strain extinction. It is ordinarily white or colorless; but some is dark from included remnants of earlier minerals, particularly of the specular hematite. Its relations
to other minerals are much the same as those of the barite, feldspar, and calcite, except that these minerals are also retained in the quartz as sporadically distributed remnant inclusions. The quartz seems less able to remove the thorite and monazite in its infiltration than it does the other minerals and consequently microscopic inclusions of the radioactive minerals are rather common in it. The mineralization ended with the deposition of quartz.

Paragenesis

As brought out in the mineral descriptions, the relations of the various minerals are such as to indicate an orderly sequence of formation that began with the deposition of sericite (possibly biotite locally) and ended with the deposition of quartz. Within the sequence the minerals show a somewhat unexpected succession. One of the silicates, the feldspar, appears rather late, after the oxides and barite, instead of with the earlier silicates. The thorite and monazite are also somewhat earlier than normally expected. Paragenetically, the mineralization is rather unique.

The position of some of the minerals is known only within certain limits; the position of others is more precisely fixed. For the latter the succession begins with biotite or sericite followed successively by thorite, monazite, specular hematite, barite, feldspar, calcite, and quartz. It is known that the allanite is older than and precedes the monazite, but its relations to the thorite were not established. It could be about the same age or a little older than the thorite. The apatite and xenotime(?) are closely associated with the monazite, but whether a little older or a little younger than the monazite could not be determined. The magnetite was observed with the specularite in deposits containing calcite, but whether it is an actual associate of the specular hematite or was brought in with the calcite cannot be decided from the present available data. The pyrite seems to prefer the calcite and was probably introduced along with it or just after.

Distribution of the minerals

The minerals in these deposits show a generally spotty distribution. They may occur irregularly through the broad zones of sheared or otherwise fractured rock, usually in greater concentration in areas of more extensive fracturing than in other areas. In some deposits the minerals are largely concentrated in thin lenticular bodies and discontinuous veins up to several feet thick and several tens of feet long; in other deposits they are distributed among several veins spaced a few feet apart. In other fracture zones the minerals are largely restricted to irregular masses and pockets. Such mineral concentrations mark the areas of high radioactivity; but less intense radioactivity may continue far beyond the borders of these visible concentrations, indicating some mineralization to the very borders of the shear or fracture zone. The irregular distribution applies to the individual as well as to the mineral groupings. The spotty character of so much of the mineralization is especially shown by such minerals as the megascopically visible specular hematite, feldspar, and late quartz. These usually occur together in variable proportions with any one dominant locally.

In the quartz and copper veins the introduced minerals are largely confined to irregularly distributed fractures. These fractured veins range from a few inches thick and 100 feet long to 30 feet thick and several hundred
feet long, but the distribution of the specular hematite and radioactive minerals is as irregular and uncertain as the fractures. Along the broad, independent zones of sheared and fractured rock the radioactive and associ-
ted minerals may show notable concentrations; for some tens of feet along the zone, exceptionally for several hundred feet, and may then dwindle in quantity and even disappear. Such concentrations may range from several feet to 10 feet or more across, with less extensively mineralized rock extending out-
toward to the walls. Mineralized zones may thus measure up to 40 feet or more across and may continue on strike for some hundreds of feet before the miner-
alization shows conspicuous signs of weakening.

Tenor of the deposits

The writer did not sample the deposits and cannot offer first-hand data on the actual content of thorium and rare earth elements. Owners report several percent of these metals in some of the deposits but did not disclose whether the deposits were sampled systematically throughout or only along the richer parts of the mineralized zones. Microscopic studies tend to confirm the re-
ports of several percent thoria and rare earth oxides along the more highly mineralized parts of the fracture zones.

A sample of the more highly radioactive hematitic material at the Cago No. 12, taken by Russell Wood in the writer's presence and analyzed at the Mountain Pass Laboratory of the Molycorp Corporation of America, tends to confirm reports by the owners of high thorium and rare earth content. Re-
turns on the sample collected by Ir. Wood showed 14.79 percent combined thoria and rare earth oxides, a value somewhat higher than the returns from two samples collected and submitted earlier by the owners. One of these samples, submitted by the owners contained 13.5 percent thoria plus rare earth oxides and the other 9.6 percent of these same constituents. Microscopic examination of some of the most highly radioactive hematitic material revealed more thor-
ium than specular hematite, considerable amounts of monazite, and a little xenotime(?). Another sample of the more siliceous material with dark inclusions, collected by Ir. Wood, contained 0.7 percent thoria and rare earth oxides.

The two samples from the owners were sent to the Rare and Precious Metals Experiment Station, U. S. Bureau of Mines, at Reno, Nevada, for a breakdown of the various rare earth elements. The Bureau of Mines returns are tabulated below:

<table>
<thead>
<tr>
<th>Sample 1 (percent)</th>
<th>Sample 2 (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total rare earth oxides plus thorium</strong></td>
<td></td>
</tr>
<tr>
<td>Y₂O₃</td>
<td>13.5</td>
</tr>
<tr>
<td>La₂O₃</td>
<td>2.0</td>
</tr>
<tr>
<td>Ce₂O₃</td>
<td>3.5</td>
</tr>
<tr>
<td>Nd₂O₃</td>
<td>11.5</td>
</tr>
<tr>
<td>Sm₂O₃</td>
<td>15.1</td>
</tr>
<tr>
<td>Eu₂O₃</td>
<td>11.5</td>
</tr>
<tr>
<td>Gd₂O₃</td>
<td>1.3</td>
</tr>
<tr>
<td>Er₂O₃</td>
<td>4.0</td>
</tr>
<tr>
<td>Tm₂O₃</td>
<td>0.6</td>
</tr>
<tr>
<td>Yb₂O₃</td>
<td>3.0</td>
</tr>
<tr>
<td>Lu₂O₃</td>
<td>1.6</td>
</tr>
<tr>
<td>ThO₂</td>
<td>43.8</td>
</tr>
</tbody>
</table>
As pointed out by Trits and Tooker (1953, p. 169) and later by Sharp and Cavender (1953, p. 1555), the thoria (ThO₂) content of most of the deposits probably ranges from 0.1 to 2.0 percent and averages less than one percent; but some deposits such as the Cago No. 12, the Lucky Horseshoe, and several others discovered since the publication of the above reports contain greater concentrations of radioactive minerals than the others and may average well over one percent thoria.

Origin of the deposits

The thorite and associated minerals have been introduced into the zones of sheared and fractured rock, into reopened quartz and copper veins, and into lodes from sources presumably deep within the earth. The mineral constituents were borne in by fluids notably enriched in thorium, rare earth elements, phosphorus, iron, potassium, barium, calcium and sulfur (as sulphates), and less abundantly enriched in carbon dioxide and silica.

The association of thorium and the rare earth metals with phosphates, iron oxides, barium sulfate, potash feldspar, calcium carbonate, and silica is not an uncommon one. It is an association that has been observed in many places in conjunction with igneous activity, representing some of the final products formed during the differentiation of alkalie magmas. The local association of elements has much in common with the carbonatites (monazite-bearing deposits) in the North Fork area, but is without the abundant carbonates, the titanium, the columbium, and the constituents that combine to form actinolite. The thorite deposits differ further from the carbonatites in the much greater concentration of thorium and in the relative abundance of potassium. Unlike the carbonatites, the thorite-rare earth deposits lacked the environment for coarse-grain growth.

