Geology of the Midnite mine area, Spokane Indian Reservation, Stevens County, Washington

By Eugene L. Boudette and Paul L. Weis

Trace Elements Investigations Report 634

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

March 26, 1957

AEC - 387/7

Mr. Robert D. Nininger
Assistant Director for Exploration
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-634, "Geology of the Midnite mine area, Spokane Indian Reservation, Stevens County, Washington," by Eugene L. Boudette and Paul L. Weis, November 1956.

A short version of this report is planned for publication as a Geological Survey mineral investigations field studies map. A comprehensive report on the geology of the entire Turtle Lake quadrangle is in preparation for publication as a Geological Survey bulletin.

Sincerely yours,

John H. Eric
for W. H. Bradley
Chief Geologist

Geology and Mineralogy

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGY OF THE MIDNITE MINE AREA, SPOKANE INDIAN RESERVATION STEVENS COUNTY, WASHINGTON*

By

Eugene L. Boudette and Paul L. Weis

November 1956

Trace Elements Investigations Report 634

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

USGS - TEI-634

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GEOLOGY OF THE MIDNITE MINE AREA, SPOKANE INDIAN RESERVATION, STEVENS COUNTY, WASHINGTON

By Eugene L. Boudette and Paul L. Weis

ABSTRACT

The Midnite mine is on the Spokane Indian Reservation, Stevens County, Wash. Geologic mapping and reconnaissance in the vicinity of the mine indicate metasedimentary rocks of probable Precambrian age have been intruded by two varieties of quartz monzonite of probable Cretaceous age. Porphyritic quartz monzonite underlies about three-fourths of the mapped area, and equigranular quartz monzonite underlies about one-thirtieth of the area. Metasedimentary rocks have been thermally metamorphosed in the vicinity of the intrusives.

Uranium minerals are restricted to the vicinity of the contact between porphyritic quartz monzonite and schistose or spotted phyllite. The largest and richest uranium deposits are where the contact is relatively steeply dipping and highly irregular in detail. Uranium minerals are most abundant in brecciated and fractured or jointed schist but are also present along joints and grain boundaries in the adjacent quartz monzonite.

Secondary uranium minerals comprise all known ore deposits; uraninite was found only in one diamond-drill core from the Midnite property. The origin of the deposits is not known, but several features suggest a hydrothermal origin.

INTRODUCTION

Purpose, location, accessibility

Uranium minerals were discovered in 1954 along an intrusive contact between granitic and metasedimentary rocks on the Spokane Indian Reservation in southern Stevens County, Wash. To obtain information on this potentially important area the U. S. Geological Survey, on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission, undertook geologic reconnaissance and detailed mapping in the vicinity of the uranium deposit.

Most of the field work connected with this report was done by Boudette, assisted by Anthony B. Gibbons. Boudette also prepared the illustrations and the preliminary draft of the report. Weis acted as general supervisor of the study and assisted in the completion and revision of the manuscript.

The uranium deposit, which is known as the Midnite mine, is in secs. 1 and 12, T. 28 N., R. 37 E. (Willamette meridian), about 35 airline miles northwest of the city of Spokane (fig. 1). Nine miles of gravel road extends from Wellpinit, Indian Agency headquarters for the Spokane Indian Reservation, to the mine.

The area mapped is at the south end of the Huckleberry Mountains, a NNE-trending range that has a total relief in the map area of about 2,400 feet (fig. 2). The highest point is Spokane Mountain (not to be confused with Mount Spokane in Spokane County, Wash.) with an altitude

