Reconnaissance for Radioactive Minerals in Washington, Idaho, and Western Montana 1952-1955

By PAUL L. WEIS, FRANK C. ARMSTRONG, *and* SAMUEL ROSENBLUM

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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RECONNAISSANCE FOR RADIOACTIVE MINERALS IN WASHINGTON, IDAHO, AND WESTERN MONTANA 1952–1955

By Paul L. Weis, Frank C. Armstrong, and Samuel Rosenblum

ABSTRACT

About 50 occurrences of radioactive minerals and nearly 50 properties not abnormally radioactive were examined during geologic reconnaissance for radioactive minerals in Idaho, Washington, and western Montana during the period July 1952 to June 1955. The most important uranium deposits are in or near granitic to quartz monzonitic intrusions of probable Cretaceous age in central and northern Idaho, westernmost Montana, and northeastern Washington. These areas are considered to be most favorable for prospecting. Margins of granitic intrusive bodies in central Montana and western Washington may also be favorable. Uranium-bearing pegmatites associated with granitic intrusive rocks are considered too small and too low grade to be potential sources of uranium. Some placer deposits in southern and central Idaho contain sufficient concentrations of uranium minerals to be of interest as a source of uranium.

Known thorite-bearing veins are confined to Precambrian rocks of the Belt series in northern and east-central Idaho and southwestern Montana. Monazite-rich layers in metamorphic rocks in east-central Idaho do not seem large enough and continuous enough to permit profitable mining.

INTRODUCTION

Although prospecting for radioactive minerals has been active in parts of the United States since the end of World War II, little interest was aroused in the northwestern part of the country until recently. One factor contributing to the lack of interest on the part of prospectors was the small amount of information available on the geology and distribution of radioactive minerals in the Northwestern States. To contribute to a better understanding of radioactive-mineral deposits of the area, members of the U. S. Geological Survey, on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission, spent 5 man-years in reconnaissance for radioactive minerals in the Northwest.

The work began on July 1, 1952. Frank C. Armstrong was assigned to the project at its start, and on July 1, 1953, he was joined by Paul L. Weis. Armstrong left the project on June 30, 1954, and Samuel Rosenblum joined it. Weis and Rosenblum worked on the project until its termination on June 30, 1955.

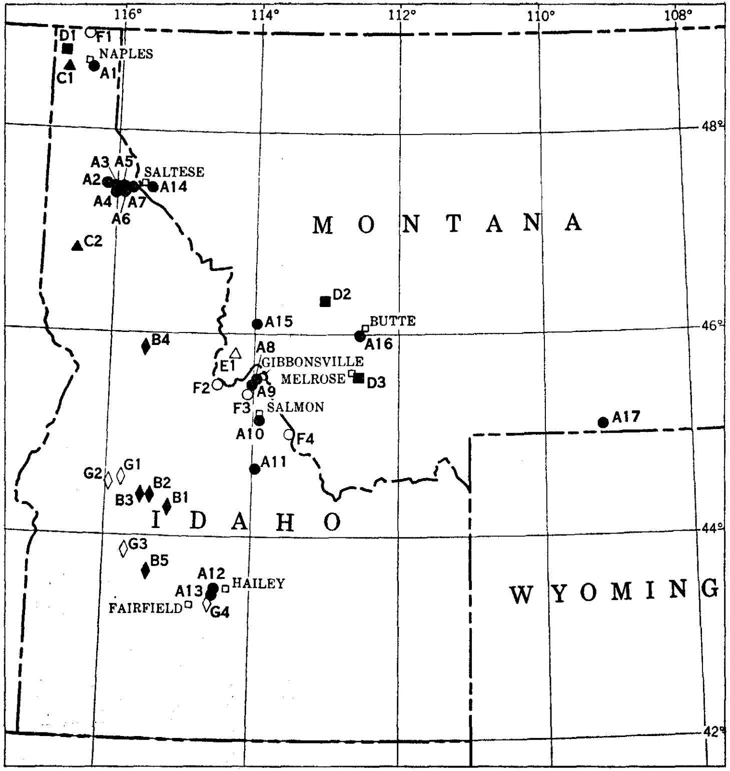
The reconnaissance was done in Washington, Idaho, and western Montana (figs. 1, 2). Specifically excluded from reconnaissance were areas being intensively studied by other groups in the U. S. Geological Survey: (a) the Boulder batholith area, Montana; (b) the Phosphoria formation, in southwestern Montana and southeastern Idaho; and (c) the uraniferous-lignite deposits in southeastern Idaho and eastern Montana. The uranium- and thorium-bearing placers in central Idaho were examined briefly, however, although they were studied in detail by a separate Geological Survey group.

This report summarizes the recommendations and conclusions developed during the reconnaissance. Brief geologic descriptions are given of properties on which radioactive minerals occur, and the significance of certain geologic features of some of the deposits is is discussed.

The radioactive-mineral deposits of Idaho, Washington, and western Montana comprise a wide variety of geologic types and ages. Epigenetic uranium minerals occur in veins and veinlike bodies and as coatings on fractures, joints, and grain boundaries in igneous and metamorphic rocks, and as interstitial material which has been introduced in detrital sedimentary rocks. Syngenetic uranium minerals are found in pegmatites and placers. Epigenetic thorium minerals are found in veins cutting igneous and metamorphic rocks, and as disseminated deposits in metamorphic rocks. Thorium-bearing placers are also known. Ages of formation of radioactive deposits range from Precambrian(?) for uranium veins in the Coeur d'Alene district, Idaho (Eckelmann and Miller, 1956) to Recent for uranium- and thorium-bearing placers in central Idaho.

Radioactive minerals that have been reported in the Northwest, and their composition, are listed below:

Uranium minerals:
- Uraninite $UO_2 \cdot UO_3$
- Betafite $(U, Ca)\ (Nb, Ta, Ti)_3\ O_9 \cdot n\ H_2O$?
- Brannerite $(U, Ca, Fe, Th, Y)_3\ (Ti)_5\ O_{16}$
- Davidite $(Fe^2$, rare earths, $U, Ca, Zr, Th)\ (Ti, Fe^3, V, Cr)_3\ (O, OH)_7$
- Euxenite $(Y, Ca, Ce, U, Th)\ (Nb, Ta, Ti)_2\ O_6$
- Samarskite $(Y, Ce, U, Ca, Fe, Pb, Th)\ (Nb, Ta, Ti, Sn)_2\ O_6$
- Autunite $Ca\ (UO_2)_2\ (PO_4)_2 \cdot 10\text{–}12\ H_2O$
- Meta-autunite $Ca\ (UO_2)_2\ (PO_4)_2 \cdot 2\frac{1}{2}\text{–}6\frac{1}{2}\ H_2O$
- Metatorbernite $Cu\ (UO_2)_2(PO_4)_2 \cdot 4\text{–}8\ H_2O$
- Uranophane $Ca\ (UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$



EXPLANATION

URANIUM OCCURRENCES

● Veins and veinlike occurrences

A 1. Naples prospect
2. Page mine
3. Bunker Hill mine
4. Crescent mine
5. Sunshine mine
6. Coeur d'Alene mine
7. Galena mine
8. Surprise claims
9. Garm-Lamoreaux mine
10. Williams Creek prospect
11. Pahsimeroi Valley
12. Rustler claims
13. Camas mine
14. Waterhole claim
15. Crystal Mountain mine
16. Norwich-Plutus mine
17. Royse claim

◆ Uranium-bearing placers

B 1. Stanley basin
2. Bear Valley
3. White Hawk basin
4. Elk City area
5. Dismal Swamp

▲ Uranium-bearing pegmatites

C 1. Priest Lake prospect
2. Mica Mountain

■ Miscellaneous uranium occurrences

D 1. Mosquito Bay area
2. D. G. claims
3. Melrose area

△ Uranium-bearing rhyolite

E 1. Trapper Peak area

THORIUM OCCURRENCES

○ Veins and veinlike occurrences

F 1. Porthill area
2. Shoup-North Fork area
3. Shoup-North Fork area
4. Lemhi Pass area

◊ Thorium-bearing placers

G 1. Big Creek
2. Cascade-Long Valley area
3. Lakow Flats
4. Hailey-Fairfield area

FIGURE 1.—Index map showing the location of uranium- and thorium-bearing deposits and occurrences in Idaho and Montana.

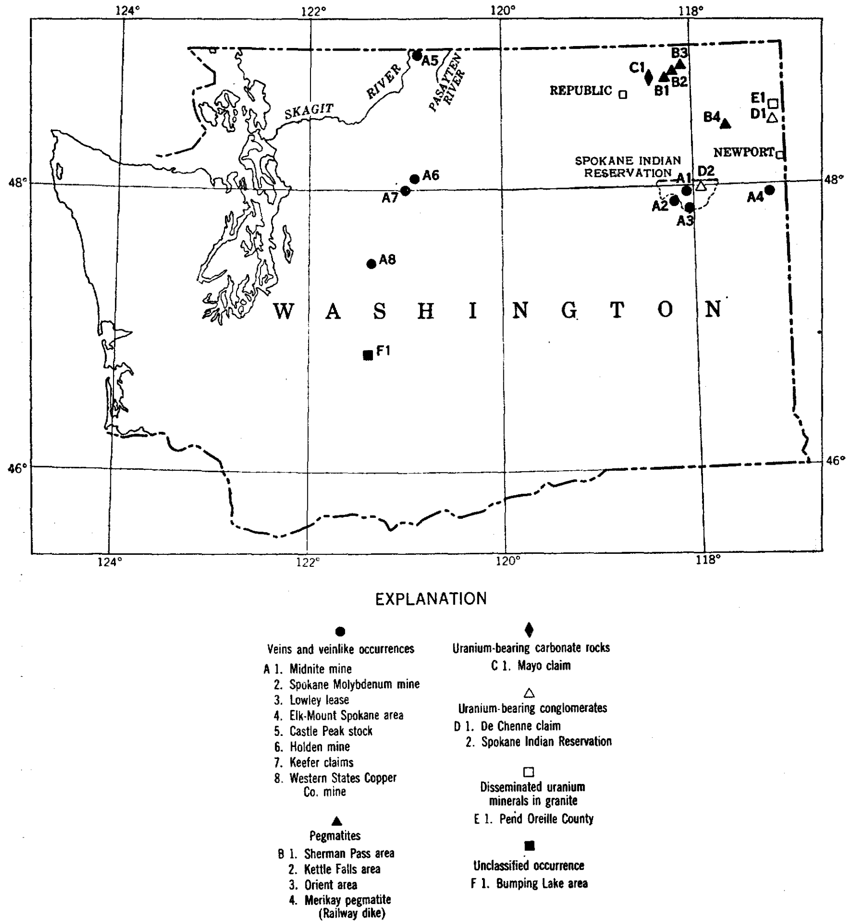


FIGURE 2.—Index map showing the location of uranium deposits and occurrences in Washington.

Uranium minerals—Continued

- Coffinite $U(SiO_4)(OH)_4$
- Schroeckingerite $NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$
- Zippeite—Basic sulfate of uranium; formula uncertain ($2UO_3 \cdot SO_3 \cdot nH_2O$?)
- Liebigite $Ca_2(UO_2)(CO_3)_3 \cdot 10\text{–}11H_2O$
- Phosphuranylite $Ca(UO_2)_4(PO_4)_2(OH)_4 \cdot 7H_2O$
- Carnotite $K_2(VO_2)_2(VO_4)_2 \cdot 3H_2O$

Thorium minerals:

- Thorite $ThSiO_4$
- Monazite $(Ce, La, Th)PO_4$
- Allanite $(Ca, Ce, Th)_2(Al, Fe, Mg)_3Si_3O_{12}(OH)$

The radioactive-mineral deposits described below are divided into three categories: uranium-bearing lode deposits, thorium-bearing lode deposits, and uranium- and thorium-bearing placer deposits. Under each of these headings deposits are grouped by States, and by mode of occurrence.