As the fluids with their variable concentration of thorium, rare earths, and other constituents moved up along the zones made permeable by fracturing, they entered into the rock and earlier fillings and contributed first much of their thorium, next their rare earths, then in turn the iron, barium, potassium, locally calcium, and lastly silicon. Most of the thorium combined with the silicate ion to form thorite, but in places the thorium entered the allanite, a complex rare earth silicate. Thorium not used by the thorite and allanite attached itself to the rare earths and with them combined with the phosphate ion to precipitate as monazite and perhaps in much more limited extent as xenotime(?). The phosphate also combined with some of the calcium to form apatite. The iron then came out in oxide form as specular hematite. The barium, combined with the sulfate ion to form barite was next added to the hematite-rare earth-thorite assemblage, after which the potassium joined with alumina and silica to precipitate as the potash feldspar, microcline. The remaining calcium came out as calcite. The mineralisation terminated with the deposition of quartz, which may consist of the silica incorporated into the fluid as the siliceous host was replaced by the earlier minerals.

The source of the mineralising fluids was probably in a magma centered deep in the earth. The mineral constituents of the magma was probably assembled during the process of magmatic differentiation and concentrated in late differentiated fractions. The presence of a few dioritic and lamprophyric dikes in the vicinity of the deposits may serve as evidence that such a magma did exist at depth. The spatial association of the deposits with the dikes prompted Sharp and Cavender (1953, p.1555) also to suggest a possible
genetic association. As some of the similar thorite deposits in the Diamond Creek area north-northwest of Salmon cut the granitic rock of the Idaho batholith, the thorite mineralization and the dikes are obviously younger than the main mass of the batholith (Cretaceous) but not so young as the cover of Challis Volcanics (Oligocene). The intrusive activity and mineralization at Lemhi Pass are thus probably local manifestations of the widespread magmatic action of late Cretaceous and early Tertiary time.

Outlook

The deposits need to be more thoroughly explored, especially at depth, before satisfactory estimates can be made of the grade of ore and size of reserves. The meager surface exploration points to a substantial reserve of both thorium and rare earth metals. The district has promise and all that may be needed to initiate active development is a favorable market for the mineral products.

Properties

Idaho Thorium

Location

The property of the Idaho Thorium Company, Inc. is in the Pattee Creek drainage. It covers a large area extending up the slopes on both sides of Pattee Creek, reaching south-eastward to the Agency Creek divide (Fig. 6). The property comprises three groups of claims, composed collectively of 132 claims and some fractions: the Apex Lode; the Silver Queen (accounting for more than 80 percent of the total); and the Lone Star. The only work on the property consists of a number of bulldozed cuts, most of which are at seven rather widely separated localities, each denoting a zone of more noteworthy mineralization. These different locations are indicated on the map (Fig. 6) by numbers and are designated in the report as showings.

Showing No. 1

The principal showing is on the southeast side of Pattee Creek just below the mouth of Poison Gulch (Fig. 6). This showing is exposed in a long, high bank bulldozed in the side of the steep slope just above the creek and in a series of bulldozed cuts above, the upper cuts extending into the sides of Poison Gulch. Some other cuts have been made along minor showings a few hundred feet to the south.

The cut bank has uncovered a complex zone of mineralization more than 30 feet across, cutting rather thin, bedded, impure quartzite and phyllite. These beds locally strike N 30° E and dip 15° SE, whereas the broad zone of complexly sheared and mineralized rock strikes about N 70° W and dips 65° NE. The mineralized zone contains one apparently persistent vein from two to three feet thick which, near the base of the bank, has been offset six to seven feet laterally by a relatively flat fault striking N 30° E and dipping 25° NE. Two other veins exposed in the upper bank apparently pinch before reaching the fault. One of these veins near the hanging wall of the mineralized zone and about 10 feet from the main vein is about a foot thick near the top of the bank, but pinches to six inches before disappearing beneath a cover of broken rock. The second vein lies between the other two and is up to five feet thick, but it pinches
abruptly and is more like a pocket of mineralization than a true vein. The mineralized zone apparently contains an irregular distribution of these small, relatively high grade veins which individually have little length or depth, but which singly and collectively provide the richer concentrations of minerals. The mineralized zone may be traced for several hundred yards up the slope by means of the bulldozed cuts, showing an overall width of more than 20 feet with here and there minor veins or lenslike concentration of ore and gangue minerals.

The more highly mineralized parts of the zone are characterized by the presence of conspicuous pinkish or reddish feldspar and black, metallic-appearing specularite. These minerals and quartz are the only minerals that may be recognized without the microscope. They tend to show a rather bunched distribution. Some of the feldspar appears as small breccia fragments cemented and penetrated by irregular masses of specularite. Both minerals are in turn cut by thin seams and otherwise permeated by coarsely crystalline quartz.

The microscope reveals that the pinkish or reddish feldspar and the specularite are generally accompanied by small microscopic grains of biotite, thorite, monazite, apatite, and barite, all as residual inclusions in the feldspar. The microscope further reveals the presence of two generations of specular hematite, one as small included grains in the feldspar and the other as much larger grains or crystals cutting the feldspar. This coarse specularite is locally accompanied by relatively large grains of thorite and in some cases also by coarse crystals of monazite. Locally the coarse thorite grains are grouped in clusters. A little epidote and sparse zircon-like crystals of xenotime (?) also appear in some of the specimens.

Much of the mineralized rock is highly radioactive, the intensity of the radioactivity depending largely on the quantity of thorite present. In general the specularite denotes the presence of thorite; but in some parts of the mineralized zone, the coarse, specularite-containing material is not radioactive.

A parallel shear zone about a hundred yards to the southeast shows notably weaker mineralization.

The second showing of note is about three-fourths of a mile below the No. 1 on the opposite side of the creek (Fig. 6). There, a series of cuts along the nose of the ridge bordering the creek has exposed at least three zones of sheared and fractured rock. These zones apparently strike N 60°-70° W, but are for the most part sporadically or rather lightly mineralized. One of these zones has been exposed by cuts both across the ridge and on the lower slope near the creek. These cuts reveal a broad zone of complexly fractured rock with no sharply defined vein or fissure system. A lamprophyric dike intruded along the fracture zone is exposed in the cut near the creek. Within the fracture zone are some small shoots showing reddish feldspar and specular hematite. Microscopic examination reveals the presence of considerable amounts of apatite, some monazite, rather large crystals of thorite, and much specular hematite, all older than and largely engulfed in or retained as remnant inclusions in the feldspar. The feldspar is cut and locally replaced by calcite, and the calcite and older minerals in turn are cut and
The third showing is on the west side of Pattee Creek almost a mile above the mouth of Poison Gulch, in a small, steep gulch opposite some abandoned ranch buildings along the creek (Fig. 6). A series of bank cuts on the steep north side of the gulch has uncovered a broad zone of shattered and locally fissured rock about 100 feet across. This zone strikes about N 60° W and dips 45°-50° SW, cutting obliquely across the bedding of the quartzitic rocks, whose strike north of the gulch is N 20° W, dipping 35° SW and whose strike south of the gulch is N 70° W, dipping 60° NE. The gulch is carved along the fault that lies between the exposures.

The first cut, only a short distance up the gulch, uncovers the full width of the fractured and fissured zone, which at this point is heavily stained by reddish iron oxides produced by surface weathering. In the zone, however, are some areas of bleached rock, the main one along the hanging wall. This bleached rock encloses a deeply weathered vein one to two feet thick with some recognizable specular hematite and appreciable amounts of reddish feldspar. The vein appears to be quite irregular and shows a notably bumpy distribution of minerals. Other parts of the broad zone of fractured rock contain minor stringers of mineral matter.

The zone of shattered rock is also well-exposed in the second cut some 75 feet above the first. In this cut the vein is eight to 10 inches thick and, as in the cut below, is highly weathered.

The vein is much better exposed in the third cut some 75 feet above the second. This cut which has been made along the strike of the vein, exposes it for about 50 feet. For about 20 feet along the floor of the cut, the vein contains a streak of specular hematite up to eight inches thick accompanied by much calcite. This part of the vein is strongly radioactive.