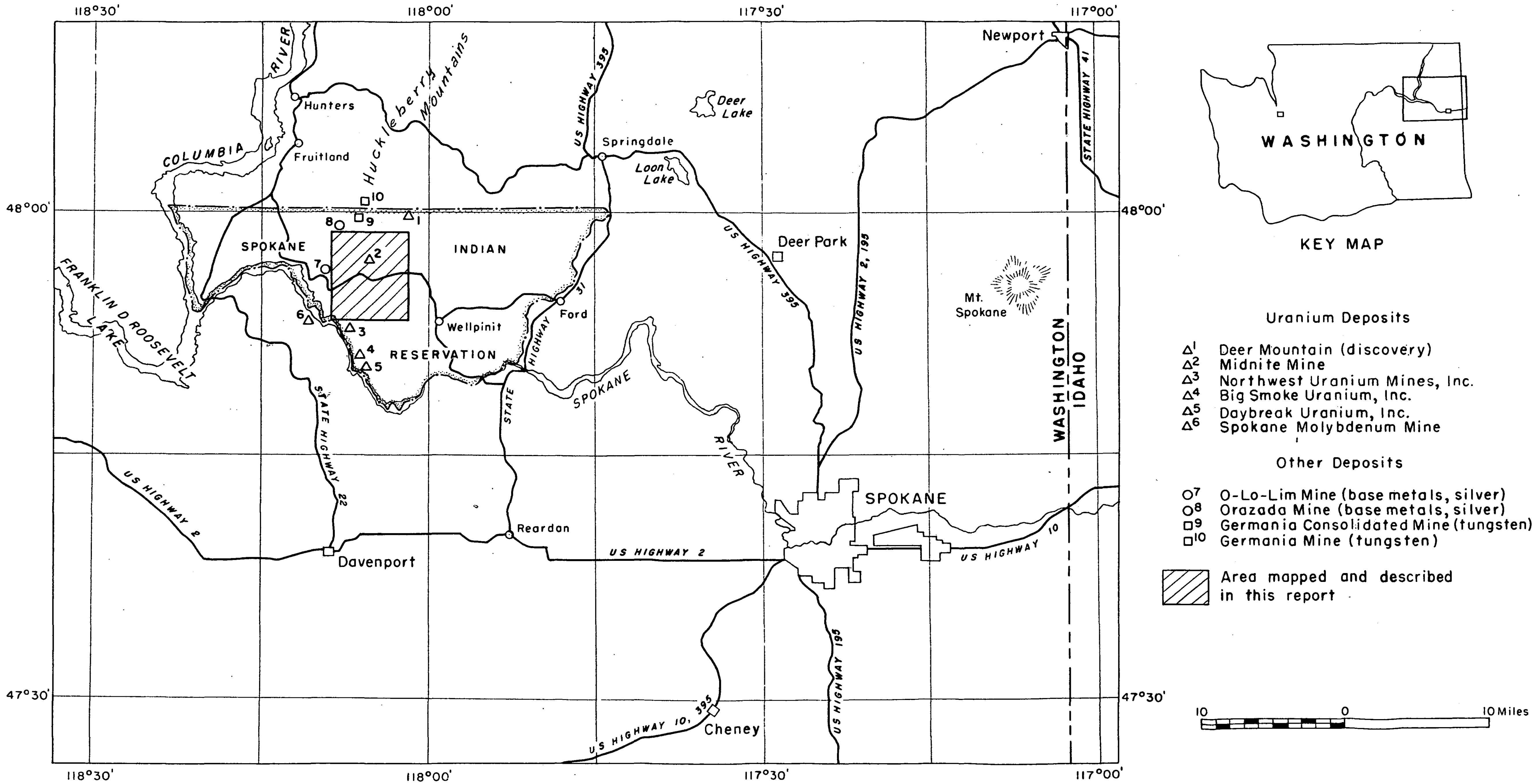

FIGURE 1 - INDEX MAP SHOWING THE LOCATION OF THE MIDNITE MINE AREA AND THE NEARBY MINERAL DEPOSITS

of 3,870 feet. The area is drained by several perennial and intermittent streams that are tributary to the Spokane River (Franklin D. Roosevelt Lake).

Records of the U. S. Weather Bureau show that annual precipitation in the Midnite mine area is about 16.5 inches. More than one-third falls as snow during November, December, and January, the wettest months. Summers are dry and July is the dryest month, with less than one inch of precipitation. Vegetation includes scattered Ponderosa pine and grass on south-facing slopes and dense brush, fir, and pine on north-facing slopes.

PREVIOUS WORK

Bancroft (1914) did the first comprehensive geologic work in northeastern Washington but restricted his studies to the mineral deposits. Later, Weaver (1920) studied the mineral deposits of Stevens County and prepared a generalized map of the county showing the location of the principal mines and distribution of the major rock units. Weaver's map is the only one showing the geology of the whole of Stevens County. Bennett (1941) studied and mapped the rocks of the Magnesite Belt, and Campbell and Loofbourow (unpublished report, 1945) did further work in the same area during World War II. The U. S. Atomic Energy Commission (Hetland, oral communication, 1956) is preparing a report on the results of diamond drilling at the Midnite mine during 1954-55.

FIELD WORK

The geology of an area of about 25 square miles centering around the Midnite mine was mapped at a scale of 1:24,000 on a topographic base enlarged from the Turtle Lake 15-minute quadrangle. Field work was started in July 1955, and continued until November 1955. A portable scintillation counter was used to measure radioactivity. Sixty-seven soil samples were collected at the Midnite mine for chemical analysis, to determine whether metallic elements other than uranium were present in unusual amounts in soil overlying the deposit. The presence of unusual amounts of metals other than uranium at the Midnite mine could provide clues to the origin of the deposit as well as contributing information regarding the usefulness of the method in this general area.

HISTORY

Uranium deposits

In the spring of 1954, James and John LeBret of the Spokane Indian Tribe discovered fluorescent uranium minerals while prospecting for scheelite by ultraviolet light on the southern slopes of Spokane Mountain. The deposit was named the Midnite mine. Following the discovery, a partnership was formed between the LeBrets and other members of the Spokane Tribe, and exploration was started on the Midnite property. During the winter of 1954-55, the Dawn Mining Company acquired control of the property. The principals in this closed corporation are the Newmont Mining Company of New York and the original members of the partnership. The Dawn Mining Company then started to develop and mine the deposit.

Before the discovery of the Midnite mine, uranium minerals had been reported at the Spokane Molybdenum mine, about 6 miles southwest of the Midnite mine (Vhay, 1950). Shortly after the discovery of the Midnite mine, uranium minerals were found 8 miles south on the Daybreak Uranium, Inc. Lowley lease. During 1954 and part of 1955 uranium minerals were discovered (fig. 1) on Deer Mountain, 5 miles northeast of the Midnite mine; on property held by Big Smoke Uranium, Inc., about 6 miles south of the Midnite mine; and on property held by Northwest Uranium, Inc., about 5 miles south of the Midnite mine. Only the Midnite mine had shipped ore as of May 15, 1956.