The following analysts, all of the U. S. Geological Survey, have provided information referred to in this report: Jerome Stone, Robert Meyrowitz, Esma Campbell, Robert S. Jones, John W. Adams, Charles Spengler. Reference is made in the text to the appropriate individual wherever an analysis is quoted.

In the text that follows, the words "deposit" and "occurrence" appear frequently. As the authors use them, an occurrence is any body of rock that contains recognizable uranium- or thorium-bearing minerals. A deposit is any uranium (or thorium) occurrence of sufficient size and grade to constitute a potentially minable ore body, under present economic conditions, or under economic conditions that are reasonably likely in the foreseeable future. Thus all deposits are also occurrences, but not all occurrences are deposits.

URANIUM-BEARING LODE OCCURRENCES

IDAHO

Uranium mineralization of commercial or near-commercial grade has been found in many places in Idaho, but none of the occurrences are large enough to sustain more than small-scale mining operations.

VEINS AND VEINLIKE OCCURRENCES

GIBBONSVILLE AREA, LEMHI COUNTY

The Gibbonsville area is underlain by light-colored schistose micaceous quartzite of the Belt series of Precambrian age. Regional structure and stratigraphy are largely unknown. Uranium minerals have been found at two places west of Gibbonsville: the Garm-Lamoreaux mine, and the Surprise group of claims.

GARM-LAMOREAUX MINE

The Garm-Lamoreaux mine (fig. 1, A9), in sec. 31, T. 26 N., R. 21 E., was operated for gold previous to about 1930. It has been explored by 5 adits, which total more than 2,900 feet in length and which are distributed over a vertical distance of about 430 feet (Armstrong and Weis, 1955). Four of the adits were partly or wholly caved at the time of the writers' visit in 1954.

The property is in schistose micaceous quartzite of the Belt series of Precambrian age. Conspicuous schistosity strikes north to northeast, and dips steeply east. Bedding was observed in only one place, where it strikes approximately east and dips 45°–60° S.

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The mine was opened to develop the Lamoreaux vein, which D. C. Gilbert (written communication, 1933) and G. I. Hurley, local mine manager (oral communication, 1948), reported to be a fractured quartz vein that contains pyrite, galena, and free gold. The vein is in a fault that strikes east to southeast and dips 45° NE. to vertical.

Mr. G. I. Hurley first noted uranium minerals at the mine in 1948. At that time he submitted a grab sample to the Spokane office of the U. S. Geological Survey. Uranium was identified in the sample by Robert Meyrowitz (J. S. Vhay, oral communication, 1955).

In 1954 Armstrong and Weis visited the property and collected vein material from the dump at the portal of tunnel 3. The vein material is fractured, somewhat iron-stained quartz containing minor amounts of chlorite, pyrite, and galena. Part of the dump is more than 10 times as radioactive as the normal background radiation for the area. Picked samples of the most radioactive material contain as much as 1 percent uranium. Uraninite and zippeite were identified in this material.

SURPRISE GROUP OF CLAIMS

The Surprise claims (fig. 1, A8) in sec. 28, T. 26 N., R. 21 E., were discovered in 1954 and were explored by 5 bulldozer trenches and 1 tunnel under a Defense Minerals Exploration Administration contract in 1954 and 1955. The country rock is schistose, micaceous quartzite of the Belt series, similar to that at the Garm-Lamoreaux mine. Strike and dip of the quartzite is indistinct, but at one place foliation that seems to be bedding strikes N. 48° W. and dips 38° SW. The quartzite is cut by a brecciated quartz vein that is at least 1,200 feet long and 10 to 40 feet thick. The vein is in a shear zone that has been traced to the northwest for about 100 feet beyond the end of the quartz vein. The vein and shear zone strike N. 60° W.; the dip is vertical. Brecciation of the quartz vein is remarkably uniform; most of the fragments are ¼- to ½-inch in diameter. They are coated with a thin film of clayey material.

Autunite is the principal uranium mineral at the Surprise claims. At the surface, bulldozer trenches expose coarsely crystalline autunite in narrow, discontinuous zones near the southwest wall of the vein. In the underground working, however, small autunite flakes form thin, discontinuous coatings on the breccia fragments. Torbernite was tentatively identified at one place in the underground working, where it forms a coating on joint surfaces near a small stringer of chalcopyrite. The chalcopyrite stringer is the only sulfide occurrence known at the property.

Although small ore-grade bodies are present at the surface, the average grade of the vein exposed in the underground working does not seem high enough to permit profitable mining.

OTHER OCCURRENCES IN LEMHI COUNTY

Secondary uranium minerals have been found in two places in Lemhi County in the Challis volcanics of Tertiary age. The Challis volcanics are a series of andesitic and rhyolitic tuffs and flows and interbedded sedimentary rocks that underlie about 500 square miles in east-central Idaho.

Near the mouth of Williams Creek (fig. 1, A10), about 8 miles south of Salmon, uranophane was found coating the walls of joints and small shears in rhyolite. A few tons of uranium-bearing material was shipped from this deposit in 1955, but the grade of the material is too low and the reserves are apparently too small to permit further mining.

Schroeckingerite and carnotite(?) has been found in carbonaceous sandstones on the north side of the Pahsimeroi River (fig. 1, A11), within 2 miles of the Salmon River, about 40 miles south of Salmon. Although this occurrence is not veinlike in form, it is similar in origin to the Williams Creek occurrence described above. It is probably too small to be mined profitably.

The presence of secondary uranium minerals in near-surface natural openings in rocks of the Challis volcanics suggests that they were deposited from ground water that leached the uranium from the overlying acid tuffs.

CAMAS DISTRICT, BLAINE COUNTY

The Camas mining district is west of Big Wood River, near Hailey. The area is underlain by quartz monzonite of the Idaho batholith, which is locally capped by Tertiary basalt. The quartz monzonite is cut by several faults (Anderson and Wagner, 1946, p. 7).

RUSTLER CLAIMS

The Rustler claims (fig. 1, A12) are in secs. 8, 9, 16, and 17, T. 1 N., R. 17 E. In the past the deposit was mined for lead and silver. Most of the old workings are caved. The Rustler Mining Co. has explored a quartz vein by a 220-foot inclined shaft, put down at an angle of 45° in a N. 10° E. direction. Exploration on the 120 level (measured down incline) consists of approximately 75 feet of crosscuts and 90 feet of drifts; on the 220 level there are 115 feet of drifts and crosscuts.

The claims contain a quartz vein that strikes about east and dips about 40° N. The vein has a strike length of about 3 miles; for most of its length it is 5 to 8 feet thick, but locally it is 40 feet thick. There has been postmineralization movement along the vein, and the rocks exposed in the mine are brecciated and weathered. Most recent movement along the vein was a combination of normal and strike-slip faulting (Rustler Mining Co., written communication, 1956).

Minerals identified in the vein, in order of abundance, are quartz, galena, cerrusite, sphalerite, pyrite, chalcopyrite, siderite, and uraninite. The uraninite occurs principally as a sooty coating along joints and grain boundaries in galena (Rustler Mining Co., written communication, 1956). Its position suggests that the uraninite is later than the galena in the sequence of mineralization.

At the surface, several echelon veins a few inches to 2 feet thick and about a hundred feet long crop out a few hundred feet to half a mile north of the main Rustler vein. These small veins occupy fractures that strike east, parallel to the Rustler vein, and dip south into the vein at about 45°. In attitude they resemble tension fractures that may have formed during the same period of movement that formed the fault occupied by the Rustler vein.

The echelon veins consist of quartz that is slightly to heavily coated by iron oxides. Both the quartz and the iron oxides contain malachite and chrysocolla in a few places. Torbernite was identified in one vein, and several of the veins show local abnormal radioactivity. None of the echelon veins appear large enough or rich enough in uranium to be of economic interest.

CAMAS MINE

The Camas mine (fig. 1, A13) is on a southeast-trending quartz vein located in secs. 18 and 19, T. 1 N., R. 17 E., 2 miles southwest of the Rustler mine. It was mined for gold. D. L. Schmidt of the U. S. Geological Survey (oral communication, 1955) found abnormally high radioactivity at the surface along one side of the vein.

Further investigation, not only along the Rustler and Camas veins but along all of the quartz veins in the Camas mining districts, might be worthwhile.

COEUR D'ALENE DISTRICT, SHOSHONE COUNTY

Uranium has been found in five mines in the Coeur d'Alene district, and abnormal radioactivity, probably due to the presence of uranium, has been found in a sixth. The uranium occurrences are (from east to west) at the Galena, secs. 28, 29, T. 48 N., R. 4 E., Coeur d'Alene, sec. 24, T. 48 N., R 3 E., Sunshine, sec. 15, T. 48 N., R. 3 E., Crescent, sec. 16, T. 48 N., R. 3 E., and Bunker Hill mines, secs. 1, 2, 11–14, T. 48 N., R. 2 E., and the abnormal radioactivity is at the Page mine, secs. 9, 10, T. 48 N., R. 2 E. (See fig. 1, A7–A2.) The uranium occurs over a known vertical extent of about 4,000 feet in a zone about 12 miles long that trends N. 70°–75° W. at a small angle to the major structure in the district, the Osburn fault. The ore deposits in the east part of the zone are silver and copper rich and contain a small amount of cobalt minerals. The western part of the zone is lead and zinc rich.

The pitchblende or uraninite is in veinlets which cut the St. Regis and Wallace formations of the Precambrian Belt series. The uranium minerals are not everywhere closely associated with the sulfide-bearing veins. The uranium-bearing veins are bordered by red hematite-stained zones apparently similar to the red alteration zones along uranium veins in the Goldfields region, Saskatchewan, Canada (Dawson, 1951).

Thurlow and Wright (1950), Robinson (1950), and Kerr and Robinson (1953) have described the uranium occurrences at the Sunshine mine; Thurlow and Wright (1950), that at the Coeur d'Alene mine; and H. D. Norman (written communications, 1953, 1954) has briefly described the occurrences at the Crescent, Galena, Page, and Bunker Hill mines.

CRESCENT MINE

In the Crescent mine (fig. 1, A4) pitchblende or uraninite occurs in two zones that are in and along the hanging wall of the Alhambra fault, where it is exposed in the main adit level, the Hooper tunnel. The Alhambra fault brings the Wallace formation in the footwall into contact with the St. Regis formation in the hanging wall. The uranium minerals occur within the fault in red iron oxide-stained zones of minutely fractured quartzite which is 1 to 2 feet thick. The fractures are filled with relict sericite, fine-grained pyrite, a black material (pitchblende?), chalcopyrite, a little tetrahedrite, calcite, and quartz, apparently in that paragenetic sequence.

The larger zone is 55 feet long and has been cut by a diamond-drill hole on the downward projection of the Alhambra fault 55 feet vertically below the Hooper tunnel level. The strike of this zone diverges slightly from the drift so that at its east end the zone goes into the south wall of the drift. Where the zone is reddest, on the south wall of the drift, it is most radioactive and yielded the highest uranium assay obtained in the mine, 0.633 percent U_3O_8 (H. D. Norman, written communication, 1953), which is more than three times the estimated average uranium content (0.19 percent U_3O_8) of the zone.

The smaller radioactive zone is about 200 feet east of the larger and is 1 foot thick and 10 feet long. It is similar in appearance to the larger zone except that it is less red and shows considerably less radioactivity. It was not sampled.