The specimens collected in the floor of the third cut contain much calcite and specular hematite; but the microscope also reveals the presence of biotite, thorite, monazite, barite, magnetite, and quartz. The barite and thorite are locally abundant, the former as scattered aggregates, the other as small scattered crystals. The biotite, which has apparently been inherited from the country rock, is penetrated by crystals of thorite and closely associated minerals and occurs as remnant inclusions in the calcite. The thorite, monazite, barite, and specular hematite are in part also engulfed in the calcite. Some magnetite appears to accompany the specular hematite. The specimens show late invasion by coarsely crystalline quartz.

Other cuts above the third are not on the trend of the vein and are largely off the fracture zone.

A second small vein occupies a minor fracture zone several hundred feet to the northeast. This vein has been exposed in a small cut in the bank of a bulldozer-made road. This vein, a few inches thick, shows no radioactivity of consequence.
Downstream a few hundred yards below the mouth of the gulch is a short adit just above creek level driven into a reddish-stained zone of shattered, faulted rock that strikes N 70° E and dips 45° NW. This zone contains a vein up to two feet thick with much calcite, a little specular hematite, and reddish feldspar. The vein is weakly radioactive. The zone of fractured rock also contains some scattered seams and bunches of calcite and associated minerals. The mineralized zone is cut by slips which strike N 30° E and dip 30° NW, some of which have up to six inches of gouge.

Another zone of mineralization is exposed in the first tributary gulch on the south side of Poison Gulch less than a mile east of the No. 1 showing on Pattee Creek (Fig. 6). This zone of mineralization is several hundred feet above the bottom of Poison Gulch and has been explored by three bulldozed cuts, two small ones on the east side of the steep tributary gulch and one large one on the west side.

The west cut has exposed a broad zone of prominently sheared rock which appears to strike about W 60° W and dip northeast at a moderate angle. Westward the cut abuts against a ledge of massive, highly silicified quartzite. The cut is a long one and has uncovered the mineralized zone for more than 100 feet. Unfortunately, the surface of the cut is not free of debris and the exact nature and extent of the mineralization is somewhat uncertain. One reddish, highly radioactive seam about four inches thick is exposed for a few feet along the upper side of the cut. Chunks of coarse specular hematite are scattered through the bulldozed debris, but the source of the hematite is covered.

In the cuts on the east side of the steep, shallow gulch, the zone of sheared and shattered rock contains a vein up to two feet thick which may be traced along the floor of the cut for about 30 feet. The vein appears to strike N 70° E. It has considerable reddish feldspar and specular hematite, apparently appreciable amounts of thorite, and perhaps other minerals. The material was not examined microscopically; but hand specimen study discloses that the specular hematite occurs in two generations, one earlier than the feldspar and one later, and that much of the radioactivity appears to be associated with minerals older than the feldspar. The filling also shows a minor amount of quartz.

Another showing of mineralization occurs on a high, sharp ridge between two prominent gulches tributary to Poison Gulch about a mile due east of the main deposit on Pattee Creek (Fig. 6). The work at this place consists of four bulldozed cuts, one along the sharp crest of the ridge, another just over the crest on the west side of the ridge, with two others immediately below. These cuts are alongside some bold quartzite outcrops and were difficult to work by the bulldozer. The cuts have uncovered some sheared and fractured rock, the shearing apparently directed about N 60° W. The mineralization seems light and the radioactivity is weak.

The sixth showing is near the head of the prominent gulch east of the No. 5 showing or about 1.5 miles east-southeast of the main occurrence on Pattee Creek (Fig. 6). Three cuts have been made at this locality: one on the north-
east side of the gulch, a very short distance below the volcanic contact; one near the bottom of the gulch in and along the road; and one almost directly across on the southwest side of the gulch.

The two cuts along the gulch bottom have uncovered a broad zone of highly fractured rock best exposed in the southwest cut. Strong radioactivity is indicated from place to place, but no well-defined zones of iron and feldspar mineralization were observed. Locally the sheared rock shows minor feldspathization with thin seams of pale reddish feldspar and interbands of dark, finely crystalline specular hematite and quartz.

Showing No. 7. The seventh showing is on the high divide between Pattee and Agency Creeks about 1.25 miles airline southeast of the mouth of Poison Gulch (Fig. 6). Several small bulldozed cuts have been made along small veins less than a foot thick, striking approximately N 80° W. These veins are mildly radioactive and contain variable amounts of pale, flesh-colored feldspar, black specular hematite, and minor amounts of late quartz. Much of the specular hematite appears to have been deposited in advance of the feldspar but some was added later. As the material was not examined microscopically, the presence of thorite and other minerals is not definitely established.

Other showings Location and other cuts are scattered over the property, but these are not singled out for individual description.

Last Chance

The Last Chance is on upper Pattee Creek about a mile above the mouth of Poison Gulch and more or less directly across the creek from the No. 3 showing on the Idaho Thorium property. Location notices indicate ownership by Tony Schwartz and Pete Samora. The work consists of some old cuts and adits in the high gravel-covered bedrock bank bordering the creek and more recent bulldozed cuts in and bordering the gravel-covered bank, and on the ridge slope east and several hundred feet above the creek.

The old and new work near the creek is in sheared, sericitized quartzite, which shows scanty copper mineralization and weak radioactivity. The cut on the ridge slope to the east has uncovered a broad zone of shattered, iron-stained quartzite with widely scattered small stringers of reddish feldspar. Parts of the mineralized zone are weakly radioactive.

Iola

The Iola is on the south side of Pattee Creek immediately west of the Idaho Thorium property (Fig. 6). It is largely within and at the borders of a prominent gulch that reaches almost to the top of the mountain separating Pattee Creek from Agency Creek. The property consists of a group of 25 claims and a fraction, leased to the Lewis Corporation by B. C. Anglin, the original locator. The work on the property consists of an extensive series of bulldozed cuts made by the American Lead and
Zinc Company in the autumn of 1956. These cuts extend along both sides of the gulch and in part cut on the bordering slopes, with one above the other almost to the top of the mountain. These cuts make vivid scars on the mountain slope, visible from afar.

The extensive work with the bulldozer has uncovered some evidence of mineralization, particularly on the northeast side of the gulch. Several of the lower and one of the higher cuts have revealed small amounts of highly oxidized material with some recognizable specularite and feldspar occurring mostly as lumps or small masses sorted out from the bulldozer debris and piled to one side of the cut. The distribution of the mineral matter in the several cuts suggests a zone of mineralization of N 60°W trend. The condition of the cut was such that little information could be obtained on the size and characteristics of the mineralized zone and its structural relationship. The oxidized material is somewhat radioactive but no microscopic work was undertaken to determine the identity of the minerals present in the deposit.

**Lucky Horseshoe**

The Lucky Horseshoe is on Plume Creek about a mile above its junction with Agency Creek (Fig. 6). It lies on the lower frontal slope of the mountain where Plume Creek emerges from its deep, rocky canyon and enters the lower country carved in the bordering volcanic rocks. (Pl. 2, B). The Lucky Horseshoe group comprises 12 claims acquired from the original locators by Fred Guderjohn of Idaho Falls, Idaho. Mr. Guderjohn also has ownership of the adjoining Independence group of about 28 claims. The work on the property consists of a half-dozen bulldozed cuts, an uncompleted crosscut several hundred feet long, and a considerable amount of drilling. The property was one of the few receiving serious attention during the summer of 1957.