Other deposits

Base metals, gold and tungsten minerals have been mined near the Midnite mine (fig. 1). The O-Lo-Lim and Orazada mines were operated in the early 1900's, but the properties are now abandoned. The O-Lo-Lim was mined mainly for copper and silver (Patty, 1921) and the Orazada for silver, lead, antimony, gold, zinc, and copper (Purdy, 1951). Tungsten minerals have been mined at the Germania and Germania Consolidated mines from about 1900 to the present time.

ACKNOWLEDGMENTS

The writers are indebted to Robert J. Hundhausen, Superintendent, and Robert Sheldon, Geologist, of the Dawn Mining Company, for their generous cooperation during the course of field work.

REGIONAL GEOLOGY

Southwestern Stevens County is underlain by Precambrian and Paleozoic metamorphic rocks that have been extensively intruded by a batholith of probable Cretaceous age. Intermediate and basic lavas of Tertiary age unconformably overlie the batholith and older rocks in places. Much of the area was glaciated during Pleistocene time and locally, glacial deposits cover the bedrock.

Weaver (1920, p.44) states that the metamorphic rocks of the area are slate, argillite, phyllite, dolomitic limestone, quartzite, and limestone. He believed that they were of Paleozoic age and named them the Stevens series. They are commonly referred to as the Magnesite Belt, because of the magnesite deposits in them near Chewelah. The lowermost stratigraphic unit described by Weaver is called the Deer Trail argillite. Weaver also described the granitic batholith, which he named the Loon Lake granite. He recognized a variety of textures in the batholith, and stated that its composition ranges from granite to diorite (1920, p. 88).

Bennett (1941) mapped the metamorphic rocks of the Magnesite Belt in greater detail. He subdivided the Deer Trail argillite into several units which he called collectively the Deer Trail group. Because the Deer Trail group is overlain unconformably by rocks containing Lower Cambrian fossils, he considered the entire group Precambrian in age.

Campbell and Loofbourow, in a report they are currently preparing, support Bennett's view that the Deer Trail group is of Precambrian age, and observe that it resembles the Coeur d'Alene and Purcell facies of the

Belt series. They added some detailed information on the metamorphic rocks, particularly in southwesternmost Stevens County, and proposed tentative names for the units that Bennett assigned to the Deer Trail group. The lowermost unit of the group is predominantly an argillite, for which they proposed the name Togo formation, and it is the "Togo" formation which the writers believe make up the metamorphic rocks described in the present study. For convenience, the name "Togo" is used in this report.

The writers, accompanied by A. B. Campbell, made a reconnaissance trip north of the Spokane Indian Reservation with the principal purpose of visiting some of the exposures of the Deer Trail group described by Campbell and Loofbourow. During the course of this trip A. B. Campbell called attention to the striking similarity between the "Togo" formation and the Pritchard formation of the Belt series in the Coeur d'Alene mining district, Idaho.

The dominant structural feature of the region is the Deer Trail anticline, a northeast-trending fold that involves all of the pre-intrusive rocks, and which extends about 30 miles, from the Spokane River northeast to Chewelah (Weaver, 1920, p. 108). Near its southwest end the anticline is overturned to the west. Much of the area once underlain by the east limb of the fold is now occupied by Loon Lake granite. Faults and minor folds are superimposed on the major structure in a number of places.

GEOLOGY OF THE MIDNITE MINE AREA

The Midnite mine area (fig. 2) is near the southwest end of the Magnesite Belt. About three-fourths of the mapped area is underlain by the Loon Lake batholith; one-fourth of the area is underlain by the Deer Trail group.

Metamorphic rocks

The metasedimentary rocks in the Midnite mine area probably are correlative in part with the "Togo" formation. Campbell and Loofbourow (report in preparation) measured and described the uppermost 4,000 feet of the "Togo" formation near the south end of the Magnesite Belt, and state that the formation may be as much as 6,000 feet thick. They describe the "Togo" formation as predominantly a dark gray to almost black, somewhat slaty argillite. Near the top it contains thinly laminated black and white siliceous slates and a few impure dolomitic and calcareous beds. At the top is a quartzitic member that serves more or less as a marker. The quartzitic member is not normally a truly massive quartzite; its composition ranges from quartzitic slate and argillite to slaty quartzite and local thin beds of relatively pure quartzite. Campbell and Loofbourow also state that in the southern part of the Magnesite Belt the quartzitic member is nearly 1,000 feet thick.

The metamorphic rocks of the Midnite mine area are very similar to the "Togo" formation described by Campbell and Loofbourow. In the Midnite mine area stratigraphically lowest (the easternmost) rocks are predominantly argillitic; stratigraphically higher (to the west) they grade into a predominantly quartzitic facies. Discontinuous dolomitic layers are present in a few places. The Midnite mine area lies south on the projected strike of the "Togo" formation, and the attitudes of the rocks in the Midnite area are essentially the same as they are to the north. Background radioactivity over the metamorphic rocks ranges from 0.008 mr/hr to 0.022 mr/hr, and averages about 0.020 mr/hr.

Metamorphic rocks in the Midnite mine area provide an excellent example of the thermal metamorphism of an argillaceous sediment as described by Harker (1932, p. 48-61). All gradations from argillite to quartz-mica schist are present. Zones representing the more widespread metamorphic facies were mapped (fig. 2); accordingly, the units described below differ from one another in degree of metamorphism as well as original lithology.