GALENA MINE

Pitchblende has been found at 5 places in the Galena mine (fig. 1, A7): 3 on the 3000 level and 2, the most radioactive, on the 2800 level (H. D. Norman, written communication, 1953). Only those occurrences on the 2800 level were examined by members of the reconnaissance project. They are in a crosscut and a drift approximately 1,000 feet apart.

In the crosscut about 35 feet into the hanging wall of the "B" strand of the Galena fault, a small bedding-plane fault in quartzite of the St. Regis formation strikes about N. 50° W. and dips about 70° NE., roughly parallel to the "B" strand. The direction and amount of displacement on the small fault is not known.

Irregularly distributed in the footwall of the bedding plane fault are discontinuous small fractures filled with quartz-pyrite-pitchblende veinlets that strike about east and dip 50°–80° S. Pitchblende and a little galena have been identified by Jerome Stone, using X-ray diffraction patterns from a sample from the largest of these veinlets. The veinlets range in thickness from a knife edge to 2½ inches, and the largest one exposed has maximum strike and dip lengths of 8 and 7 feet, respectively. They are thickest next to the fault and thin away from it. Adjacent to the veinlets the wallrock is stained red by introduced iron oxides. Along the largest veinlet (8 feet long, 7 feet wide, and as much as 2½ inches thick) the red alteration zone extends 6 inches into the hanging wall and as much as 12 inches into the footwall.

Two channel samples cut in the northwest wall of the crosscut along the largest veinlet, one where it is 2½ inches thick and one where it is 1½ inches thick assayed 0.33 and 0.39 percent uranium, respectively. A third sample was cut in the other wall, across a slightly red zone 10 inches thick that contained two ½-inch and two ¾-inch veinlets. This sample, assayed by Esma Campbell, contained 13.5 percent uranium and, on reassay, 11.5 percent uranium.

The attitude of the veinlets suggests that they may be filled tension fractures (feather joints) along the fault. If the veinlets occur in sufficient abundance, a narrow zone next to and in the footwall of the bedding plane fault, and perhaps the hanging wall also, may contain enough uranium to be ore.

The other uranium occurrence is in a zone of red quartzite in the St. Regis formation in the south wall of a drift along the Silver vein. The zone is about 12 inches thick and 6 feet long, and it contains pitchblende-bearing veinlets about ⅛ inch thick similar to those described above. The veinlets are cut off at one end by the Silver vein, and at the other end they pinch out. They are irregular and discontinuous, and locally pinch and swell. The largest swell measures 5 inches by 5 inches. A sample from this swell assayed 1.3 percent uranium. The occurrence is too small to be of commercial interest.

BONNER COUNTY

A prospect in sec. 21, T. 60 N., R. 1 E., near Naples, Bonner County (fig. 1, A1), is in weathered pyrrhotite-bearing quartz monzonite that is probably part of the Kaniksu batholith. The quartz monzonite is cut by joints and fractures that are filled or partly filled with clay, iron oxides, and ferruginous clay. The ferruginous clay in the joints is intensely radioactive in places, but although the material gave a positive fluoride bead test for uranium, no uranium minerals were recognized in hand specimens.

An explanation for the origin and distribution of the uranium in the fractures is suggested in a paper by Lovering (1955). He states that some uranium minerals are readily dissolved in acid water produced by the oxidation of sulfides. If the water is neutralized, iron, which is also in solution, will form hydrous iron oxides, which in turn probably adsorb uranium ions. In the deposit near Naples, the abundant clay in the fractures might enter into a base-exchange reaction with the acid water formed from the oxidized pyrrhotite. This reaction might in turn raise the pH of the water sufficiently to precipitate colloidal ferric hydroxide. The ferric hydroxide could then adsorb uranium released from the quartz monzonite by weathering. Deposits formed in this way are likely to be too small to have any economic value.

PEGMATITE OCCURRENCES

Although pegmatites are fairly numerous in Idaho, particularly around the margins of the Idaho and Kaniksu batholiths, only a few have been reported to contain radioactive minerals. Two such pegmatites were examined.

BONNER COUNTY

On the east side of Priest Lake, in sec. 30, T. 61 N., R. 3 W., Bonner County, autunite and a primary uranium mineral tentatively identified as uraninite occur as small, scattered grains in a pegmatite (fig. 1, C1). The pegmatite forms a pod about 10 feet in diameter in quartz monzonite(?) of the Kaniksu batholith.

LATAH COUNTY

Mica Mountain pegmatite (fig. 1, C2), which is in sec. 22, T. 41 N., R. 2 W., Latah County, contains crystals of a fluorescent uranium mineral scattered along a few widely spaced fractures. The crystals were identified as either autunite or meta-autunite, or both, by Robert S. Jones. Stoll (1950, p. 20) reported a similar occurrence of meta-torbernite at the Last Chance mine, also in sec. 22, T. 41, N., R. 2 W., but this deposit was not visited.

OTHER AREAS

Uranium minerals have been reported from pegmatites elsewhere in Idaho (Fryklund, 1951; Mackin and Schmidt, 1953; Cook, 1955), but none of the occurrences were seen. None of the pegmatites in Idaho are known to contain enough uranium to permit profitable mining.

MISCELLANEOUS OCCURRENCES—MOSQUITO BAY AREA

In the Mosquito Bay area, at the north end of Priest Lake in sec. 10, T. 62 N., R. 4 W., Boundary County (fig. 1, D1), unusually high radioactivity was noted in small, scattered patches in diorite(?) on a knoll about 50 by 75 feet in size. No uranium minerals were identified.

OTHER PROPERTIES EXAMINED

The following properties were examined but not found to show abnormal radioactivity.

- Divide Creek area, secs. 14 and 15, T. 16 N., R. 28 E., Lemhi County.
- The 111 claims, sec. 36, T. 19 N., R. 21 E.; sec. 30, T. 19 N., R. 22 E.; sec. 1, T. 18 N., R. 21 E.; sec. 6, T. 18 N., R. 22 E., Lemhi County.
- Delmar mine, sec. 3, T. 22 N., R. 21 E., Lemhi County.
- Pope-Shenon mine, secs. 16, 21, T. 20 N., R. 22 E., Lemhi County.
- Ima mine, secs. 14, 15, 22, 23, 24, T. 14 N., R. 23 E., Lemhi County.
- Apache mine, sec. 24, T. 2 N., R. 17 E., Blaine County.
- Heart Mountain area, sec. 27, T. 12 N., R. 31 E., Clark County.
- Wells chromite property, Custer County.
- Dewey property, sec. 14, T. 6 N., R. 19 E., Custer County.
- Chalspar mine, secs. 1 and 12, T. 13 N., R. 17 E.; sec. 3, T. 13 N., R. 18 E., Custer County.
- American Silver Mining Co. mine, sec. 24, T. 48 N., R. 3 E., Shoshone County.
- Northfork mine, sec. 2, T. 49 N., R. 4 E., Shoshone County.

MONTANA

VEINS AND VEINLIKE OCCURRENCES

ROYSE CLAIM

Abnormal radioactivity was reported by the U. S. Atomic Energy Commission (E. E. Thurlow and M. L. Reyner, written communication, 1951; D. L. Hetland, written communication, 1953) at the Royse property in sec. 34, T. 8 S., R. 20 E., Carbon County (fig. 1, A17).

The 54-foot adit, which was driven to explore the occurrence, was mapped in November 1953 by Armstrong and Weis. The adit exposes the gently dipping contact between the Precambrian gneiss and the overlying Flathead quartzite of Cambrian age. The Flathead quartzite is cut by several joints, which are filled with mud and dirt. Some of the material in the joints is intensely radioactive. The most radioactive joint strikes N. 74° W. and dips 80° N. It is about an inch wide and is exposed for about 6 feet.

Samples of the most radioactive material in the joint contained no visible uranium minerals. Chemical, radiometric, and spectrographic analyses of the samples showed that it was out of equilibrium; it contained only 0.08 percent uranium, together with as much radium as would be in equilibrium with 0.1 percent uranium.

The appearance of the material in the joint suggests that it and its associated radioactivity was derived from overlying rocks, rather than having formed from the surface alteration of a hydrothermal vein.

The abnormal radioactivity at the Royse property, and radioactive occurrences elsewhere in the Flathead quartzite along the east front of the Beartooth uplift (Stow, 1953), suggests an analogy to the uranium deposits in the Blind River-Quirke Lake area, Ontario. At Blind River fine-grained uraninite and brannerite are disseminated in the matrices of quartz-pebble conglomerate lenses in the Mississagi quartzite, the basal member of the Bruce series of Huronian age, which unconformably overlies Archean type rocks. The Mississagi has been folded since it was deposited. Granite of an unknown age that could be younger than the Bruce series crops out in the area (Abraham, 1953; Traill, 1954).

In several areas in Montana the basal Flathead quartzite of Cambrian age or the Neihart quartzite of Precambrian (Belt) age rest unconformably on Archean type rocks in areas of uplift that have been intruded by younger granites. The similarity of the geologic environment of these areas to that of the Blind River deposits empirically suggests that parts of Montana, as for example the Little Belt Mountains, are favorable areas to prospect for uranium.

CRYSTAL MOUNTAIN MINE

The Crystal Mountain fluorspar mine (fig. 1, A15) (Taber, 1952, 1953), is in secs. 17 and 18, T. 3 N., R. 18 W., Ravalli County, on the Retirement (sec. 17) and Lumberjack (sec. 18) groups of claims. As of the end of 1955 only the fluorspar deposits on the Lumberjack claims were being mined.

The Lumberjack claims are underlain by coarse-grained biotite granite, which contains inclusions of hornblende-plagioclase gneiss, biotite-quartz-plagioclase gneiss, and pegmatite granite. Foliation in the inclusions strikes about north and dips 20°–30° E. The granite contains three tabular bodies of coarsely crystalline purple, pale green, and white fluorite, known as the North, South, and East ore bodies. They are close together and before erosion may have formed one large, continuous body. The floors of the fluorite bodies strike north and dip gently east, about parallel to the foliation of the gneiss inclusions in the granite. Small dikes of granite cut the gneiss and fluorspar.

Some, but not all, of the dark purple fluorite is abnormally radioactive. Three different radioactive occurrences are recognized:

1. One of the principal impurities in the ore is biotite, and areas of biotite concentration are slightly radioactive, presumably due to inclusions of a radioactive mineral in the biotite. Halos of dark purple fluorite occur around the biotite crystals.

2. On the east side of the South ore body small dark-brown strongly radioactive euhedral to subhedral crystals, 5 millimeters or less in length, occur in coarsely crystalline light-colored fluorite. Around the crystals are halos of dark purple to black fluorite as much as half an inch thick. These crystals were identified by John W. Adams and Charles Spengler using an X-ray diffraction pattern, after heating and semiquantitative spectrographic analysis, as metamict fergusonite. The spectrographic analysis of the fergusonite shows:

	Percent
NB, Y	>10
Dy, Er, Fe, Si, Gd, Ta, Yb	1–10
Ho, Lu, U, Al, Ti, Ca, Th, Ba, Mn	.1–1

Also present in the fluorite in the area of fergusonite occurrence are numerous frosted somewhat rounded quartz crystals that have short prism zones and appear to be doubly terminated.

3. The most radioactive fluorite found at the deposit is a dark-purple layer 1 foot thick, which is exposed for a distance of 50 feet in the wall of a bulldozer cut near the north edge of the North ore body. The layer seems to parallel the floor of the enclosing tabular fluorite mass which strikes about north and dips about 20° E.