The work on the Lucky Horseshoe No. 1 claim on the northwest side of the creek and on the No. 10 claim on the southeast side has uncovered a prominent zone of sheared and complexly fractured phyllitic rock. This zone is as much as 60 feet wide and perhaps as much as a half-mile long, trends about N 60°W, and apparently dips about 30° S. The best exposure is in a long cut some distance up the ridge northeast of the creek. The structurally disturbed zone there is about 60 feet wide, but most of the mineralization is within a zone less than 20 feet across. The rock is a dark-colored phyllite containing biotite as the main constituent; but its color in the main zone of mineralization ranges from black to light gray, depending on the character of the minerals introduced into the phyllitic rock. The foliation is prominent throughout the deposit and much of the ore resembles a banded gneiss. The foliation dips southwest at a rather low angle. Conformable with the foliation are irregular streaks, zones, pods, seams, and bunches of reddish feldspar, specular hematite, and barite. An iron vein several feet thick is also exposed in the face of the cut but does not extend to the next cut a short distance above. The lower face of the cut also reveals a slip, dipping about 10° SW, bordered by a broad band of specular hematite. This slip splits near the east end of the cut and then apparently dies out.
In a cut about 50 feet beyond, the shearing is less pronounced and the rock lighter-colored. It shows less of the reddish colorations and greatly decreased radioactivity. In another cut about 100 feet beyond, feldspar and specular hematite reappear in small pods and irregular seams and bunches and the radioactivity increases very markedly. In the other direction a cut about 100 feet below the main exposure discloses about six feet of mineralized phyllite with some feldspar, specular hematite, and other minerals.

Southeast across the creek on the No. 10 claim the relations continue much as on the No. 1 claim. The phyllite is exposed in three cuts along the slope of the ridge above the gravel terrace, with evidence of mineralization in each cut manifested by reddish and blackish colorations and marked radioactivity. The shear zone maintains its low dip, but the phyllite exposed in the lowest cut is highly drag-folded, with the drag folds overturned up the ridge (to the northeast). In places the phyllites are cut by flat slips.

The various exposures indicate that the mineralization is somewhat irregular with the minerals showing a sporadic distribution and a tendency to occur as irregular seams, streaks, pods, and bunches mostly controlled by the shearing and the foliation. The shear zone, however, shows recurrent, if not entirely continuous, mineralization throughout its observed length.

The mineralization is somewhat different from that of the region as a whole in that thorite is not a conspicuous mineral and may be largely absent except on the No. 10 claim. Instead of the thorite, there is abundant allanite as well as a high concentration of monazite. Specularite and barite are also irregularly abundant. The barite is not readily recognized on sight; but it is one of the most abundant, if not the most abundant mineral in the deposit and is largely responsible for the light-colored zones and the gneissic appearance of much of the ore. Microcline feldspar is also abundant locally, but the late quartz is only a minor accessory in the deposit. Some apatite and xenotime (?) appear sparsely under the microscope. The allanite is responsible for much of the dark coloration of the ore not attributed to specular hematite.

Independence

The Independence adjoins the Lucky Horseshoe on the northwest (Fig. 6). The main work is on the No. 8 claim and consists of a large, bulldozed cut about three-fourths of a mile from the work of the Lucky Horseshoe No. 1 claim.

The cut is in the zone of phyllitic rocks just above the volcanic contact. The phyllites appear to be a part of the same belt that extends along the lower front of the main range, the belt striking about N 60° W and lying against more massive quartzites, which strike about N, 30° W and dip 30° NE. The mineralized zone is in the phyllites and appears to trend in an almost east-west direction and to dip 20°-30° NE, into the mountain.

The mineralization consists of discontinuous seams of specular hematite through a zone about five to six feet wide, accompanied locally by small irregular bunches and streaks of reddish feldspar. In places there
is but one seam of specular hematite; in other places there are several, each one to two inches thick. The material was not examined microscopically and hence the other minerals in the deposit remain unidentified.

**Sparky**

The Sparky group is near the western edge of the broad, southward-facing, escarpment-like slope between Flume Creek and Horseshoe Bend Creek about three-quarters of a mile due east of the main workings on the Lucky Horseshoe property (Fig. 6). The work comprises several small cuts on the Sparky No. 2 claim. The location notices indicate that the claims are owned by Clyde L. Goodman and Frank A. Harris.

The cuts expose two veins about 12 feet apart along a broad fracture zone in the northeastly dipping quartzitic beds bordering the phyllites that extend along the base of the slope. These veins strike about N 80° W and dip northeast, one more steeply than the other so that the two may join at depth. One vein is about four feet thick with bulges that locally make it much thicker. The other vein is about five feet thick. Both contain notable amounts of reddish feldspar and specular hematite and both are notably radioactive. Some of the vein material shows a peculiar banding of the light feldspathic and darker minerals. Examined microscopically, the banded material discloses an abundance of feldspar, quartz, barite, and specularite; and considerable amounts of allanite along with some thorite, monasaite, and biotite. The biotite and some of the quartz are inherited from the locally phyllic quartzite and are mainly remanent inclusions penetrated and replaced by the thorite, allanite, monasaite, specularite, and barite. The feldspar is younger than these minerals but older than another generation of coarse specularite and late quartz, the latter with a load of minute inclusions of specularite and other minerals.

**Skylark**

The Skylark is on the same southwestward-facing slope as the Sparky but lies to the northeast and in part is higher on the slope (Fig. 6). The work comprises some old cuts low on the slope which reveal nothing of the structure. More recent cuts higher on the slope, both on the nose of a low ridge and in the bottom of a shallow gulch, have more to offer in the way of geology, but location notices were not found and the newer workings are not necessarily on the Skylark property.

The quartzitic rocks exposed along the slope have a cleavage that is more prominent than the bedding. Whereas the beds strike N 30° W and dip about 25° NE, the cleavage strikes N 60° W and dips 45° SW and is responsible for the escarpment-like slope between Flume and Horseshoe Bend Creeks, a dip slope controlled by cleavage.

The only mineralization observed was in a long bulldosed cut across the nose and side of the low ridge mentioned above. This cut has exposed a vein for about 100 feet, a vein conspicuous by its high content of secondary black and brown limonitic iron oxides. The vein strikes N 60° W, dips nearly vertically, and measures from eight inches up to more than two feet thick. Where not masked by secondary iron oxides, the vein filling is chiefly reddish feldspar with considerable coarsely crystalline specularite. There is also some infiltrated quartz, in part as thin seams cutting
the feldspar. Parts of the filling are strongly radioactive; but as no microscopic examination was made, the other minerals remain unidentified.

Betty Joe

The Betty Joe is exposed along a bulldozed road descending from the head of the slope above the Skylark into the upper valley of Horseshoe Bend Creek (Fig. 6). Location notices indicate J. L. Pattee and E. A. Smith as owners.

The fracture zone is large and complicated, and for some distance is parallel to the road. Unfortunately, debris slides from above have covered much of the exposure and have obscured the relationships. Visible, however, is a relatively flat fault which strikes N 30° W and dips 20°-30° NE. In the fracture zone are some bunches of white as well as of brownish jasperoid quartz, and here and there are minor amounts of reddish feldspar. The deposit appears to be mildly radioactive.

Buffalo

The Buffalo is on the ridge between Agency and Flume Creeks a little less than a mile north of the Copper Queen mine and is reached by road from lower Flume Creek (Fig. 6). The property is one that was known in earlier days for its copper production; but all the workings on the copper vein, which is on the ridge slope west of Agency Creek, are inaccessible. The recent work is a short distance to the southwest across the crest of the ridge and includes a padlocked adit of unlearned length and a number of bulldozed cuts on and across the ridge.

Several small quartz-hematite veins extend across the ridge, striking about N 60°-75° W and dipping about vertically. Some of these veins have been exposed in cuts for about 400 feet. Much white quartz is visible not far from the portal of the padlocked adit, but northward up the slope, the white quartz yields to a darker blackish quartz.

Some of the white quartz contains thin, reddish iron seams along minor, widely scattered fractures; but the main radioactivity appears to be associated with the darker quartz. Microscopic examination of the darker, somewhat mottled material, seemingly composed of blackish quartz, brecciated and cemented by white, more coarsely crystalline quartz, disclosed a breccia of fine-grained quartz, darkened by tiny scattered grains of biotite and finely crystalline specularite, cemented and permeated by more coarsely crystalline quartz. A few small crystals of thorite were observed with the specular hematite. Apparently thorite and specularite were introduced into and replaced a somewhat micaceous quartzite, which was then soaked through by the coarser-grained quartz. In places, the hematite-thorite mineralization entered fractures in older vein quartz.