Argillite, phyllite, spotted phyllite

Argillite and phyllite crop out in a small area in section 31 along the northeast border of the mapped area (fig. 2). They are commonly gray to black, thinly laminated, with well-developed bedding-plane foliation. Layers of quartzose and calcareous argillite an inch to a few feet thick are present in a number of places. Thermal metamorphism has affected these rocks only slightly. No coarsening of texture was noticed, but graded bedding, if originally present, can no longer be recognized.

The argillite and phyllite grade into spotted phyllite to the east, south, and west, in sections 31, 36, 1, and 12 (fig. 2). Gradational boundaries shown on the map represent zones that are for the most part 100-200 feet wide. The spotted phyllite is gray to brown, thin bedded, and readily cleavable along bedding-plane foliation. Planes of foliation are largely determined by growth of micaceous minerals parallel to bedding. Much of the rock is somewhat quartzose; most of it is spotted and could equally well be called spotted slate. A thin section of a specimen collected near the quartz monzonite contact at the Midnite mine contains in approximate amounts: quartz, 60 percent; biotite, 25 percent; muscovite, 5 percent; minor minerals, including zircon, rutile, apatite, tourmaline, and magnetite, 10 percent. A specimen of spotted phyllite collected in section 31 near Bear Mountain contains abundant andalusite porphyroblasts and segregations of very fine-grained magnetite.

In a few places within 25 feet of the quartz monzonite contact the argillite has been converted to a medium-grained, spotted, quartz-muscovite schist. Schistosity generally parallels bedding, but in a few places the schistosity makes a large angle with bedding.

Quartzite

Quartzite beds are present in all of the metasedimentary rocks but are thicker and more abundant in the upper part of the "Togo" formation, in sections 11, 34, and 35 (fig. 2). Quartzitic layers are from less than an inch to about 500 feet thick. Some contain considerable argillaceous material. Relatively pure quartzite layers are typically fine grained, light brown, massive, and very hard.

Dolomitic marble and calc-silicate hornfels

Dolomitic marble and its thermally metamorphosed equivalents crop out on the south and east slopes of Spokane Mountain in sections 1, 13, and 6 (fig. 2). Apparently they are some of the larger discontinuous carbonate lenses typical of the upper part of the "Togo" formation. The rocks are light gray, medium to coarse grained, and thin bedded. They weather to blocky boulders several feet in diameter. Some of the beds are argillaceous. All the carbonate layers are within the contact aureole and those that are close to the contact in sections 6 and 13 are completely recrystallized to hornfels. The rock about 300 feet from the contact in section 6 is a diopside hornfels made up in approximate amounts of: diopside, 55 percent: grossularite, 25 percent; calcite, 10 percent; wollastonite, 5 percent; sericite, 5 percent; and a trace of sphene. Rock in section 13 exposed within 30 feet of the contact is gehlenite hornfels.

Intrusive rocks

Loon Lake granite

Approximately three-quarters of the map area is underlain by rock known as the "Loon Lake granite," named by Weaver (1920, p. 87). Two varieties are present, one equigranular quartz monzonite, the other porphyritic quartz monzonite, which are different in mineralogy, and radioactivity, as well as in texture. In the map area the two varieties form discrete bodies separated by a belt of metasedimentary rocks about half a mile wide, but their contacts dip toward each other at a low angle, and it appears likely that the two masses join at depth (fig. 2, sec. A-A').

Porphyritic quartz monzonite.--Porphyritic quartz monzonite is the most abundant rock type in the mapped area (fig. 2). It nearly surrounds the metasedimentary rock that forms the top of Spokane Mountain, and it extends east, south, and southwest beyond the limits of the map. It locally occurs as small dikes and sills, as well as in masses of batholithic proportions.

The porphyritic facies of the Loon Lake granite is a massive, light pink to light brownish-gray rock that contains orthoclase, plagioclase, and quartz phenocrysts as large as 1 inch in diameter in a coarse- to medium-grained matrix. Near its contact with metamorphic rock, the monzonite is fine grained. Thin sections of six typical specimens contain 23-36 percent orthoclase, 23-42 percent plagioclase, 16-39 percent quartz, and 3-8 percent biotite. Accessory minerals are magnetite (as much as 1 percent), hornblende, muscovite, zircon, and apatite. In some of the thin sections, part of the biotite is altered to chlorite, and some of the plagioclase is altered to sericite. Plagioclase makes up 38-61 percent of the total feldspar. Its composition ranges from An_{32} to An_8. It is locally myrmekitic. The rock is deeply weathered in most places and is largely covered with gruss and soil. Its background radioactivity ranges from 0.20 mr/hr over weathered rock to 0.30 mr/hr over fresh outcrops. Where soil cover is less than a few feet thick, surface radioactivity can be used to recognize concealed contacts between porphyritic quartz monzonite on the one hand, and equigranular quartz monzonite and unmineralized metamorphic rock on the other.