A 1-foot channel sample, which was cut across the layer, contained no recognizable uranium minerals but assayed 0.13 percent equivalent uranium and 0.078 percent chemical uranium. Although the reason for the difference between chemical and radiometric uranium analyses in the Crystal Mountain fluorite sample is not known, it is suspected that some of the radioactivity is due to thorium. The presence of fergusonite, which contains both uranium and thorium, in another part of the mine appears to support this suggestion. A similar radioactive fluorite from the Blue Jay mine, in Colorado, was found to contain uranothorite of hydrothermal origin (Phair and Onoda, 1951). It would appear that thorium is not an uncommon associate of fluorite in some deposits.

The fluorite occurrence in the Retirement claims is similar to that on the Lumberjack claims. Most of the fluorite, however, is not radioactive and only very little of the dark-purple fluorite is slightly radioactive.

The radioactive occurrences examined at the Crystal Mountain fluorite deposits are too small and too low grade to be an economic source of uranium or thorium.

WATERHOLE CLAIMS

East of the Coeur d'Alene district, on the Waterhole claims near Saltese (fig. 1, A14) in sec. 18, T. 19 N., R. 30 W., Mineral County, autunite occurs in the fractures of a shear zone which cuts quartzite of the Belt series of Precambrian age. Although an exploration program financed by the U. S. Atomic Energy Commission did not develop ore at this property, the presence of uranium-bearing minerals in that area may be significant when related to the position of pitchblende in zoned mineral districts as developed by Leonard and others (Leonard, written communication, 1952; Leonard, 1952; S. R. Wallace, and others, written communication, 1955).

Leonard has shown that in the Front Range of Colorado, particularly the Central City district, pitchblende occurs in a zone transitional from an area of pyrite-gold deposits to an area of lead-silver-zinc deposits, and that the position of copper deposits in this zoned sequence is the same as that of pitchblende.

Reconnaissance mapping of a large area around Saltese in western Mineral County has shown a crude metal zoning that trends northwest roughly parallel to the Osburn fault (Wallace and Hosterman, 1956). Near this fault, which passes about 2 to 3 miles north of Saltese, are lead-zinc deposits that contain silver-bearing tetrahedrite and chalcopyrite and are much like the uranium-bearing deposits of the Coeur d'Alene district. About 6 miles south of Saltese is a northwest-trending zone of deposits in which the principal ore mineral is chalcopyrite; and south of the chalcopyrite deposits the Buffalo, Deer Creek, and Aladdin prospects suggest a third zone characterized by gold-bearing quartz-pyrite-chalcopyrite veins. In this zonal arrangement the uranium at the Waterhole claims is between the lead-zinc and chalcopyrite-rich deposits, but closer to the lead-zinc deposits.

In an area as geologically complex as western Mineral County, it is not likely that the spatial relation of metals is the sole or best prospecting guide. In the absence of other guides, however, and on the basis of the location of the Waterhole claims and the position of some pitchblende deposits in zoned mineral districts as demonstrated by Leonard, it is suggested that the chalcopyrite-bearing veins and the area between the lead-zinc veins and the chalcopyrite-bearing veins are the most favorable parts of the area to prospect for uranium.

NORWICH-PLUTUS MINE

At the Norwich-Plutus mine (fig. 1, A16), secs. 10, 15, T. 3 N., R. 8 W., near Butte, Silver Bow County, a rhodochrosite vein on the 300 level shows slight abnormal radioactivity.

OCCURRENCES IN RHYOLITE

Autunite has been recognized in rhyolite dikes that cut quartz monzonite or grandiorite of the Idaho batholith near Trapper Peak, sec. 22, T. 2 N., R. 21 W., Ravalli County (fig. 1, E1). The autunite occurs as small, widely scattered flakes on the walls of fractures and joints in weathered, hydrothermally altered rhyolite. The distribution of the autunite suggests that it may have formed through precipitation from ground water which dissolved the uranium from overlying altered and weathered rhyolite.

MISCELLANEOUS OCCURRENCES

DG CLAIMS

Abnormal radioactivity was found on the DG No. 1, 2, and 3 claims, sec. 9, T. 7 N., R. 12 E., Granite County (fig. 1, D2). On this property, granite has intruded marble and graphitic schist. The granite is suronded by a halo of skarn rocks that formed as a result of contact metamorphism. Magnetite-epidote-garnet rock shows moderately high radioactivity in a few places, as does some of the graphitic schist and the magnetite-calcite rock. No uranium minerals have been recognized and no commercial-grade ore has been found.

MELROSE AREA

Several breccia pipes in limestone east and southeast of Melrose, Madison County (fig. 1, D3), contain heavily iron-stained gossan capping. Locally, small areas of the gossan are abnormally radioactive. No radioactive minerals have been identified.

CENTRAL MONTANA AS A POSSIBLE SOURCE OF URANIUM

The geology of central Montana is strikingly similar to that of the Colorado Plateau. On the Colorado Plateau, Tertiary stocks, laccoliths, and other bodies have intruded a thick sequence of sedimentary rocks (Hunt and others, 1953). Soda-rich syenites and andesites are exposed in the LaSal, Henry, Abajo, Carrizo, and Ute Mountains. Dikes and volcanic rocks of the Four Corners area of the Colorado Plateau are subsilicic, potash-rich varieties such as nepheline syenite, shonkinite (melanocratic syenite with alkaline affinities), leucite basalt, and minette (syenitic lamprophyre). The sedimentary rocks are mostly of continental origin and range in age from Pennsylvanian to late Tertiary. Uranium ore deposits have been found in rocks of Permian through Late Cretaceous age. The most consistently favorable host rock is continental sandstone that contains interlayered thin beds of shale. Organic matter in the sedimentary rocks has been an important factor in localizing some uranium deposits.

In central Montana a suite of Tertiary granitic and alkalic igneous rocks similar to, though more potassic than, those on the Colorado

Plateau, intrude interbedded marine and continental sedimentary rocks of varied lithology that range from Precambrian to Late Cretaceous in age. The igneous rocks are granites, syenites, quartz syenites, syenite porphyries, shonkinites, and trachyte and phonolite porphyries (fine-grained equivalents of syenite and nepheline syenite, respectively) that have formed laccoliths, stocks, sills, dikes, and flows (Larsen, 1940; Lyons, 1944). Many of the sedimentary rocks are continental sandstones that contain interlayered shales and abundant organic remains. In central and west-central Montana many of the formations change from marine on the east to nonmarine on the west. This change in environment of deposition causes a further interlayering of sandstones and shales by the intertonguing of marine shales and nonmarine sandstones and shales.

If the uranium deposits of the Colorado Plateau are in some way genetically related to the rather unusual suite of igneous rocks on the Colorado Plateau, as thought probable by some geologists (McKelvey and others, 1955), then the sedimentary rocks intruded by similar igneous rocks in Montana may contain plateau-type uranium deposits (Armstrong, 1957a).

WASHINGTON

Until 1954 only a few widely scattered occurrences of uranium minerals were known in the State of Washington, and none of them appeared to contain enough uranium ore of minable grade to permit profitable mining. Since 1954, however, many new deposits and occurrences have been discovered, and a few contain an appreciable tonnage of ore.

Uranium occurrences known in Washington are veins and veinlike occurrences, occurrences in carbonate rocks, pegmatites, occurrences in conglomerates, and disseminated uranium minerals in granite. All are either in or very close to granitic rocks.

Although the Midnite mine and the Lowley lease, which are discussed below under veins and veinlike deposits, do not clearly belong under this classification, the deposits of uranium minerals at the two properties do resemble veins in that they occur along fractures, joints, and shears. For that reason, and for the sake of convenience, the two properties are considered along with the other veinlike deposits in northeastern Washington.

VEINS AND VEINLIKE OCCURRENCES

SPOKANE INDIAN RESERVATION AREA

MIDNITE MINE

The Midnite mine (fig. 2, A1), discovered in 1954, is in secs. 1, 2, 11, and 12, T. 28 N., R. 37 E., on the Spokane Indian Reservation, Stevens County. As of July 1, 1955, it was the only mine in the State from which uranium ore had been produced. It was reported that 700 tons of ore averaging 0.285 percent U_3O_8 had been shipped and that reserves of more than 100,000 tons of ore were indicated by preliminary exploration (Conrad, 1955).

The mineralized area is partly underlain by argillite and schistose phyllite of Precambrian age (Bennett, 1941) that strikes about N. 10° E. and dips 50°—60° E. These rocks occupy approximately the east half of the Midnite mine property. They have been intruded by porphyritic quartz monzonite of Cretaceous(?) age, which underlies about the west half of the Midnite mine property. In those parts of the quartz monzonite immediately adjacent to uranium ore the quartz is smoky to black in color. The igneous rocks and, to a somewhat lesser extent, the metamorphic rocks have been moderately to intensely weathered to depths of 10 feet or more.

The contact between the quartz monzonite and the metamorphic rock trends N. 10° E. and dips 60° E. across most of the Midnite mine property, a distance of about 2 miles. Although the average strike and dip of the contact is about parallel to the foliation in the metamorphic rock, in detail the contact is extremely irregular. Considerable shearing and brecciation are present in the metamorphic rock within a few feet of the quartz monzonite, but no large, throughgoing fault has been recognized.

The uranium minerals recognized at the Midnite mine, in approximate order of abundance, are meta-autunite, uranophane, liebigite, torbernite, and uraninite. Only meta-autunite and uranophane are abundant. Uraninite was recognized in a section of a diamond-drill core by the U. S. Atomic Energy Commission (D. L. Hetland, oral communication, 1955). All other uranium minerals were found near the surface. Pyrite, chalcopyrite, and molybdenite are present, but all are rare in present exposures.

The uranium minerals are distributed in discontinuous zones for more than a mile along the contact between the igneous and metamorphic rock. The uranium minerals are found in both rock types, but most of the ore-grade material is in metamorphic rock. In mineralized zones uranium minerals occur in all available openings; joints and fault surfaces are commonly coated with meta-autunite and uranophane. Meta-autunite is also found along grain boundaries in quartz monzonite. The distribution of uranium suggests that the contact of the quartz monzonite and schistose phyllite has influenced the localization of ore.

LOWLEY LEASE

Seven miles due south of the Midnite mine, in the SW¼ sec. 13, T. 27 N., R. 37 E., is a second occurrence of uranium along a quartz monzonite contact (fig. 2, A3). Here, granite similar to that at the Midnite mine has introduded quartzitic schist. Along the contact a coarse-grained, nearly pure anthophyllite rock contains scattered grains of uranophane on grain boundaries and joint surfaces. The occurrence is exposed over a strike length of only a few feet in one side of a narrow gulch, and no radioactivity has been found elsewhere in the immediate area. The potential of the deposit is unknown.

SPOKANE MOLYBDENUM MINE

The Spokane Molybdenum mine, in the SE¼ sec. 32, T. 28 N., R. 37 E., Lincoln County (fig. 2, A2), is near the southwest margin of the Loon Lake granite of Weaver (1920). In a drift on the lowest adit at this property uraninite and metatorbernite with sparse pyrite, molybdenite, and chalcopyrite occur in a quartz vein in altered granite. The vein is 3 to 4 inches thick and is exposed along the strike and the dip for 9 and 7 feet, respectively. A sample from the most radioactive part of the vein contained 0.53 percent uranium, but present exposures suggest that the vein is too small to be an economic source of uranium ore.

ELK-MOUNT SPOKANE AREA

An area of approximately 20 square miles, which is about 5 miles west of Mount Spokane and about 6 miles southeast of the town of Elk, in Spokane County (fig. 2, A4), contains a number of uranium occurrences that are different in mineralogy and crystal size from any known elsewhere in the United States. The first discovery was made in February 1955 on the Alfred Dahl ranch. By July 1955, 7 similar occurrences had been found within a radius of about 4 miles. All seem to be the same type as the original discovery.

DAYBREAK MINE

The Daybreak mine in the NE¼ sec. 11, T. 28 N., R. 44 E., is the site of the original discovery of uranium in Spokane County.