The deposits show a sporadic distribution of minerals. On the north-west side of the ridge the bulldozer has uncovered large chunks of massive specular hematite. Elsewhere the bulldozer has exposed small pods or pockets rich in hydrous iron oxides.
Agency

The Agency claim is on the south side of Agency Creek at the road turnoff to the Copper Queen mine (Fig. 6). The claim is one located by E. G. Peron and the work on it consists of a long high cut about 30 feet above the creek extending into the gulch occupied by the Copper Queen.

The cut has uncovered a broad zone of complexly fractured rock: about 120 feet across, half of which bears some evidence of mineralization. The zone apparently trends N 60°-70° W and, if two cuts farther up the ridge above the Copper Queen mine are on the same structure, it has considerable length. Mineralized or iron-stained fractures in the road cut north of Agency Creek mark its continuance in that direction.

The mineralized part of the fracture zone displays variable degrees of radioactivity, the most intense in or near seams, pods, and irregular areas of recognizable mineral substance. Some fractures contain thin, visible seams of specular hematite; but the specular hematite is not so abundant in this deposit as it is in most of the others. Iron-stained limonitic and hematitic fractures occur throughout the more highly disturbed parts of the fracture zone. The minerals that stand out in the more highly mineralized and radioactive areas are rather coarsely crystalline calcite and barite, both of which show reddish coloration, apparently from inclusions of ore minerals.

Microscopic examination of the highly radioactive carbonate and barite reveals the presence of considerable amounts of thorite and monazite, apparently a little xenotime(?), minor amounts of specularite, and a little apatite, pyrite, and late quartz. The thorite, monazite, apatite, and specular hematite are closely associated and are commonly contained as irregular, remanent aggregate masses within the barite and calcite. The calcite penetrates into and partly replaces the barite. The quartz in turn permeates the calcite as well as the other minerals. Small, widely scattered crystals of pyrite occur chiefly in the calcite.

Black Bull

The Black Bull is mostly along the north side of Agency Creek at and above the road turnoff to the Copper Queen mine (Fig. 6). The most significant mineralization is on the Black Bull No. 4 claim fraction a few hundred yards above the turnoff on the road to Lemhi Pass. This group of four claims was located by Peron and Hengardner and is one of the properties of the Salmon Uranium and Thorium Company, Inc. The work on the No. 4 claim fraction comprises a high, bulldozed bank just above the road. Bulldozed cuts on other claims are mainly in basal volcanics and not in thorium-containing host rocks.

The mineralization on the No. 4 claim fraction conforms with a broad zone of fractured quartzite which appears to trend across the creek in an easterly direction. The boundaries of the fracture zone are not sharply defined; but the zone of mineralization, which is confined to the more highly shattered quartzite, is about 70 feet across. This zone contains a relative abundance of irregularly distributed reddish feldspar, finely crystalline specular hematite, and quartz, the minerals generally so associated and distributed as to produce a reddish and blackish mottling.
Microscopic examination reveals an abundance of microcline and specularite, and relatively large amounts of thorite. The thorite is intimately associated with the specular hematite, generally as crystals within and protected by the specularite aggregates. Much of the specularite and thorite occurs as irregular patches within the feldspar aggregates, apparently as scattered remnant masses unreplaceably by the feldspar. The replacement by the feldspar has been such as to produce a pseudobreccia effect, the feldspar appearing to the unaided eye as breccia-like masses in a matrix of the dark specularite. Monazite, apatite, barite, and other minerals normally expected were not observed in the ore examined microscopically.

Gage

The Gage property is on the upper, west side of a steep, shallow gulch north of lower Agency Creek almost directly across from the mouth of Cow Creek (Fig. 6). It lies some 400 to 500 feet above the creek at the end of a narrow jeep road bulldozed in the side of the steep mountain slope. The work on the property consists of several short adits about 100 feet apart vertically, and a small cut about midway between.

The work is along a somewhat silicified fracture zone in dark gray, phyllitic quartzite. Because of the silicification, the zone of fractured rock tends to stand out in relief and may be readily traced from the gulch bottom to the top of the ridge, its strike being about N 80° W and its dip 65° SW. Because of an abundance of disseminated pyrite in the fracture zone, the outcrop is heavily stained by hydrous iron oxides.

At the lower adit the silicified fracture zone appears to be about 10 feet across, but the more intense mineralization is limited to a zone about one foot thick. This narrow zone is highly quartzose; but contains some thin reddish seams in fractures, suggestive of thorite mineralization. The adit has been driven along the zone for about 10 feet.

The upper adit is about 15 feet long, but it has been driven alongside the mineralized zone and actually reveals nothing of the mineralization. To the side of the portal the mineralized zone appears to be several feet thick.

The cut midway between the two adits extends across the ledge and affords the best exposure of the mineralized zone.

The deposit is appreciably radioactive; but the only mineral visible to the unaided eye other than the quartz and secondary iron oxides is pyrite, which occurs as tiny crystals along minor fractures in the altered country rock, occasionally as larger crystals and granular aggregates. Thorite and rare earth minerals are not visible and their presence has not been confirmed by microscopic observations. Some reddish iron staining along fractures in the quartz suggests that thorite may be present as microscopic grains. The radioactive minerals are apparently later introductions into a pyritic-quartz deposit.

Scott

The Scott property is in the same gulch as the Gage on lower Agency Creek, but is directly across the gulch on the east side, apparently on a
continuation of the same mineralized fracture zone (Fig. 6). The work on the property consists of a half-dozen bulldozed cuts, four of them on the steep slope along the side of the gulch and two of them on and just over the crest of a spur ridge.

The two lower cuts failed to penetrate the overburden and uncover the fracture zone, but the next two reached bedrock and extend across the mineralized zone. The rock in the first of the two upper cuts is rather highly radioactive, but in the uppermost cut the radioactivity is perceptibly weaker than it is below. In the cut across the top of the ridge along the strike of the mineralized zone, the radioactivity is also less than on the slope below. The sixth cut just over the crest of the ridge reveals little, if any, radioactivity, and may be in large part off the structure.

In the main part of the fracture zone the rock is extensively shattered with most fractures heavily stained or coated by limonitic oxides. The zone is not so silicified as across the gulch and altered grains of biotite are evident in the rock, possibly accompanied by small grains of allanite. Microscopic studies were not undertaken and the minerals actually responsible for the radioactivity remain unidentified. Some of the lode material seems unduly heavy, which suggests the possibility of the presence of barite.

**Badger**

The Badger is east of the Copper Queen mine and covers the high ridge between the mine and the Idaho-Montana line (Fig. 6). The group contains not less than 10 claims located in September of 1956 by Jacob and Mary Schenk and Everett J. and Lila L. Harton. The work on these claims consists of a number of bulldozed cuts, the principal ones in a gulch that joins Agency Creek at the Copper Queen mine.

Some of the cuts have been made in volcanic rock, but the main cuts are in quartzite near the volcanic contact. The largest one is on the north side of the gulch a short distance below the water trough. This cut, which is about 150 feet long, extends across a broad fracture zone and exposes a vein which contains 12 inches of specular hematite. Quartz and silicified rock add another two to three feet to the thickness of the vein, and reddish-stained rock in the shattered walls adds several feet more. The vein strikes N 30°-40° W and appears to dip about 60° NE. A cut higher on the slope in line with the trend of the vein and fracture zone was not examined. Another cut on the other side of the gulch exposes some reddish iron staining and a little specular hematite.

The vein material shows some radioactivity, but the only minerals recognizable by the unaided eye are specular hematite and quartz. The vein was not studied microscopically and the identity of other minerals is not known.