Equigranular quartz monzonite.--Equigranular quartz monzonite underlies an area of about 1 square mile in sections 35 and 36 in the northwestern part of the mapped area (fig. 2). The rock is light gray, medium grained, and is locally iron stained. Like the porphyritic quartz monzonite, the equigranular body is typically fine grained along its contacts with metamorphic rocks, perhaps as a result of chilling. Typical monzonite contains 30-31 percent potash feldspar, 29-30 percent plagioclase, 35-36 percent quartz, and 0-4 percent biotite. Some of the monzonite examined under the microscope showed evidence of alteration. One thin section contained chlorite formed from biotite, and biotite, chlorite, and magnetite aggregates possibly formed from amphibole. Plagioclase in this section is somewhat sericitized. A second thin section contained plagioclase considerably altered to coarse sericite (muscovite). Quartz monzonite along Owl Creek is conspicuously richer in biotite than elsewhere in the mass. Erosion along the creek has cut relatively deeper into the intrusive; perhaps the rock exposed there is typical of the interior, and the rock exposed elsewhere represents an outer shell of biotite-poor rock. A zone of greisen is present along Owl Creek in section 36.

Radioactivity over the equigranular quartz monzonite ranges from 0.015 mr/hr to 0.022 mr/hr and averages about 0.018 mr/hr.

Dike rocks

Small dikes and sills are present in many places. Four lithologic types were recognized: hornblende lamprophyre, aplite, pegmatite, and a felsic rock of unusual composition. The aplites and pegmatites intrude both igneous and metamorphic rocks; felsic and lamprophyric bodies intrude only the metamorphic rocks.

Hornblende lamprophyre

Hornblende lamprophyre sills or dikes intrude spotted phyllite along Sand Creek near Spokane Mountain, near the top of Grouse Ridge, and on the east side of Owl Creek in section 35 (fig. 2). Their age is not known; but, because they were found only in rocks presumed to be Precambrian, they are tentatively called Precambrian in age. They may be examples of the (Precambrian?) greenstone dikes and sills described by Bennett (1941, p. 10).

The rock is a dark gray, medium- to fine-grained porphyry. Hornblende phenocrysts make up 60-75 percent of the rock in a groundmass of hornblende and plagioclase of uncertain composition. In part the hornblende has been altered to chlorite and magnetite or ilmenite. The entire rock has undergone low-grade thermal metamorphism.

The outcrop on the east side of Owl Creek is intensely sheared. Study of thin sections of rock from other outcrops showed that they are slightly sheared.

Aplite

Aplite dikes intrude the porphyritic quartz monzonite at almost all outcrops (fig. 2). These dikes are typically a few inches to a foot thick and have apparently been intruded along joints. Megascopically they are very fine to medium grained, light brownish-gray, and are composed of quartz, salmon-colored orthoclase, plagioclase, and biotite.

Pegmatite

Pegmatites form narrow tabular dikes and plug-like masses in a few places in the porphyritic quartz monzonite. Plug-shaped pegmatite dikes crop out on the western flank of Spokane Mountain in section 1, and near Sand Creek in section 10 (fig. 2). Neither of these dikes was studied in detail, but field observation showed significant differences in them. The dike on the flank of Spokane Mountain is very coarse grained (crystals more than 1 foot in diameter) and contains doubly terminated euhedral quartz crystals more than 1 foot in diameter. Other coarse-grained minerals are potash feldspar (orthoclase?), plagioclase, and sparse muscovite in radial aggregates. The dike is within 200 feet of uranium minerals along the quartz monzonite-metasedimentary rock contact, but no uranium-bearing minerals were recognized in the pegmatite although background radioactivity is approximately twice as great over the dike as it is over the nearby porphyritic quartz monzonite. The pegmatite body near Sand Creek is finer grained and consists of intergrown plagioclase and orthoclase, quartz, muscovite, and biotite. It contains abundant graphic granite. Background radioactivity over this pegmatite is the same as it is over the enclosing quartz monzonite. One tabular dike about two feet thick is in section 13 near Blue Creek. It appears to have been intruded along a joint.

Felsic dikes

Dike rocks of unusual composition intrude metasedimentary rocks in sections 11, 2, and 36, north and south of Sand Creek. Their distribution along a northeast-trending line suggests that they are part of a single unit. The rock is light gray, medium- to fine-grained, with quartz phenocrysts. The rock contains approximately 40 percent potash feldspar, 30 percent quartz, 10 percent muscovite, and 20 percent andalusite. The quartz forms rounded euhedra that are surrounded by a fine-grained border of groundmass. The muscovite is largely intergrown with the andalusite. The potash feldspar occurs in segregations. The rock may represent a pre-intrusive breccia that had its argillitic fragments replaced by andalusite and quartz, and the intervening areas filled by a mixture of orthoclase and quartz.

STRUCTURE

Deer Trail anticline

The metasedimentary rocks in the Midnite mine area lie in the overturned west limb of the Deer Trail anticline (Weaver, 1920). The strike of the beds is about N. 15° E. and average dips are about 55° SE. Evidence for overturning is lacking in the map area, but reconnaissance in less metamorphosed rocks on strike to the north showed overturned beds that could be recognized by graded bedding and fracture cleavage relations. These beds probably continue into the map area with the same attitudes that they have to the north. Variations in both strike and dip are common in the map area, particularly near contacts with quartz monzonite, where strikes range from northwest to almost east-west, and dips are vertical or steep to the east.