Granite and quartz monzonite of Cretaceous(?) age underlie the area. At the Daybreak mine and for several miles in all directions, the granite contains small simple segregation-type pegmatites that locally may make up about 25 percent of the rock. The granite is jointed and is cut by a few faults. Soil cover ranges from a few inches to more than 5 feet in thickness, and the underlying rock is weathered to an additional depth of 10 feet or more. Soil and vegetation make it difficult to recognize and trace faults at the surface.

Bulldozing at the Daybreak mine has exposed the granite in an area about 200 feet wide and 300 feet long. In the deepest exposure, which is about 20 feet below the former surface, the granite is cut by a shear zone at least 6 feet thick that strikes east and dips 25°–35° N. Brecciated granite in the shear zone is locally intensely kaolinized and sericitized. This zone is intersected by a second kaolinized shear zone that is poorly exposed but appears to strike about N. 60° E.; the dip is not known. Diamond drilling at the property by the U. S. Atomic Energy Commission has revealed sheared and altered granite at depths of 40 to 200 feet (H. D. Norman, oral communication, 1954).

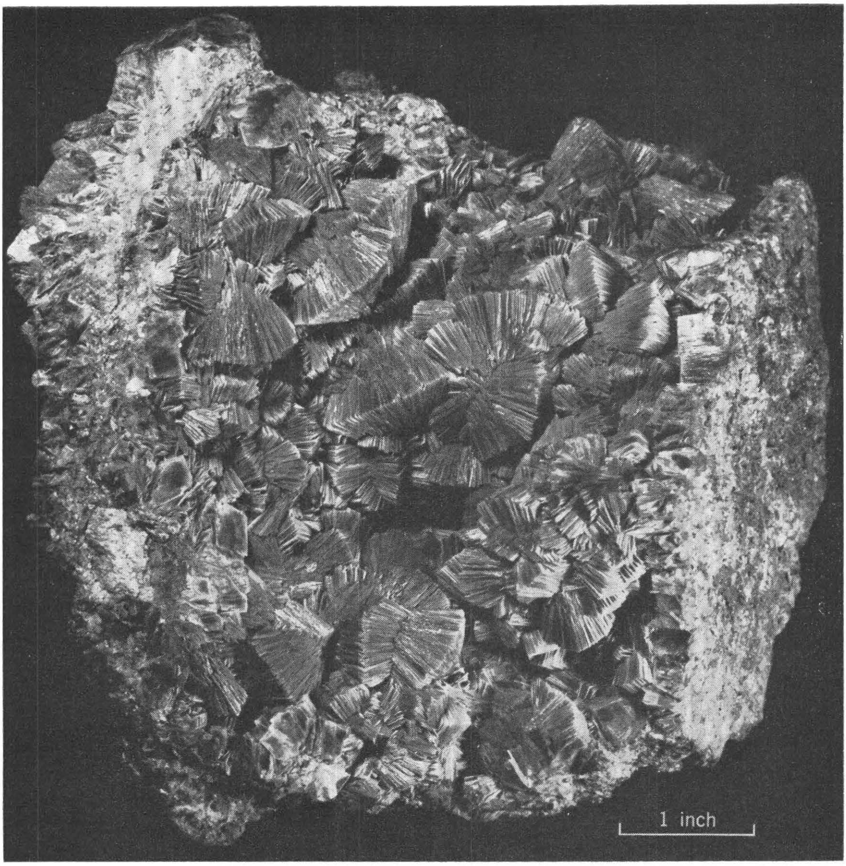
The mineral assemblage at the deposit is simple. Meta-autunite is the only uranium mineral present. Sericitized and kaolinized granite in and near the shear zones may be due to hydrothermal alteration, but no sulfides, or common gangue minerals such as carbonates or quartz, or any other minerals generally associated with hydrothermal deposits, have been found.

The deposit has been the source of some of the most spectacular meta-autunite crystals known (pl. 2). Crystals 2 inches in diameter have been found, and crystals ¼ to 1 inch in diameter are common. When fresh, the crystals are deep emerald green to lime green, locally grading to greenish yellow, but upon exposure to the air for several weeks some of the specimens lose their deep-green color and fade to a pale yellow green. All color varieties fluoresce brilliantly under ultraviolet light.

The meta-autunite typically occurs as an incomplete filling of all available open spaces in the uranium-bearing zones, forming vuggy masses with many well-developed crystal groups. Deposition of the meta-autunite appears to have taken place solely by open-space filling; no evidence of replacement has been seen. In places kaolinized gouge partly fills the cavities and coats the meta-autunite crystals.

Uranium ore is confined to the vicinity of the shears at the Daybreak mine. The greatest concentration is at the intersection of the two shear zones, where a pod of nearly pure meta-autunite at least 5 feet long, 4 feet wide, and 1 foot thick was found. Meta-autunite is also irregularly distributed along the hanging wall of the east-trending shear zone, where it is found along joints, fractures, and grain boundaries in both the brecciated and unbrecciated granite. Ore-grade material was also found in 1 diamond-drill hole at a depth of 92 feet. At the surface the mineralized zone is a few inches to several feet thick. Many joints that contain meta-autunite near the footwall of the shear contain none a few feet away. The meta-autunite appears restricted to certain zones whether or not open spaces were present elsewhere.

It is not known whether the meta-autunite was formed from hydrothermal or ground-water solutions. Although hydrothermal alteration is suspected because of the zones of kaolinization and sericitization, much of the altered rock contains no uranium ore, and a considerable amount of uranium ore is in unaltered rock.



META-AUTUNITE FROM THE DAYBREAK MINE, SPOKANE COUNTY, WASHINGTON. PHOTOGRAPHED UNDER ULTRAVIOLET LIGHT; SPECIMEN IS ILLUMINATED BY ITS OWN FLUORESCENCE.

OTHER OCCURRENCES

Other occurrences of coarse meta-autunite are known at the Dahl Uranium mine, in the SE¼ sec. 1, T. 28 N., R. 44 E., and the SW¼ sec. 6, T. 28 N., R. 45 E., the Morning Sun property in sec. 12, T. 28 N., R. 44 E., the Kit Carson property, in sec. 13, T. 28 N., R. 44 E., and on Washington State Park land in secs. 21 and 32, T. 28 N., R. 45 E. (fig. 2, A4). All contain coarsely crystalline meta-autunite in fractures and openings in weathered granite. As of July 1, 1955, none were well enough exposed to establish their extent, and none showed any recognizable rock alteration except normal surface weathering. Except for the absence of zones of kaolinization and sericitization, all features described at the Daybreak mine are also characteristic of all the other known occurrences in the area. Additional occurrences in the area are likely.

RADIOACTIVE SPRINGS

A number of springs showing unusually intense radioactivity are present in the vicinity of the uranium occurrences in Spokane County. Samples were taken from 4 springs and 6 creeks, to determine whether the water in this general area contained unusual amounts of uranium. All of the springs and one of the creeks were sampled twice.

Uranium content and acidity of water samples from the Elk area, Spokane County, Wash.

[P. F. Fix, written communication]

Location	Sample	Source	Date sampled	Uranium content (parts per billion)	pH
			1955		
NE¼SE¼ sec. 1, T. 28 N., R. 44 E.	1910-213	Creek	June 5	2.7	5.0
SW¼NE¼ sec. 1, T. 28 N., R. 44 E.	214	do	do	3.8	4.5
NW¼SE¼ sec. 1, T. 28 N., R. 44 E.	215	do	do	1.2	4.75
SW¼ sec. 36, T. 29 N., R. 44 E.	216	do	do	3.1	4.75
NW¼ sec. 11, T. 28 N., R. 44 E.	152	Spring	Apr. 19	5.7	6.3
	[1] 209	do	June 5	10.0	5.25
NW¼NW¼ sec. 12, T. 28 N., R. 44 E.	153	do	Apr. 19	5.8	5.3
	[1] 211	do	June 5	12.0	4.25
NE¼NW¼ sec. 12, T. 28 N., R. 44 E.	154	do	Apr. 19	7.2	5.3
	[1] 212	do	June 5	210.0	4.5
	155	Creek	Apr. 19	3.8	
	[1] 210	do	June 5	6.3	
NW¼ sec. 3, T. 27 N., R. 44 E.	217	do	do	1.8	4.5
NE¼ sec. 2, T. 27 N., R. 44 E.	W-1	Spring	Mar. 29	210.0	5.3
	[1] 1910-208	do	June 4	45.0	

[1] Resampling.

Most spring and surface water contains less than 0.5 ppb (parts per billion) uranium (P. F. Fix, oral communication, 1955). All the samples from Spokane County contained much larger amounts of uranium, and the range of uranium content in the samples requires some comment. Two factors that have an important bearing on the interpretation of the analyses in table 1 are acidity of the water and amount of uranium available for solution. The acidity of the water sampled in the Elk area ranged from a pH of 4.25 to 6.3, or from moderately to weakly acid. However, the uranium content of the water does not appear directly related to its acidity in all cases: samples 1910–153 and W–1, with the same acidity (pH 5.3), contained 5.8 and 210 ppb uranium, respectively.

The amount of uranium available for solution appears to be highly variable. The area is underlain by granite, quartz monzonite, and locally pegmatites, but the rocks as a whole have relatively uniform composition. Variations in uranium available for solution therefore must be related in some measure to differences in concentrations of uranium minerals other than those commonly present in the granite drained by the streams and springs of the area. The uranium content of the water may therefore be of some value in outlining areas for further prospecting.

Uraium analyses of natural water are not in themselves infallible guides to ore deposits. Examples are samples 1910–152 and 1910–209, which were collected from a spring flowing from the base of the low hill 250 feet below the opencut of the Daybreak mine, largest and richest mine in the area. These samples contained 5.7 and 10.0 ppb uranium, respectively, amounts that are of the same order of magnitude as many other samples taken in the area. None of the other samples listed in table 1 represent drainage from known uranium ore bodies, and some are from areas that have been intensively prospected by bulldozing and drilling. However, if results of water analyses are interpreted with caution, the method may prove useful in places such as the Elk area, where soil and vegetation make it difficult to prospect with a Geiger or scintillation counter.

ORIGIN OF THE URANIUM

The coarsely crystalline meta-autunite deposits of the Elk area are sufficiently unusual to give rise to considerable speculation regarding their origin. Possible origins suggested are:

1. Deposition of meta-autunite from ground-water solutions that leached the uranium from overlying, essentially normal granite.

2. (*a*) Alteration in place of a primary uranium ore body.

(*b*) Transportation and redeposition of primary uranium ore by ground-water solutions.

3. Depostion of primary hydrothermal meta-autunite.

Evidence supporting the various hypotheses above is contradictory or inconclusive. Features supporting hypothesis 1 or 2 (*b*) are: No sulfides or pseudomorphs after sulfides have been found; no carbonates, quartz, or other typical hydrothermal gangue minerals, or pseudomorphs after them have been recognized. The only exception is the presence of kaolinite and sericite of possible hydrothermal origin at the Daybreak mine—a feature not necessarily related to the uranium. In addition, meta-autunite itself is generally considered to be exclusively of secondary origin (Palache and others, 1951, p. 986).

Features that appear to favor either hypothesis 2 (*a*) or 3 are: The scarcity of similar deposits in weathered granite elsewhere, and the association of uranium ore with faults and zones that may have been hydrothermally altered, as is typical of many hydrothermal deposits.