**Wonder**

The Wonder is in Camp Gulch, a tributary of Agency Creek nearly a mile above the Copper Queen mine (Fig. 6). The Wonder mine is an old copper property which received some attention in earlier years and then
again in the fifties after the discovery of thorite. The earlier work was chiefly on the west side of the gulch and across the low ridge into the next gulch. This early work consisted of seven adits and stopes, now mostly inaccessible. Except for some bulldozing along the crest of the low ridge and in the gulch beyond, all the recent work has been on the east side of the gulch, mainly in two adits: one a 475-foot adit near the gulch bottom, the other a 306-foot adit with 120 feet of crosscuts a short distance above the first. Seven bulldozed cuts continue the exploratory work on the slope above, almost to the top of the ridge. Most of the work in the adits was done in 1954 with the assistance of a government loan.

Some radioactivity is manifested in the copper lode on the west side of the gulch, but the strongest concentration of thorium is on the east side where the copper mineralization is weak or wanting. The copper mineralization is along a shear zone in phyllitic quartzite. The shear zone which strikes N 76° E, dips 80° NW, contains disseminations and masses of bornite, chalcopyrite, pyrite, and their oxidation products in a gangue of quartz and country rock. Some thorite has been added to the lode and also to the shattered country rock, which on the crest of the low ridge is marked by seams and veinlets of reddish hematite. The copper lode is about three feet thick and has been exposed for more than 500 feet.

The adits on the east side of the gulch have been driven along the broad zone of extensively fractured rock, apparently on the continuation of the same zone across the creek, although the strike has changed to N 85° W and the dip to 65° SW. Inasmuch as the adits have not revealed as much data on the mineralization as the cuts above, most of the local observations were confined to the surface.

The broad zone of fractured and mineralized rock is well exposed in a cut just over the top of the upper adit. The zone shows radioactivity of variable intensity across about 20 feet of the fracture zone with a strong radioactivity for the first 10 feet. The more intense radioactivity appears to be associated with a brownish, jasperoid-like material. Minor reddish areas composed of thorite or feldspar have not been entirely blotted out by weathering oxidation.

In the next cut above, the structural zone seems to have widened and measures 40 feet across, with additional disturbance but no mineralization in the bordering walls. The zone appears to reflect a merging of two independent zones of diverse trend, one with a distinctive blackish, manganese-stained vein, which is traced in the cut to the top of the ridge, the other a continuation of the dominant structure exposed in the cut below. In this second cut the disturbed zone is not uniformly mineralized. For about 15 feet above a rather indefinite footwall the rock is lightly radioactive. For the next 15 feet the radioactivity is strong though somewhat sporadic; then it is weak for the next eight feet, except for a seam or streak along the hanging wall, which is highly radioactive. Stringers and small masses of reddish material, presumably feldspathic, occur through parts of the zone.

In the third or next cut above, the separation of the structural zone into two parts becomes more evident. The structural zone is about as broad as in the cut below. The shattered rock above the footwall shows light radio-
activity for the first 10 feet and then somewhat increased radioactivity from there on. The "black" vein is exposed about 25 feet to the south, mainly in the floor of the cut where it measures up to a foot across. This vein strikes about N 55° W, dips 45°-50° NE, and pulls out of the broad fracture zone exposed in the cuts below. From this point on all the cuts are on the fracture zone containing this highly radioactive vein.

In the next or fourth cut the "black" vein is exposed along the floor of the excavation for 20 feet. The vein is about a foot thick and lies above a foot of reddish gougy material. The structural zone that contains the vein is approximately 20 feet across.

In the fifth cut the structure is somewhat flatter than above and below and dips about 45° NE. About eight feet of the zone of shattered rock contains thin, rather widely spaced reddish iron seams and stringers, which are highly radioactive; but the "black" vein exposed below was not uncovered in the cut.

In the next cut above, the sixth, the "black" vein is again exposed, measuring six to 10 inches thick and contained in a structure about three feet wide which also holds reddish hematite seams even more highly radioactive than the vein itself. The mineralized zone thus becomes a lode about three feet thick, with a somewhat erratic distribution of values. At this point the lode strikes N 60° W and dips about 55° NE.

In the seventh or last cut visited the black streak had barely been uncovered; but about three feet of hematitic and limonitic material is exposed, which is quite radioactive.

Some of the black oxidized, reddish spotted, rather highly radioactive material from the "black" vein was examined microscopically and was found to be composed chiefly of barite and specularite with considerable thorite and monazite, and a little infiltrated quartz. The specularite with enclosed thorite and monazite form irregular masses within the barite, the specularite apparently protecting the thorite and monazite from replacement by the barite aggregates.

Lander Lode No. 18

The Lander Lode No. 18 claim is on the Continental Divide almost against the Montana line (Fig. 6). The location notice states that the claim belongs to G. E. Shoup of Salmon, but according to reports the claim has been taken over by the Lewis Corporation. The work on the claim comprises two closely spaced groups of bulldozed cuts, each on a different vein.

Most of the cuts are along the course of a conspicuous quartz-hematite vein exposed across the crest of a low knoll just off the surveyed line of the Continental Divide and down the southwest slope. The vein strikes N 75° E. and dips 80° E. Its outcrop may be traced for several hundred feet. The vein is from two to four feet thick, locally seven feet thick, and is composed of white, massive quartz cut by small, discontinuous veinlets of fine-grained, reddish hematite, some of which extend outward into the bordering, quartzitic walls. The vein is sporadically mineralized, but in places shows appreciable radioactivity, especially along a 10-foot length near its northeast end. The vein material was not examined microscopically,
but it is presumed that the radioactivity comes from thorite associated with the hematite.

The second vein, which may intersect the first, is exposed in two nearby cuts. This vein strikes N 40° W, dips 30° SW, and, if continuous, may be traced for several hundred feet by cut exposures. This vein is smaller than the other and in the exposure measures up to a foot thick. It is composed of black, manganese-coated quartz with veinlets of a reddish mineral. The vein is highly radioactive and microscopic examination shows an abundance of thorite and monazite, relatively large amounts of apatite and barite, and the inevitable black specular hematite and late quartz. This vein is almost identical to the "black" vein on the Wonder property.

Little Dandy

The Little Dandy group adjoins the Wonder No. 18 claim on the south (Fig. 6). The group consists of five claims on the Idaho side of the Continental Divide, the State line forming the southeast boundary of the group. The claims were located June 1955 by J. Thompson, C. Wells, and J. Schenk, but have since been acquired by D. B. Lewis. The work comprises several small cuts almost on the State line.

The cuts have exposed an iron-rich vein up to a foot across along a broad zone of fracturing. The vein strikes N 80° E. Where the vein shows yellowish oxidation products, it is locally highly radioactive and contains visible grains of thorite. Where specularite predominates, the radioactivity appears to be weaker. The thorite has spotty distribution.

Some large chunks of shattered country rock with reddish seams probably containing thorite are piled on the surface to the side of the cut.

Beaverhead

The Beaverhead straddles the Continental Divide less than midway between the Wonder Lode No. 18 claim and the Cago group. It is close to the west boundary of the Little Dandy group (Fig. 6). Part of the claims are in Montana and part are in Idaho, but the only deposits examined were along the Idaho side of the Continental Divide. The number of claims composing the Beaverhead group was not learned, but the group is reported to be among those held by D. B. Lewis. The only work on the Idaho side consists of a few small prospect holes almost on the State line.