Center fault

A strike fault about $2\frac{1}{2}$ miles long, named for convenience the Center fault, is in sections 36, 1, 12, and 13 (fig. 2). It strikes about NNE. and dips steeply, possibly to the east. Its presence is partly inferred because of the valley, saddle, and springs whose alinement suggests a zone of weakness in the underlying rocks. The Center fault is a normal fault with the eastern side downthrown. It cuts both sedimentary and igneous rocks, but the displacement is not known. Some indication of the displacement is given, however, at its northern end where the fault is nearly vertical and strikes about N. 10° W. The fault brings argillite on the east in contact with spotted phyllite on the west. If, as appears likely, the fault has brought argillite from above the contact into juxtaposition with spotted phyllite nearer the contact, the amount of vertical movement may be 300 feet or more, the approximate thickness of the contact metamorphic zone. In sections 12 and 13, the Center fault, mapped in place, strikes about N. 10° E.; its dip is not known. Evidence for the fault and its relative movement in sections 12 and 13 is the offset trace of the north-dipping igneous-metamorphic contact on opposite sides of the valley eroded parallel to the fault strike.

Minor shear zones, breccia zones, and joints

Two shear zones and three outcrops of fault breccia are known in the map area (fig. 2). In addition many faults that are too small to map cut both metasedimentary and igneous rocks along the contact at the Midnite mine. However, bulldozing at the Midnite mine has exposed the bedrock, and similar exposures are not found elsewhere. Hence it is not known if similar exposures are not found elsewhere. Hence it is not known if similar faulted zones, especially along contacts, are in the map area. The possibility that the contact area at the Midnite mine is a fault zone is evaluated below. Joints are abundant in both the metasedimentary and igneous rocks. Jointing in the metasedimentary rocks is too complex to permit interpretation in this study and only joints in batholithic rocks are shown in figure 2. The similarity in attitudes of faults and dikes suggests that dikes may provide clues to the location of faults.

Two shear zones cut the quartz-monzonite porphyry; one is near the center of section 13 and the second is in the southwest part of section 7. Both are less than 20 feet wide and are of unknown displacement. The shear zone in section 13 strikes about N. 5° E. and dips 19° SW. The shear zone in section 7 is vertical and strikes about N. 5° W.

In the northeast corner of section 2 phyllite and felsic dike rock are locally brecciated. The breccia fragments are 1 to 2 inches in diameter and are silicified and locally iron stained. The brecciated felsic rock contains limonite and hematite derived from pyrite. Late quartz is abundant as euhedral crystals that line open spaces in the breccia. The felsic material in the dike is likely related to the intrusion of the quartz monzonite; therefore, some movement appears to have taken place after intrusion of the batholith. The remaining two breccia zones mentioned above are in quartzite in sections 2 and 35. The two zones are about half a mile apart and probably involve the same quartzite bed. A line drawn between the breccia zones is about parallel to the regional strike of bedding in the metasedimentary rocks. The breccia zone in section 35 comprises a small roof pendant in the equigranular quartz monzonite. In both these zones the brecciation is intense and the fragments have been intruded by quartz monzonite, silicified, and considerable iron has been introduced into them. The breccia is probably a pre-intrusion fault breccia that was modified during the intrusion of the equigranular quartz monzonite. The intervening metasedimentary and intrusive rock is covered, and a fault relating them cannot be definitely extended from one zone to the other.

The joints in both the quartz monzonite bodies are in conjugate sets (fig. 2). Those in the porphyritic quartz monzonite strike about northwest and northeast. Thin aplite and pegmatite dikes intrude some of the joints in the porphyritic quartz monzonite.

Probable faults

Three probable faults are placed in the map area (fig. 2). Two are based on interpretations of the breccia zones and one interpretation of the offset trace of the contact in a valley. The probable faults are named for convenience the South, Ridge, and West faults.

South fault

The South fault is in the southwest corner of section 12 (fig. 2). It is interpreted from the apparent offset of the contact trace along the boundary between sections 12 and 13, and from the zone of weak rocks suggested by the position and trend of the valley along which it is projected.

Ridge fault

A probable fault striking about NNE. about $1\frac{1}{2}$ miles long is placed in the eastern halves of sections 2 and 11 (fig. 2). The dip of the fault is probably to the east if the fault trace is placed correctly. The position and extent of the fault is interpreted from the presence of three parallel-trending breccia zones along the projected NNE.-trending line. If, as believed, the breccia zone postdates the batholithic intrusion, the proposed Ridge fault may cut both the quartz monzonite and older rocks.

West fault

A probable fault striking about NNE. and of unknown dip is placed between and connecting the two breccia zones in sections 2 and 35 (fig. 2). The fault is about half a mile long and may or may not cut the quartz monzonite as shown (fig. 2).

Intrusive contacts

The distribution of igneous and metamorphic rocks, and the distribution and degree of thermal metamorphism in metamorphic rocks suggest that about the northern one-third of the map area is near the roof of the Loon Lake batholith. The distribution of igneous rocks and of thermally metamorphosed rocks also suggests that the batholith roof is an irregular surface which, in a general way, may dip gently to the north.

In several places contacts between metamorphic rocks and quartz monzonite are parallel or subparallel to the regional strike of the metamorphic rocks. The best example is along the east side of the northeast-trending tongue of porphyritic quartz monzonite at the Midnite mine; the contact about three-quarters of a mile east, in sections 6 and 12, is another good example. Contacts dip steeply (generally 45 degrees or more) where subparallel to the strike of metamorphic rocks, and dip gently (generally 25 degrees or less) where they crosscut the strike of the metamorphic rocks.