Features favoring hypothesis 3 are: Large high-grade pods of unusually coarse meta-autunite crystals, which are not typical of deposits elsewhere that contain meta-autunite of unquestionably secondary origin, and the presence of only one uranium mineral in the deposit. Uranium deposits in the Boulder batholith, Montana, are very similar in geologic, topographic, and climatic environment to the deposits in the Elk area. Secondary uranium minerals in the Boulder batholith deposits include meta-autunite I, metatorbernite, uranophane, and beta-uranophane (Wright and others, 1954, p. 70). Although their relative abundance might vary from deposit to deposit, a variety of secondary uranium minerals might be expected as a result of surface alteration of pitchblende deposits in the quartz monzonite of the Elk area.

Hypotheses 1, 2 (*a*), and 2 (*b*) could apply only if the meta-autunite deposits were of relatively recent origin. Deposits formed by hydrothermal solutions (hypothesis 3) might also be recent but would not have to be. If the meta-autunite is relatively old, hypotheses 1, 2 (*a*), and 2 (*b*) could be eliminated.

Two meta-autunite samples from the Daybreak mine were analyzed by Esma Campbell for chemical-uranium content and radioactivity. The ratio between chemical-uranium content and radioactivity of 1 sample corresponded to an age of 500,000 years; in the other sample, an age of 90,000 years. The difference in the apparent ages of these two samples confirms the expected conclusion that the meta-autunite has not remained in a closed system since its deposition, and that analyses such as these will not provide an accurate measure of the age of the deposits. Considerable additional work will be necessary before the age and origin of the deposits is established.

LEONARD'S ZONING HYPOTHESIS APPLIED TO NORTHEASTERN WASHINGTON

In some zoned mineral districts primary uranium minerals occur in a zone intermediate between pyrite-gold centers and lead-zinc-silver peripheries, commonly in association with primary copper minerals (B. F. Leonard, written communication, 1952: Leonard, 1952; R. E. Wallace, B. F. Leonard, and R. H. Campbell, written communications, 1955). Thus, the hypothesis of the position of uranium in zoned mineral districts as developed by Leonard may be an aid to prospecting for uranium in northeastern Washington.

In 1952, when the only known uranium occurrence in northeastern Washington was that in the Spokane Molybdenum mine, Leonard and Campbell,[1] working solely from the literature, noted that "in southern Stevens County there is a vague suggestion of a zonal pattern with respect to the Loon Lake granite," and suggested that reconnaissance for uranium be done in southern Stevens County. To more sharply define the area in which reconnaissance should be done they suggested that "the central portions of batholithic exposures" are probably "unfavorable for the deposition of pitchblende," and that "those mines which have shown a high copper content in their ores" be examined first. They pointed out that "the zonal pattern, if valid as recognized, is greatly complicated by the complex shape of the batholith roof" and that "it would be difficult, if not impossible, to choose a 'zone' for intensive radiometric reconnaissance." Leonard and Campbell also recognized a "faint zoning" in the Covada Mining District, Ferry County, where silver occurs "in the metasediments near the margins of the grandiorite intrusive" and "those mines from which gold values are of primary importance lie within the central area of the granodiorite area."

In an area where primary uranium minerals have been found, the zoning concept, in the absence of or in conjunction with other guides to prospecting, may help to outline the area to be intensively prospected and suggest areas to be prospected first.

NORTHERN CASCADE MOUNTAINS AREA

Uranium minerals or usually intense radioactivity have been recognized at three places in the Northern Cascade Mountains and have been reported from others. None of the known occurrences appear large enough for production of ore.

The Holden mine (fig. 2, A6) is in the northeast part of the Holden quadrangle, Chelan County. Abnormal radioactivity is associated with biotite, chalcopyrite, and pyrrhotite in the western part of the 2,500 level (F. W. Cater, Jr., oral communication, 1956). Uranium minerals have not been identified.

The Keefer claims (fig. 2, A7) are on the north and west side of Red Mountain in the north-central part of the Chelan quadrangle. At the Ambassador, Midnite, and Mohawk claims, uraninite is reported to occur associated with tourmaline, chalcopyrite, pyrrhotite, and

[1] The quoted material is from notes prepared by B. F. Leonard and R. H. Campbell in the winter of 1952 in anticipation of doing reconnaissance for uranium in selected zoned mineral districts in the summer of 1952. Plans were changed, and they did not do the reconnaissance.

arsenopyrite in a vuggy intrusive breccia in granodiorite (R. D. Elliot, written communication, February 1954; F. W. Cater, Jr., and D. F. Crowder, oral communication, February 1956).

At the Western States Copper Co. mine, sec. 16, T. 24 N., R. 10 E., King County (fig. 2, A8), brecciated granodiorite has been cemented by quartz, pyrite, and chalcopyrite. Small intensely radioactive crystals of brannerite have been found in the quartz in a few places (W. P. Puffett, written communication, 1953).

The Bumping Lake area, in secs. 3, 10, and 15, T. 15 N., R. 12 E., Yakima County (fig. 2, F1), is underlain by Snoqualmie granodiorite, locally cut by feldspar porphyry and quartz porphyry dikes (Hobbs, 1942). Uranium, in an unidentified form, has been found in plant remains and soil at the surface of the ground. The origin of the uranium is unknown. Although one sample contained 0.80 percent uranium (D. F. Kellum, oral communication, 1955), the deposit does not contain enough uranium to permit profitable mining.

A uranium sample reportedly from the Castle Peak area, Whatcom County (fig. 2, A5), was submitted to the Geological Survey. The sample is grayish-buff medium-grained somewhat alkalic granite, containing black veinlets ¼ to ½ inch thick. The veinlets are made up entirely of uraninite and coffinite.

The Castle Peak stock is described by Daly (1913, p. 493) as a granodiorite. However, no other igneous rocks are known near Castle Peak, and the possibility of finding granitic differentiates in the granodiorite appeared good. Weis and Rosenblum visited the area, but found no granite and no uranium mineralization. During the visit, water samples were collected from streams draining the Castle Peak stock. Samples from Route Creek and Crow Creek, near the east edge of the stock contained slightly more than 0.2 ppb uranium; no other water samples contained more than 0.15 ppb uranium (P. F. Fix, written communication). The significance of these analyses is not known.

PEGMATITE OCCURRENCES

A large part of northeastern Washington is underlain by granitic rocks. Along the borders of the granites, in both the igneous rocks and the older rocks surrounding them, are numerous pegmatites. Many of the pegmatites contain small scattered crystals of uranium-bearing minerals, and these occurrences, although below commercial grade, have stimulated prospecting in the area. Eight pegmatites were examined in the field.

KETTLE FALLS AREA

Two pegmatites in the Kettle Falls area, Ferry County, were examined: the Hurrell claim, and the Box Canyon claim.

Hurrell claim.—Mr. John Hurrell, of Inchelium, Wash., discovered a pegmatite in sec. 21, T. 36 N., R. 37 E., Ferry County (fig. 2, B2), which contains a few small areas of unusually high radioactivity. The most radioactive parts are associated with garnet. No radioactive minerals have been identified from this pegmatite.

Box Canyon claim.—The Box Canyon claim is in sec. 28, T. 37 N., R. 37 E., Ferry County (fig. 2, B2). Rocks in the area are quartzites and biotite and chlorite schists. Locally, the biotite shows abnormal radioactivity. No uranium minerals were recognized.

SHERMAN PASS AREA

Three pegmatites near Sherman Pass, Ferry County, were examined. They are the Lemvig, Rosalie, and Autunite claims.

Lemvig claim.—A small pegmatite that locally is unusually radioactive is exposed at the Lemvig claim, about 3 miles southeast of Sherman Pass (fig. 2, B1). The minerals responsible for the radioactivity were not identified. This deposit contains a fluorescent, nonradioactive mineral that was suspected to contain uranium, but chemical analyses showed that it was not uranium bearing. It was not identified.

Rosalie claims.—Abnormal radioactivity associated with biotite pods in a granite pegmatite was found on the Rosalie claims, in an unsurveyed part of Ferry County about 1½ miles east of Sherman Pass (fig. 2, B1). Jerome Stone found that the mineral produced X-ray diffraction patterns that identify the radioactive mineral as monazite.

Autunite group.—The Autunite group of claims, about 1 mile west of the Rosalie claims, near Sherman Pass (fig. 2, B1), is underlain by granite pegmatite that is locally intensely radioactive. Some of the radioactivity is associated with biotite segregations as at the Rosalie claims, and some is in a biotite-poor part of the pegmatite. The radioactive minerals were not identified. Fluorescent opal, which is abundant at this pegmatite, was at first mistaken for autunite by prospectors. The opal is not radioactive, however, and it contains no uranium.

ORIENT AREA

Two pegmatites near Orient, Ferry County, were examined. They are at the Doren claim and the AA No. 2 claim.

Doren claim.—A property in sec. 6, T. 38 N., R. 37 E., Ferry County (fig. 2, B3), is owned by Mr. Martin Doren, of Bellingham, Wash. The claim is underlain by granite and pegmatite that is cut by a few small quartz veins. The pegmatite shows local high radioactivity, but no uranium minerals were recognized.

AA No. 2 claim.—The AA No. 2 claim is in sec. 26, T. 40 N., R. 36 E., Stevens County (fig. 2, B3). A few intensely radioactive black heavy crystals, tentatively identified as samarskite, have been found at this pegmatite. The black crystals are one-quarter inch or less in diameter and make up only a very small percentage of the pegmatite. Scattered yellow autunite flakes are found around some of the black crystals.

OTHER AREAS

Merikay pegmatite (*Railway dike*).—The Railway dike, in sec. 33, T. 34 N., R. 42 E., Stevens County (fig. 2, B4), has been explored for beryl under a Defense Minerals Exploration Administration contract. The pegmatite locally shows intense radioactivity. One radioactive specimen of pegmatite contained uranium-bearing columbite.

OCCURRENCES IN CARBONATE ROCKS

Abnormal radioactivity has been reported in limestones and marbles from several places in northeastern Washington, but only one was examined in the field. None are known to contain enough uranium to permit profitable mining. The prospect examined is owned by Stuart Mayo, of Tonasket, Wash., and is about 10 miles east of Republic (fig. 2, C1). At this locality, granite intrudes metasedimentary rocks of many types. A coarse white to dark-greenish-gray marble about 20 feet thick is exposed adjacent to and in an adit driven into the hill for about 15 feet. Locally, the darker facies of the marble are highly radioactive. One sample of the most radioactive rock contained 0.20 percent equivalent uranium and 0.22 percent chemical uranium. Analytical work by Jerome Stone disclosed that the uranium is associated with epidote in the marble.

OCCURRENCES IN CONGLOMERATE

Uranium minerals have been found on the De Chenne claim, sec. 6, T. 34 N., R. 44 E., Pend Oreille County (fig. 2, D1). The property is underlain by conglomerate that is probably a part of the Tiger formation of Tertiary age (Park and Cannon, 1943, p. 23). The conglomerate consists of pebbles and cobbles of argillite, limestone, granite, schist, and quartzite, in a somewhat arkosic iron-stained clayey-sand matrix. It crops out over an area of about 300 by 600 feet and is probably less than 100 feet thick.

Five small hand-dug prospect pits expose the uranium minerals, which form thin coatings and interstitial material in the fine-grained matrix of the conglomerate. Autunite is the only uranium mineral positivey identified, but uranophane may also be present. The distribution of uranium minerals at the deposit is sparse and spotty. Although the deposit probably does not contain enough uranium to warrant mining, the presence of uranium minerals in this formation suggests that other Tertiary sedimentary rocks in northeastern Washington merit investigation.

A conglomerate on the Spokane Indian Reservation in sec. 16, T. 28 N., R. 38 E., Stevens County (fig. 2, D2), is cemented by manganese oxides. The rock has been examined by the Mining Experiment Station, Washington State Institute of Technology, Division of Industrial Research, State College of Washington, at Pullman. At the Experiment Station, in the course of beneficiation experiments to recover the manganese oxides, unusual radioactivity was noted in some of the material (James Crosby, oral communication, 1955). No radioactive minerals have been identified.