Several small veins are exposed on the ridge. These veins strike N. 60° W and continue across the ridge into Montana. They are one to two feet thick, and are highly radioactive. The fillings are extensively weathered in the surface exposures and are mostly composed of brownish, siliceous, jasperoid-like materials, with some remnant areas of reddish feldspar and fine blackish and light-colored, coarsely crystalline quartz. Microscopic examination reveals rather abundant thorite and monazite; variable and sporadically distributed amounts of specularite, apatite, barite, and feldspar; and, as usual, considerable amounts of late quartz. Most of the vein material appears to contain more monazite than thorite, but this may reflect the general irregular, more or less sporadic distribution of the various minerals.
The Cago group of claims extends across the Continental Divide from the head of Camp Creek, an upper tributary of Agency Creek, into Montana; but the investigation was restricted to the Idaho side of the line and centered on a deposit on the Cago No. 12 claim, a few hundred yards down the Idaho slope (Fig. 6). The group of claims is one of several owned by the Salmon Uranium and Thorium Company, Inc., now included among the holdings of D. B. Lewis. The work on the No. 12 claim consists of a large bulldozed cut about 200 feet long and a steep, bulldozed jeep road from the Continental Divide to the cut. This cut extends diagonally down the side of the steep, timbered-covered slope reaching almost to the bottom of the small head gulch.

The deposit on the No. 12 claim is one of the most radioactive, if not the most radioactive in the district, containing a greater concentration of thorite than in any other deposit examined. The deposit comprises a large lenticular vein, exposed only in the cut where it is partly covered by slide debris. The vein appears to strike about N 55° W and dips 45°–55° S, a dip which carries it into the steep slope. The enclosing country rock is completely covered by a deep soil mantle; but the float indicates quartzitic rock, locally much sheared and otherwise fractured. The vein is as much as eight feet thick and is composed for the most part of a brownish, jasperoid-like material, its brownish color in part the result of weathering oxidation. The jasperoid-like material is actually a fine-grained quartz containing variable amounts of included minerals recognizable individually only with the microscope. Some dark gray to black quartz and minor amounts of white quartz also go to make up the deposit. Within the vein are some specular hematite pods or lenses up to 10 inches thick, some of which are very rich in thorite.

None of the minerals other than the specular hematite and quartz can be identified without the microscope, although crystals of thorite are visible in some of what appears to be rich hematite ore, but whose reddish tone actually comes from the small, locally more abundant thorite crystals. The microscope reveals not only an abundance of thorite throughout much of the deposit but also the presence of considerable monazite and minor amounts of xenotime(?), apatite, barite, sericite, and feldspar. The quartz appears in two generations: one as small grains in company with the thorite, specularite, and associated minerals; the other as much larger grains which have penetrated into and have largely replaced the earlier grains of quartz, engulfing the other minerals and holding them as inclusions. It is the included material that has given so much of the quartz its brownish to blackish appearance.

The writer was present when samples of the vein were taken by Russell Wood, who later furnished a copy of the analyses. One sample of the highly radioactive, hematite material contained 14.79 percent combined rare earth and thorium oxides. Another sample of the more siliceous material contained 0.7 percent rare earth and thorium oxides. Earlier studies of samples from the deposit by the U. S. Bureau of Mines indicate that the content of rare earths oxides exceeds that of the thoria by a small amount.
Black Bear

The Black Bear is high on the slope south of Agency Creek on a small tributary that joins Agency Creek not far east of White Creek, more precisely just across from the point where the road to the Buffalo and Lucky Horseshoe properties leaves the Agency Creek road (Fig. 6). The Black Bear group of 11 claims or more was located by Earl Pyeatt and G. E. Shoup.

The best showing appears to be on the No. 2 claim where a bulldozed cut across a low ridge projecting between forks of the tributary valley has uncovered a broad, partly mineralized fracture zone with local concentrations of reddish feldspar and specular hematite. Some of this material is highly radioactive; and microscopic study confirms the presence of considerable thorite and scant amounts of monazite, apatite, and biotite, the biotite as an inheritance from the country rock. The thorite is intimately associated with the specular hematite and appears to be present in two generations: one as small crystals accompanied by small crystals of specularite, monazite, and apatite, generally included within granular aggregates of microcline; and the other as much larger crystals enclosed by and contained in larger crystals of specularite. In places a little late quartz has infilttered into the mineral aggregates.

Several cuts have been made on the brow of the ridge to the west, one of which has uncovered a fault zone along which an altered basic dike has been intruded. This dike strikes N 30° W and dips 60° SW.

Other properties

Because of time limitations, some deposits, especially in the southern part of the map-area, were not examined. Some of these deposits are on the high hills east of Tendoy and on the slopes bordering Agency and Horseshoe Bend Creeks, but most of them are on the slopes at or near the heads of Sharky, Cow, and Yearian Creeks. The fact that these deposits are not described does not mean that they are any less worthy than many of those that are written up in the report.

DEPOSITS IN THE DIAMOND CREEK AREA

Location and accessibility

The thorite deposits in the Diamond Creek area are about half way up the east slope of the Salmon River Mountains, mainly on ridges bordering tributaries of Diamond Creek and in shallow gulches on the slope between Diamond Creek and Wallace Creek (Fig. 1). The deposits are confined to a small area of probably less than three square miles, mostly in the south-eastern part of T. 23 N., R. 19 E., but possibly extending into T. 22 N., R. 19 E., Boise meridian.

The deposits are not readily accessible. They may be reached from the Stormy Peak road which leaves the main highway about three miles north of Salmon. The Stormy Peak road passes a mile or so above the deposits and it is thus necessary to drop down a broad, tree-covered ridge
between Wallace and Diamond Creeks over a poorly marked road or jeep trail. The route is across several steep gulches and unless the trip is made in the company of the owners or with someone else who is familiar with the area, search for the deposits may be unrewarding.

Geologic setting

The deposits are in and on the lower (eastern) side of a long, narrow, granitic stock which intrudes folded and faulted quartzitic rock belonging to the Belt series. The stock is an outlier of the Idaho batholith and is composed of exceptionally coarse-grained granite, apparently of replacement origin. The stratigraphy and structure of the invaded Belt rocks have not yet been worked out. The exposed beds are composed largely of dark grey, micaceous quartzites and subordinately of schistose rock, particularly along mineralized zones. These beds in part strike about N 35° E and dip 45° NW and thus do not conform with the more general, regional, northeasterly trend. They are broken by small faults of northeasterly strike, some of which are mineralized; and apparently also by larger faults, which lie just outside the area.

Character of the deposits

The deposits are much like those in the Lombi Pass area and include mineralized shear zones and gold-quartz veins, with appreciable concentrations of thorite and rare earth elements. Because of pronounced oxidation associated with weathering, the deposits contain much hydrous iron oxides, chiefly goethite, which makes it difficult to observe the true character of the mineralization. The microscope, however, confirms their resemblance to the Lombi Pass deposits and discloses that the thorite and associated minerals are chiefly disseminated replacements of sheared and fissured rock, and locally minor additions to fractures in older, gold-quartz veins.

Structural relations

The area examined is much too small to determine whether the deposits conform with a regional structural pattern. All the deposits strike in the northeast quadrant and in this respect they differ from the deposits in the Lombi Pass region where the mineralization has been chiefly along shear and fracture zones of northeasterly trend. The local deposits show no general parallelism. Some of the deposits occupy shear and fissure zones that trend N 10° E; some N 25° E; others N 35° E; and one, at least, N 50° E. They all dip northwest at moderate to steep angles.

Most of the zones of sheared and fissured rock are not very broad; and the mineralized bodies within are less than four feet across, in some places less than a foot. Some of the mineralized zones are short—a few tens of feet—others may be some hundreds of feet long. The shearing and fissuring is about as pronounced in the granitic rock as in the schistose rocks and quartzite.

Mineralogy

The mineralogy of these deposits is little different from that at Lombi Pass. The minerals include thorite, monazite, xenotime(?), apatite, specular hematite, barite, fluorite, feldspar, and quartz. The main difference appears to be the presence of a little purplish fluorite, present microscopically in one of the deposits. Few of these minerals are recog-
nizable without the microscope. The quartz is usually visible; but the monazite, specular hematite, barite, and feldspar can rarely be recognized by the unaided eye.