Strikes and dips of the metamorphic rocks are erratic near all igneous contacts. At the Midnite mine where the contact is well exposed the attitudes of the beds are divergent from the regional trends;

closely spaced joints, moderate to extensive brecciation, and local shearing are also present at the contact. Contacts elsewhere in the map area are poorly exposed; and, although strikes and dips divergent from regional trends were measured, the presence of a brecciated zone everywhere along the igneous-metamorphic contacts cannot be demonstrated.

The position of the quartz monzonite appears at least locally controlled by pre-existing structures in the older rocks. Igneous contacts trend NNE, parallel to regional trends, in parts of sections 1, 6, 12, 31, and 36 (fig. 2).

In places the intrusive contact is parallel to regional strike of the metamorphic rocks, but divergent in dip, suggesting the possibility of influence by joints or strike faults. Exposures are not numerous or extensive enough to prove this, however. Furthermore, strike faults recognized in sections 1 and 13 appear to be either post-intrusive or to have had post-intrusive movement along them. Deformation of metamorphic rocks in the vicinity of intrusive contacts could be caused by intrusion, rather than preceding it. It appears at present that regional strikes of the metamorphic rocks, rather than faulting, was most important in localizing the quartz monzonite intrusion.

URANIUM DEPOSITS

General

Secondary uranium minerals occur at the Midnite mine in sections 1 and 12, and at one place in section 11 and one place in section 13 (figs. 2 and 3). All occurrences are at or near the contact between porphyritic quartz monzonite and schistose or spotted phyllite. Size and grade of the uranium deposits in sections 11 and 13 are not known.

Midnite mine

The Dawn Mining Company has explored the Midnite uranium deposit by 508 feet of underground workings (Hetland, oral communication, 1956), extensive bulldozing, and a large number of wagon-drill holes. The U. S. Atomic Energy Commission has explored the property with 13 diamond-drill holes. About 5,400 tons of ore, averaging slightly more than 0.20 percent U_3O_8, had been mined from the deposit as of May 1956 (Hetland, oral communication, 1956). A prospectus accompanying a recent stock offering states that 484,000 tons of probable ore has been outlined by drilling.[/]

[/] Spokane Daily Chronicle, Dec. 20, 1956.

The writers believe that this is a conservative estimate of reserves at the property.

At least four uranium ore bodies have been discovered on the property, along a zone nearly 2 miles long.(See figure 3). Barren rock between the ore bodies appears to be identical in structure and lithology to the mineralized rock, but radioactivity is markedly different. Over ore zones, background radioactivity is generally three to five times greater than normal.

Mineralogy

Uranium minerals identified from the Midnite mine are, in approximate order of abundance, meta-autunite (identified by Jerome Stone, U. S. Geol. Survey), uranophane (identified by Jerome Stone), phosphuranylite (identified by D. D. Riska, U. S. Geol. Survey), liebigite (identified by Jerome Stone), torbernite (identified by Weis), and uraninite. Sparse chalcopyrite, pyrite, and molybdenite are associated with the uranium minerals. The sulfides are probably primary, and the uraninite may be too; however, no primary uraninite ore body has been recognized at depth.

Secondary iron and manganese oxides are locally abundant, and in places the minerals of the metamorphic rocks have been altered to clay. At least some of the clay minerals have probably formed by chemical weathering, but in places they are so abundant that hydrothermal alteration is suspected. A different type of alteration has affected the quartz in the granitic rocks in and near the ore zones. There the quartz is dark gray to jet black, possibly because of irradiation.

The secondary uranium minerals form small crystals, flakes, and powdery masses in gouge seams, as coatings or joint and fracture fillings in the schistose and spotted phyllite, and as joint and fracture surface coatings and along grain boundaries in quartz monzonite. Deposition of the uranium minerals appears to have taken place in open spaces only; no evidence of replacement has been found. Megascopic examination of the ore shows no evidence that secondary uranium minerals have formed from the alteration of a primary mineral in place, and it is suggested that much of the uranium has been transported at least a short distance by groundwater solutions.

Radioactivity in open pits exposing substantial amounts of uranium ore is intense — locally as much as 5.0 mr/hr. In general it appears that much of the ore is slightly less radioactive (about 25 percent) than would be expected from its uranium content.

Structure

The localization of uranium minerals at and near the contact between porphyritic quartz monzonite and metamorphic rock suggests that structures along the contact had an important effect in controlling the deposition of uranium. All known ore bodies are composed of secondary uranium minerals, and the secondary minerals are found only in pre-existing rock openings.

At the quartz monzonite contact, much of the schist is broken and some is brecciated. Most of the schist fragments have not been rotated or crushed appreciably, but discontinuous gouge seams are present in several places. The gouge seams are typically a few feet to a few tens of feet long, a fraction of an inch to about 4 inches thick, and are generally parallel to the contact. Deformation appears to be unrelated to trend and less intense away from the contact, although exposures are so limited at distances greater than 50-100 feet away from the contact as to leave this impression open to some question. No large, through-going faults have been recognized. The quartz monzonite near the contact is less deformed than the metamorphic rocks; typically it is cut only by joints and a few small, widely spaced shears. Locally, tabular granitic sills, generally less than 2 feet thick, have intruded the schist. They appear most numerous close to the contact, but poor exposures away from the contact prevent proof of this impression. The abundant open spaces in the metamorphic rock, distributed along the contact with an igneous rock having relatively much fewer open spaces, may have provided an ideal structural environment favorable for the deposition of the uranium.