DISSEMINATED URANIUM MINERALS IN GRANITE

A prospect in secs. 18 and 19, T. 35 N., R. 46 E., Pend Oreille County (fig. 2, E1), contains fine-grained autunite as fracture fillings and impregnations in granite. The occurrence is exposed in a bulldozer cut at the top of a small knoll. The autunite is in a zone about 2 inches thick just below the soil, and its distribution suggests that it may have formed by residual concentration. No other radioactive minerals are known in this area.

OTHER PROPERTIES

Other properties in Washington visited by the authors and on which no unusual radioactivity was found are:

- Hidden Treasure mine, secs. 7–10, T. 16 N., R. 11 E., Yakima County.
- Consolidated Mining & Smelting Co., secs. 5, 6, T. 29 N., R. 33 E., Ferry County.
- Hallett claim, sec. 24, T. 27 N., R. 36 E., Lincoln County.
- Smith claim, 3 miles west of Tonasket, Okanogan County.
- Germania mine, sec. 13, T. 29 N., R. 37 E., Stevens County.
- Columbia Tungsten mine, sec. 30, T. 32 N., R. 38 E., Stevens County.
- Magnetic, Roosevelt, Neutral claims, Buckhorn Mountain mining district, Okanogan County (diamond-drill cores only).

THORIUM-BEARING LODE OCCURRENCES

Although the principal radioactive element sought in the reconnaissance work was uranium, the use of radiation-detection instruments for prospecting made it inevitable that thorium-bearing material would also be found.

Thorium is almost 3 times as abundant as uranium in the earth's crust (Rankama, 1954, p. 135), but its chemistry is such that only 2 thorium-bearing minerals can be termed common. They are the silicate, thorite ($ThSiO_4$), and the thorium-bearing rare-earth phosphate, monazite [(Ce, La, Th) PO_4]. Thorite is typically a vein mineral, although it may also be found as an accessory mineral in granite or pegmatite; monazite is commonly an accessory mineral in granite or pegmatite, although it also occurs in veinlike deposits. Both thorite and monazite are resistant to weathering and abrasion, and may therefore be found in placer deposits. Known large high-grade thorite deposits are not as numerous as large high-grade uranium deposits. Practically all of the thorium produced was recovered as a byproduct from the extraction of rare earths from monazite.

Unlike uranium, there is no guaranteed price for thorium, which makes it difficult to set a precise limit on the minimum thorium content necessary for a deposit to be termed of ore grade.

IDAHO—BOUNDARY COUNTY

Thorite deposits of considerable size have recently been found near Porthill, Boundary County, Idaho, about a mile from the Canadian border (fig. 1, F1). The deposits are on the Golden Sceptre, Wawa, and TMU groups of claims, in sec. 25, T. 65 N., R. 1 W. The Golden Sceptre claims have been explored by about 4,000 feet of underground workings on 3 levels; the only workings on the other claims are prospect pits.

The claims are underlain by Precambrian quartzite of the Belt series and intrusive diorite of the Purcell sills. The sills and quartzite strike north to northwest and dip 5°–40° E. Steeply dipping north-striking faults cut both rock types, and several that cut the lowermost diorite sill have produced a series of steplike blocks that give a misleading impression of its true thickness. A number of quartz veins a few inches to more than 10 feet thick cut the sills, but none have been found in the quartzite.

Intense radioactivity has been found in three types of occurrences: quartz veins cutting diorite, pyrite-bearing quartzite, and in brecciated quartzite.

A number of quartz veins are exposed in the middle and upper workings and at the surface of the Golden Sceptre claims. Most of the veins are white quartz, containing sparse pyrite and erythrite. One vein exposed in both the middle and upper workings is red quartz containing sparse to abundant masses of dark-reddish-brown thorite as much as 2 inches in diameter. The thorite-bearing vein is 3 to 11 feet thick. It strikes about north and dips about vertically. Approximately 2,000 feet northeast of the upper portal a second thorite-bearing quartz vein crops out at the surface. It is at least 7 feet thick.

On the Wawa claims, uphill from the diorite sill, is a small prospect pit in dark gray fine-grained quartzite. The quartzite contains abundant pyrite cubes about 1 millimeter in diameter. The rock is intensely radioactive, but no radioactive minerals have been recognized. Chemical analysis of a representative sample by Jerome Stone showed that the sample contained 3.3 percent thorium.

Several hundred feet east of the pyrite-bearing quartzite, a breccia zone is exposed in a small prospect pit on TMU No. 1 claim. The brecciation has not been intense; fragments of quartzite are close enough together so that individual beds may be traced across the breccia zone. Breccia fragments are cemented by quartz, calcite, chlorite, and locally by abundant iron and manganese oxides. The breccia is locally intensely radioactive; in places its radioactivity is as much as 10 mr per hr (milliroentgens per hour), as compared with a normal background in the area of about 0.025 mr per hr. No radioactive minerals were recognized. Chemical analyses by Jerome Stone showed no uranium in the radioactive material, and it is assumed that the radioactivity is due to thorium.

Exposures are too limited to permit the pyrite-bearing radioactive zone or the brecciated radioactive zone in the quartzite to be traced. The relation between them and the thorite-bearing quartz veins in diorite are not known.

IDAHO AND MONTANA

LEMHI PASS AREA

Several thorite deposits in the Lemhi Pass area (fig. 1, F4) have been examined by the U. S. Geological Survey (Trites and Tooker, 1953; W. N. Sharp and W. S. Cavender, written communication, 1954), and two of these, the Last Chance property and the Wonder Lode claims, have been explored under Defense Minerals Exploration Administration contracts.

The Lemhi Pass area is underlain by quartzites and schistose quartzites of the Belt series of Precambrian age, which have been intruded by rhyolite and diorite dikes, and is partly covered by Tertiary volcanic rocks that now exist mainly as erosional remnants at higher elevations. The rocks of the Belt series are complexly folded and faulted.

Red-stained quartz-barite-hematite, quartz-hematite, and quartz veins have been deposited partly as open-filling and partly as replacement deposits, in faults cutting the rocks of the Belt series. Some of the veins contain sparse to abundant sulfides, and one, at the Copper Queen mine, has been mined on a small scale for copper and gold.

Several of the quartz-barite-hematite and quartz-hematite veins contain sparse to locally rich concentrations of thorite, principally as fracture fillings in the quartz and barite. The thorite appears to have been deposited in the fractured veins at the same time as the hematite. At the Wonder Lode deposit thorite has been deposited in fractures of a shear zone in which virtually no other vein minerals have been deposited.

A characteristic feature of the thorite deposits is their association, within a few feet to a few hundred feet, with red iron-stained soil and rock.

Thorite veins examined by the authors are briefly described below.

LAST CHANCE PROPERTY

The Last Chance, Brown Bear, and Shady Tree group of unpatented claims are in secs. 20, 28, and 29, T. 10 S., R. 15 W., Beaverhead County, Mont. (fig. 1, F4). Quartzite, argillaceous quartzite, argillite, and quartzitic sandstones of the Belt series underlie the area. They strike northwest and dip gently northeast. These rocks are cut by northwest-trending faults that dip about 45°–85° SW. (W. N. Sharp and W. S. Cavender, written communication, 1954). Thorite-bearing quartz-barite-hematite veins occupy the faults and have been emplaced partly by replacement of the brecciated wall rock and to a lesser extent by fissure filling. The wall rocks have been bleached and locally silicified adjacent to the veins. Recurrent movement along the faults has fractured the veins, and the fractures thus formed have been filled with specular and earthy hematite, thorite, and later generations of quartz. The thorite, which is metamict, and the hematite are intimately associated and appear to have been the last minerals deposited in the veins.

The Last Chance vein, the largest in the area, has been traced on the surface for 1,300 feet. It ranges in thickness from a few inches near its north end to a maximum of 35 feet near its south end. At the surface the southern two-thirds of the vein is 10 to 15 feet thick. Two diamond-drill holes, which were drilled near the southern end of the vein under a Defense Minerals Exploration Administration contract, cut the vein 260 and 290 feet down the dip. In both holes the vein is about 20 feet thick.

Samples taken from strongly radioactive parts of the Last Chance vein have assayed as much as 2.1 percent ThO_2, but scattered surface samples, drill-hole data, and geologic interpretation suggest an average grade of 0.15 percent ThO_2. Analyses also showed that the vein contained small amounts of uranium and rare earths. However, no rare-earth minerals or uranium minerals have been found in the vein. Therefore, it is thought that the small amounts of these elements reported in analyses must proxy for thorium in the thorite.

WONDER VEIN

The Wonder lode claims, which contain the Wonder vein, are in secs. 22 and 23, T. 19 N., R. 25 E., Lemhi County, Idaho (fig. 1, F4). The property was explored by 13 bulldozer trenches, drifts and crosscuts on 2 levels, and 3 diamond-drill holes, under a Defense Minerals Exploration Administration contract during the period 1952–55.

The property is underlain by moderately metamorphosed red or light- to dark-gray quartzites, argillaceous quartzites, and argillites of the Belt series of Precambrian age. The rocks are folded, but because of poor exposures the pattern of folding is not clear. The sedimentary rocks are cut by a dark-green medium-grained porphyritic diorite dike about 20 feet thick. The dike strikes east and dips from vertical at the east end of the property to 58° S. at the west end. A second dike of similar composition was found in one diamond-drill hole, but it does not crop out and its attitude is not known. Both dikes are believed to have been emplaced after the quartzites were folded.

The Wonder vein occupies an east-striking shear zone parallel to and south of the diorite dike. The vein material was deposited at least in part by replacement, but postmineralization movement along the shear makes it difficult to determine how much replacement has taken place.

The Wonder vein is cut by cross faults at several places, and the vein is locally offset as much as 20 feet. Two large cross faults about 900 feet apart terminate the vein on the east and west. Both faults strike about north; the east fault dips about 60° W., the west fault dips about 55° E.

The vein material is very fine grained, somewhat porous, and locally heavily stained by iron and manganese oxides. Shearing after mineralization has crushed and sheared the vein material into a reddish to black mass in many places. Determination of the minerals present has thus been made difficult but small amounts of chalcopyrite, malachite(?), sphalerite, pyrite, quartz, and calcite have been found, and siderite and barite have been tentatively identified. The thorium-bearing mineral is thorite (W. N. Sharp and W. S. Cavender, written communication, 1954).

The upper working exposes brecciated vein material for more than 100 feet averaging 2½ feet in thickness and containing about 0.75 percent thorium oxide. In the lower working, vein material exposed for 150 feet averages 1¾ feet in thickness and contains about 0.30 percent thorium oxide. Rare-earth content of vein material in the lower working is approximately 0.3 percent.

Deep-red iron-stained soil and rock is present in broad zones that approximately coincide with the surface outcrop of the Wonder vein. Locally on the surface the red zone is found a few feet away from the vein, but in most places it envelops the vein. Red iron-stained rock encloses all the radioactive vein material exposed in underground workings.

BUFFALO CLAIMS

At the Buffalo claims, in sec. 10, T. 19 N., R. 25 E., Lemhi County, Idaho (fig. 1, F4), a quartz replacement vein 2 to 8 feet thick cuts sandstone and argillite of the Belt series. The vein contains chalcopyrite, bornite, and thorite. The thorium content ranges from 0.04 to 0.34 percent. Vein material is stained red by iron oxide (W. N. Sharp and W. S. Cavender, written communication, 1953).