The minerals are present in variable amounts. In some places the thorite is notably abundant, though commonly less so than the monazite and specular hematite. The barite is somewhat sporadic in its distribution, but in most places it is well-represented. The other minerals are generally much subordinate, but all in all the proportions and distribution of the minerals are not much different than those found at Lemhi Pass.

The mineral relations and the mineral succession are also the same as at Lemhi Pass. Thorite is the earliest mineral and the rather meager quartz the latest, with monazite, specularite, barite, and feldspar falling successively between. The apatite and xenotime (?) are closely associated with the monazite, but their exact place in the sequence has not been determined.

To describe the minerals and their characteristics and relationships individually would be needless repetition of what has already been written about the same minerals in the Lemhi Pass area.

General features of the deposits

The deposits have been little prospected and the scattered exposures provide inadequate data on the persistence of the mineralization along the shear and fissure zones. Some of the deposits are hundreds of feet long and two to three feet, exceptionally up to four feet, thick. Others are apparently much shorter and less than a foot thick. Where exposed in cuts, most of the deposits show strong radioactivity and variable amounts of thorite and associated minerals; but whether the mineralization holds up from one exposure to another or is mostly localized in the immediate vicinity of the prospected ground is not definitely known. Some deposits appear to show rather continuous mineralization but with spotty distribution of individual minerals.

Abundant yellowish and brownish hydrous iron oxides along the vein and shear zones may serve as guides to the presence of thorite and associated rare earth minerals. The highest radioactivity appears to be largely restricted to brownish, jasperoid-like material, in most places associated with compact and powdery goethite. Microscopic studies reveal that the hard, jasperoid-like material contains much of the thorite and associated minerals.

As the writer did not sample the deposits, the grade or tenor of the material was not definitely established; but the microscopic work tends to confirm statements by G. E. Group that samples taken by him across three-foot widths of the main deposit on the Contact group contain up to 0.75 percent thorium and as much as four percent rare earth oxides. He also reports some uranium in the deposits.

These deposits probably originated in the same way as those in the Lemhi Pass area. As they are contained in the granitic rock of the Idaho batholith as well as in the bordering quartzitic rocks, they came in after
the batholithic rock had been emplaced. From their close association with the mass of granitic rock, it would seem logical to presume some genetic relationship between them. However, the association of the thorite mineralization with diorite dikes in the Lemhi Pass area suggests that the source is not the batholith but the younger intrusives whose presence in the Diamond Creek area may be revealed by more extensive field studies.

Until more work is done it is impossible to evaluate the thorium-rare earth potentialities of the area. The present showings lend some encouragement to more extensive exploration.

Properties

Contact

The Contact group of claims is on Diamond Creek about 8 miles airline north-northwest of Salmon, mainly in Sec. 26, T. 23 N., R. 21 E., but partly also in the southeast quarter of Section 27. The group comprises 12 Contact claims and three Bell claims owned by P. Redington, F. Van Meter, and G. E. Shoup of Salmon, Idaho. These claims cover an old gold-quartz location, long abandoned and subsequently relocated after the discovery of radioactive and rare earth minerals. The old work comprises several short adits and shafts, mostly caved. The new work is restricted to some bulldozed cuts.

Thorium and rare earth minerals are exposed on several of the claims, with the most noteworthy showings on the Bell No. 1 claim and on the Contact No. 1 and 2 claims. These showings are in the folded and faulted schistose and quartzitic Belt rocks within a few hundred feet of the granite contact. The Belt strata locally strike about N 35° E and dip 45° NW and are cut by faults which trend about N 10° E and in part dip 35° NW.

The exposure on the Bell No. 1 claim is along the road on the ridge crest between the forks of Diamond Creek about 200 yards east of the granite contact. Rusty croppings are exposed in the road cut, but the best exposures are in a bulldozed cut just below the road cut on the north edge of the ridge. The cut and road reveal a broad mineralized zone of apparent N 10° E trend. The material along the zone is highly oxidized and contains abundant brownish limonitic oxides (chiefly goethite), some bands of brownish jasperoid-like material, scattered thin seams of quartz, and irregular spots of reddish hematite. Microscopic examination of the jasperoid-like material reveals variable amounts of monazite, thorite, specularite, apatite, barite, microcline, and quartz. The barite is notably abundant and may be recognized in some of the material without the aid of the microscope.

On the Contact No. 2 claim the mineralized zone is exposed along a 44-foot adit and in a small shaft 285 feet up the slope. The adit is driven into a schistose zone about 10 feet wide, bordered by more massive, micaeous quartzite. The schist strikes N 35° E; dips 35° NW; and, as exposed in the adit, is cut by a mineralized fault which strikes N 10° E and dips 35° NW. This fault contains a vein of highly oxidized material up to two feet thick above a band of footwall gouge. Microscopic examination of this brownish material discloses mostly goethite with areas abundantly rich in specularite, thorite, and monazite. A sample across three feet of this weathered vein material is reported by Mr. Shoup to contain 0.31 percent U3O8, 0.75 percent ThO2, and 4.8 percent rare earth oxides.
In the shaft this vein is about four feet thick. It shows high radioactivity. A microscopic study of white and gray quartz composing the vein, which is locally seamed with limonitic oxides, reveals conspicuous amounts of monazite occurring as disseminated crystals and crystal clusters and some specularite and thorite. These mineral aggregates are extensively permeated by younger quartz which tends to eliminate the specularite and thorite but not the monazite. Samples taken at the shaft across three feet of the deposit are reported to contain 0.07 percent U3O8, 0.38 percent ThO2, and 2.1 percent rare earth oxides.

At the caved adit on the No. 1 claim across a shallow gulch northwest of the No. 2 claim, a large bulldozed cut has uncovered a broad zone of sheared schistose rock which strikes N 35° E, dips 45° NW, and shows considerable radioactivity. The mineralization appears to be similar to that on the No. 2 claim.

Simer

The Simer is in a small shallow gulch just south of the Diamond Creek drainage, perhaps a mile south-southeast of the Contact No. 2 claim. The property is along the jeep road to the Contact and comprises approximately 10 claims owned by Teal and Waterman of Salmon. The work consists of several large and small bulldozed cuts.

The deposits on this property are in granite and consist of three veins, the main one in a large cut in the upper part of the gulch. This vein strikes N 50° E, and dips 60° NW. It contains two to three feet of highly radioactive, jasper-like rock, which examined microscopically shows abundant monazite and variable amounts of barite, purplish and colorless fluorite, and quartz.

A second and much smaller vein a short distance above strikes N 10° E and dips northwest at a moderate angle. This vein, which apparently does not extend beyond the limits of a 30-foot cut, contains up to eight inches of an oxidized, jasperoid-like filling.

The third vein is exposed in several small cuts lower in the gulch. This vein is about a foot thick and lies within a zone of sheared and mineralized, granitic rock about five feet across. This vein strikes about N 35° E. No material was collected for microscopic study.

Lucky

The Lucky group is just over the ridge north of Wallace Creek, also on the jeep road to the Contact property. This group, known as the Frank Burch property, comprises 10 claims on ground originally located and worked for gold. The work comprises an eight-foot shaft and a number of cuts.

The Lucky group has both gold-quartz and thorium veins, in part along the same zones of shearing. These are contained in granitic rock.
Most of the work has been on a gold-quartz vein which strikes N 25° E and dips 84° NW. This vein is about three feet thick at the shaft but thins to about a foot in a cut about 50 feet down the slope. Just beyond the cut the vein appears to pinch out altogether. In the cut the vein is along the footwall of a four-foot thick zone of fractured granite and is composed of white quartz with a scattered sprinkling of pyrite. In places the vein shows some radioactivity, especially in the vicinity of small bodies of brownish, jasperoid-like material.

Other cuts not aligned with the quartz vein show a high background count and in places high radioactivity. The radioactivity as elsewhere appears to be largely restricted to brownish jasperoidal material and not to white vein quartz.
REFERENCES CITED