Soil sampling

Chemical analyses of soil samples were made to determine the distribution of metallic elements other than uranium along parts of the intrusive contact at the Midnite mine, and to see whether any of them were characteristically associated with the uranium ore zones. It was hoped that a correlation between uranium ore and other metallic elements might provide both a useful tool for prospecting, and a clue to the origin of the uranium deposit.

Sixty-seven soil samples were collected along three lines normal to the trend of the contact (fig. 3). Line A is about 300 feet north of the nearest known ore body, line B is over a known ore body, and line C is about 750 feet south of the nearest known ore body. The samples were first analyzed for 60 elements by standard spectrographic methods. Later, rapid chemical analyses were made for Pb, Cu, Zn, Co, Mo, As, U, and V by H. E. Crowe, C. E. Thompson, and R. R. Beins of the U. S. Geological Survey, Denver laboratory.

The distribution of lead, arsenic, and molybdenum appears to be related to the intrusive contact and to the uranium deposits at the Midnite mine (fig. 4A and 4B). All were more abundant closest to the contact, and all were most abundant over uranium ore bodies. Distribution of other metallic elements did not appear related to either the intrusive contact or the uranium ore.

Some of the lead found associated with the uranium could be of radiogenic origin and, therefore, of no significance. Anomalously high percentages of arsenic and molybdenum, however, suggest the likelihood of hydrothermal activity along the contact; both elements are commonly of hydrothermal origin. Their association with uranium suggests that the uranium may also have been originally deposited by hydrothermal solutions, and that the deposit has altered after deposition to its present composition of secondary uranium minerals.

Results of soil sampling suggest that in this region it may prove a useful tool for locating new uranium deposits.

Comments on the origin of the deposit

Information at present is inadequate to permit a definite conclusion as to the origin of the Midnite uranium deposit. Certain features suggest that it may be of hydrothermal origin. The deposits are in a more or less well-defined linear zone of deformation, a structural environment typical of many hydrothermal deposits. The uranium minerals are associated with minor amounts of sulfides, and anomalously high percentages of lead, arsenic, and molybdenum have been detected in soil samples from the mineralized zone. It appears that some of the host rock may have been hydrothermally altered. Uraninite is present in one place at depth. The ore is confined to fairly well-defined zones, surrounded by halos of lower-grade material that could have been formed by surface weathering.

Other features of the deposit can be interpreted as favoring or permitting a supergene origin. Neither primary uranium minerals nor pseudomorphs of secondary uranium minerals after primary minerals have been found in exposed ore bodies. The ore is in zones of deformation that could serve as channelways for uranium-bearing ground water. The presence of sulfides along the contact could be coincidence; the alteration of metamorphic minerals to clay may be due entirely to weathering; the absence of vein minerals such as quartz or calcite, or indeed of any clear-cut vein, is also suggestive of a supergene origin.

It is apparent that considerable additional information is required to establish the origin of the deposit. On the basis of present knowledge, the writers are inclined to favor a hydrothermal origin, but with the qualification that their opinions may be subject to change on the basis of additional information in the future.

SUGGESTIONS FOR PROSPECTING

The uranium deposits in the map area have certain geologic features that may be useful to prospectors in northeastern Washington. None are known to be actual guides to ore, but each of them, or a combination of them, may be helpful in pointing out areas particularly worth while for investigation.

Uranium minerals at the Midnite mine are in brecciated, schistose phyllite along a steeply dipping, irregular contact with porphyritic quartz monzonite. Distribution of uranium ore suggests that places where the contact strikes parallel to the strike of adjacent metamorphic rocks are more favorable for prospecting. The quartz monzonite contains black quartz in and near ore zones, but not elsewhere. Uranium minerals are present adjacent to porphyritic quartz monzonite but are not present near equigranular quartz monzonite. Radioactivity over porphyritic quartz monzonite is approximately twice as high as it is over equigranular quartz monzonite and unmineralized metamorphic rock, which makes it possible to recognize concealed contacts with the aid of a scintillation counter. The uranium ore itself is, of course, strongly radioactive, and can be detected readily with any counter provided the ore is within a few feet of the surface.

Limited geochemical prospecting has detected anomalously high percentages of lead, arsenic, molybdenum, and uranium over and near uranium ore bodies.

Although the concept could not be checked in an investigation of limited areal extent such as this one, the hypothesis put forth by Leonard (1952), and Leonard and Campbell (written communication, 1952) concerning the position of uranium in zoned mineral districts may prove to be a useful tool. Leonard pointed out that in some districts where metals are arranged in a zonal pattern, primary uranium minerals occupy a position between pyrite-gold centers and lead-silver-zinc peripheries.

Uranium and copper are commonly found together in such intermediate zones. Leonard and Campbell(written communication, 1952), working solely from the literature, noted that the distribution of mineral deposits in southern Stevens County vaguely suggested a zonal pattern related to the Loon Lake granite. They suggested that those areas where copper-bearing ores have been found should be investigated for uranium.

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