PERRON CLAIM

At the Perron claim, sec. 15, T. 19 N., R. 25 E., Lemhi County, Idaho, a small exposure of a quartz-hematite vein is abnormally radioactive. One sample from this exposure contained 1.9 percent equivalent thorium oxide.

SHOUP-NORTH FORK AREA

An unusual type of monazite deposit occurs between Shoup and North Fork, in a west-northwest-trending belt of metamorphosed sedimentary rocks approximately 25 miles long and 2½ miles wide in parts of T. 23, N., R. 21 E.; T. 22 N., R. 21 E.; T. 23 N., R. 20 E.; T. 23 N., R. 19 E.; T. 24 N., RS. 18–20 E., Boise meridian, Lemhi County, Idaho, and T. 3 S., R. 22 W., Montana principal meridian, Ravalli County, Mont. (fig. 1, F2 and F3). The rocks in this belt are schists, gneisses, marbles, and lime-silicate rocks that may be a metamorphosed part of the Belt series of Precambrian age. The rocks in the southeastern end of the belt have been altered and intruded by granitic rocks, probably part of the Idaho batholith. The northeast margin of the metasedimentary rocks is in fault contact with gray to white slightly metamorphosed quartzites of Belt age (E. P. Kaiser, oral communication, 1954).

The metamorphic rocks have been compressed into isoclinal folds, the limbs of which trend N. 55° W. and dip steeply and whose axes plunge moderately northwest. In places the distance between crests of folds is as little as 20 feet.

Along the crests and troughs of the folds, and to a lesser extent along the limbs, coarse monazite is associated with actinolite, siderite, barite, columbite, calcite, hematite, and rutile. Most of the monazite appears confined to what probably were originally limy beds in the sedimentary rocks. Locally, monazite-rich pods are as much as 1 foot thick and 10 to 20 feet long. Small scattered occurrences of thorite have been found in schistose micaceous layers. The thorite does not appear to be concentrated in any particular parts of the folds.

The monazite is brown to amber and is massive to euhedral with crystals as much as 2 inches long. Most of the monazite shows only slight radioactivity; its thorium content is low as compared with most monazite (R. G. Coleman, oral communication, 1952). An exception to this is found in the southeasternmost part of the belt where monazite has been found that shows higher thorium content and considerable radioactivity.

Properties examined by the authors in this area (all in Lemhi County, Idaho) are described below.

At the Spring Creek deposits, sec. 5, T. 24 N., R. 19 E., coarse monazite is associated with siderite, calcite, actinolite, and barite(?) in lenses a few inches to more than a foot thick in gneiss and schist.

Monazite occurs as crystals one-half inch or less in maximum dimension in the Squaw Creek deposits, sec. 4, T. 24 N., R. 19 E. The monazite is associated with siderite, specular hematite, and actinolite in lenses a few inches to a foot thick that are enclosed in hornblende- and biotite-quartz-plagioclase schist and gneiss, granitic gneiss, and metamorphosed calc-silicate rocks.

On the Radiant claims 1–9, secs. 26, 35, T. 24 N., R. 20 E., monazite and thorite crystals are found in schist; allanite in pegmatite.

The Contact claims 1–13, secs. 26, 27, T. 23 N., R. 21 E., are in gouge and schist blocks faulted into quartzite of the Belt series. Unidentified thorium-bearing minerals (possibly both monazite and thorite in places) are locally intensely radioactive (4 mr per hr).

URANIUM- AND THORIUM-BEARING PLACERS

Placer deposits are numerous in the area underlain by the Idaho batholith, and many of them contain uranium- and thorium-bearing minerals. Such deposits in the Cascade-Long Valley (fig. 1, G2), Bear Valley (fig. 1, B2), Stanley basin (fig. 1, B1), and Hailey-Fairfield (fig. 1, G4) areas have been studied by the U. S. Geological Survey (Mackin, written communication, 1952; Mackin and Schmidt, 1953) and the U. S. Bureau of Mines (Eilertsen and Lamb, 1956), and several have been explored under Defense Minerals Exploration Administration contracts. The authors have examined the Lakow Flats (fig. 1, G3) and Dismal Swamp (fig. 1, B5) properties northeast of Boise, Hull's placer on Big Creek (fig. 1, G1) in Long Valley, and other placers in the Bear Valley, White Hawk basin (fig. 1, B3), Elk City (fig. 1, B4), and Cascade-Long Valley areas. Whereas most of the placer deposits were examined to determine their monazite content, some were examined principally to determine their content of uranium-bearing and niobium-tantalum-bearing minerals.

Mackin and Schmidt in their work in central Idaho (Mackin, written communication, 1952; Mackin and Schmidt, 1953, oral communication, 1955) have shown that the abundance and distribution of valuable minerals in the placer deposits depend on the weathering, erosional, and glacial history of the area as well as on the amount and distribution of these minerals in the rocks from which the placers were derived.

They have also found that the distribution of radioactive minerals in the Idaho batholith is not uniform, and that in any given area one radioactive mineral usually predominates over the others. Placer deposits that contain abundant uranium-bearing and niobium-tantalum-bearing minerals usually contain little monazite, and vice versa.

The source of the monazite in the placer deposits is the Idaho batholith, in which it occurs as an accessory mineral. The source of uranium-bearing and niobium-tantalum-bearing minerals is principally small pegmatites that cut the Idaho batholith (Fryklund, 1951; Mackin and Schmidt, 1953), and to a much lesser degree the batholith itself, in which they are local accessory minerals.

URANIUM-BEARING PLACERS

Uranium-bearing minerals occur in gravels in Dismal Swamp placer, in Elmore County; in the Red River and American River drainage areas in the Elk City district, Idaho County; in the Bear Valley and White Hawk basin areas, Valley County; and in Stanley basin, Custer County.

The principal uranium-bearing minerals in Idaho placers are euxenite, brannerite, davidite, betafite, and samarskite. All are uranium-bearing multiple oxides, containing iron, titanium, niobium, or tantalum, singly or together. Because they are so alike in appearance, they are commonly referred to collectively as "radioactive blacks." The minerals are black or dark brown, hard, refractory, and have a high specific gravity. They are difficult to identify under any circumstances and positive field identification is almost impossible. All of them are chemically stable, but Mackin and Schmidt (1953) think that they are particularly susceptible to attritional wear so that special conditions, especially transportation for only short distances, are necessary for their concentration in placer deposits.

The only placer deposit considered a potential economic source of uranium-bearing and niobium-tantalum-bearing minerals at this time (1955) is that in Big Meadow in Bear Valley (Kline and others, 1953). The deposit is currently being dredged by a placer-mining company.

The Dismal Swamp placer was examined to determine its niobium-tantalum-bearing and uranium-bearing mineral content. Only a small amount of these minerals was found and the deposit was judged small. The niobium-tantalum-bearing and uranium-bearing minerals are believed to be derived locally from small pegmatite dikes in the Idaho batholith (Armstrong, 1957b).

Two placers in the vicinity of Elk City were examined. Uranium-bearing multiple oxide minerals were identified from the jigbed concentrate of a gold dredge operating on the Red River. Not enough of these minerals was present at the properties examined to warrant their recovery from the jigbed concentrate as a byproduct of the gold dredging (Armstrong and Weis, 1957).

THORIUM-BEARING PLACERS

Thorium-bearing placers in Idaho can be separated into two groups. In one group the ore mineral is monazite, and in the other it is thorite or uranothorite, or both (D. L. Schmidt, oral communication, 1955).

Monazite-bearing placers are widespread in central Idaho, principally in Elmore, Boise, Valley, Custer, Idaho, and Clearwater Counties in the drainage basins of the Payette, Boise, Salmon, and Clearwater Rivers. Most of the deposits have been mined for monazite alone. Those in the Cascade-Long Valley area were studied by J. H. Mackin (written communication, 1952); Kline and Carlson, 1954; Kline and others (1950, 1951 a, b, 1954, 1955); and Storch and Robinson (1954). The present authors examined the Lakow Flats placer deposit, Boise County and Hull's Big Creek placer deposit, Valley County. Hull's Big Creek placer deposit appears to contain a small amount of economically recoverable monazite. In all of the monazite-bearing placers listed above, the monazite is believed to have been derived from the Idaho batholith, where it occurs as an accessory mineral.

The second type of thorium-bearing placer, in which the ore mineral is thorite or uranothorite, or both was found by the U. S. Bureau of Mines in the Hailey-Fairfield area in parts of Camas and Blaine Counties (Robertson and Storch, 1955 a, b). As of the end of 1955 this type of deposit had not been mined. The thorium-bearing minerals in these placers were derived from the underlying quartz monzonite of the Idaho batholith, where they occur as accessory minerals. Locally they are present as residual concentrations at the surface, as well as in concentrations in stream gravels (D. L. Schmidt, oral communication, 1955).

No uranium- or thorium-bearing placer deposits of Quaternary age are known in Montana or Washington. However, in Montana the Virgelle and Horsethief sandstones of Late Cretaceous age locally contain concentrations of heavy minerals which probably accumulated as beach or offshore placers. Monazite was identified in one specimen of Virgelle sandstone (Armstrong, 1957a) and concentrations of monazite or uranium-bearing minerals might be found in these formations.

SUMMARY AND RECOMMENDATIONS

The most important reserves of known uranium ore are in the deposits in eastern and south-central Idaho and northeastern Washington that occur in or near granite, granodiorite, or quartz monzonite. All productive and marginal deposits in Idaho and Washington are either in or within a few miles of granitic intrusive rocks. The distribution of the deposits suggests a genetic relationship between the uranium and the granitic rocks. The granitic intrusive rocks and the intruded rocks near their margins seem to constitute the most favorable areas for future prospecting. The deposits have not been dated, but the ages of the granitic rocks with which they are associated are of probable Cretaceous age or younger.

Areas of similar rock types in other parts of Washington and Idaho may also merit investigation. The Northern Cascades in Washington are underlain in places by intrusive rocks that are similar in age and composition to those in northeastern Washington, where the uranium deposits have been found. A similar area, underlain by granitic rocks of the Idaho batholith and drained by the Clearwater and Salmon Rivers, includes much of central and north-central Idaho.

The similarity between the geologic environment of the Colorado Plateau uranium deposits and the geology of parts of Montana suggests that the large area of continental and marine sediments in central and eastern Montana should be considered potentially favorable for the discovery of uranium.

The hypothesis of the position of uranium in some zoned mineral districts (Leonard, 1952) appears to be a useful guide in a general way, as indicated in the southern Stevens County area of Washington and the Saltese area of western Montana. One of the chief obstacles to the application of this guide is the difficulty of recognizing zonal patterns in many mineral districts.

The association of uranium with other metals, notably iron, copper, and cobalt, has been pointed out as a guide to uranium deposits in many parts of the world (McKelvey, Everhart, and Garrels, 1955). Similar associations are suggested in parts of Idaho, Montana, and Washington. Copper minerals, together with lead, silver, and zinc minerals, have been found in or near uranium-bearing veins in the Coeur d'Alene and Camas mining districts, Idaho, and the Boulder batholith area, Montana. Small amounts of copper minerals are present within a few miles of the uranium deposits on the Spokane Indian Reservation, Stevens County, Wash. An exception to the association of uranium and other metals is found in the Elk area, Washington, where uranium is the only metal present in concentrations not typical of the rocks in which the deposits occur. Primary hydrothermal origin for the uranium in this area, however, has not been demonstrated.

The largest and richest thorite-bearing veins in the Northwest are in Precambrian sedimentary rocks of the Belt series and associated rocks in Idaho and Montana. Further prospecting for thorium should be done in areas underlain by rocks of the Belt series. Numerous monazite-bearing placers are known in the southern and western part of the Idaho batholith, but present market conditions are such that the recovery of monazite is for the most part unprofitable.

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