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GEOLOGICAL SURVEY

THE OCCURRENCE OF ZEUNERITE AT BROOKS MOUNTAINS, SEWARD PENINSULA, ALASKA*

By

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Trace Elements Investigations Report 221

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ABSTRACT

Zeunerite occurs near the surface of a granite stock on the southwest flank of Brooks Mountain, Alaska. The largest deposit is at the Foggy Day prospect where zeunerite is disseminated in hematite which partially or totally fills openings and vugs in a highly oxidized lens-shaped body of pegmatitic granite and to a minor extent in openings and cracks in the weathered granite enclosing the lens. Although a few specimens from the pegmatitic lens contain as high as 2.1 percent equivalent uranium, the overall average content of the lens rock is between 0.1 and 0.2 percent equivalent uranium and about 0.07 percent equivalent uranium for both the lens material and the surrounding zeunerite-bearing granite. A smaller concentration of zeunerite occurs as surface coatings on a few of the quartz-tourmaline veins that occupy joint fractures in granite on Tourmaline No. 2 claim. The vein material here contains about 0.05 percent equivalent uranium. Zeunerite, in trace amounts, was identified in a sample from a site near Tourmaline No. 2 claim and in two samples from different sites near the Foggy Day prospect. The zeunerite at these three localities is probably related in source to the Tourmaline No. 2 claim and Foggy Day prospect deposits, respectively.

Although no primary uranium minerals were found, it is possible that a primary mineral zone may occur below the zone of oxidation at the Foggy Day prospect.

INTRODUCTION

Brooks Mountain (elevation 2,898 ft) is located in the central part of the Teller Quadrangle about 25 miles east of Cape Prince of Wales and 85 miles northwest of Nome (fig. 1). It is the highest peak in the York Mountains, which form the divide between the streams flowing north into the Arctic Ocean and those flowing south into the Bering Sea. Brooks Mountain itself constitutes the drainage source for several of the headwater tributaries of the Mint River; York Creek, a tributary to the Pinauk River; Anderson Creek, a tributary to the Don River; and Crystal Creek, a headwater tributary to Lost River.

The Brooks Mountain area is accessible by small planes which may land on a crude airstrip on the southwest slope of the mountain above Crystal Creek or on two other airstrips further down Lost River. Heavy equipment and supplies can be transported by tug and barge to the Bering Sea beach near the mouth of Lost River and thence brought up to the 1,400 ft saddle between Crystal Creek and Mint River over a tractor trail. This trail will also accomodate jeeps and trucks.

The Brooks Mountain area has been visited and described a number of times by members of the Geological Survey (Collier, 1902, pp. 14, 29, 30, 51, 1904, pp. 10, 15, 26, 1905, p. 125; Knopf, 1908, pp. 13, 17-25, 34, 41-44, 61; and Steidtmann and Cathcart, 1922). No field investigations for radioactive materials had been made in this area by the Geological Survey prior to 1951. Radiometric scanning of rock samples in the Survey collections and radiometric and mineralogic studies of samples sent to the Survey during the summer of 1950 indicated that Brooks Mountain was one of the most likely places in Alaska to contain high-grade uranium ores (Wedow, White, and Moxham, 1951, pp. 2, 26-28, 32). For this reason a radioactivity

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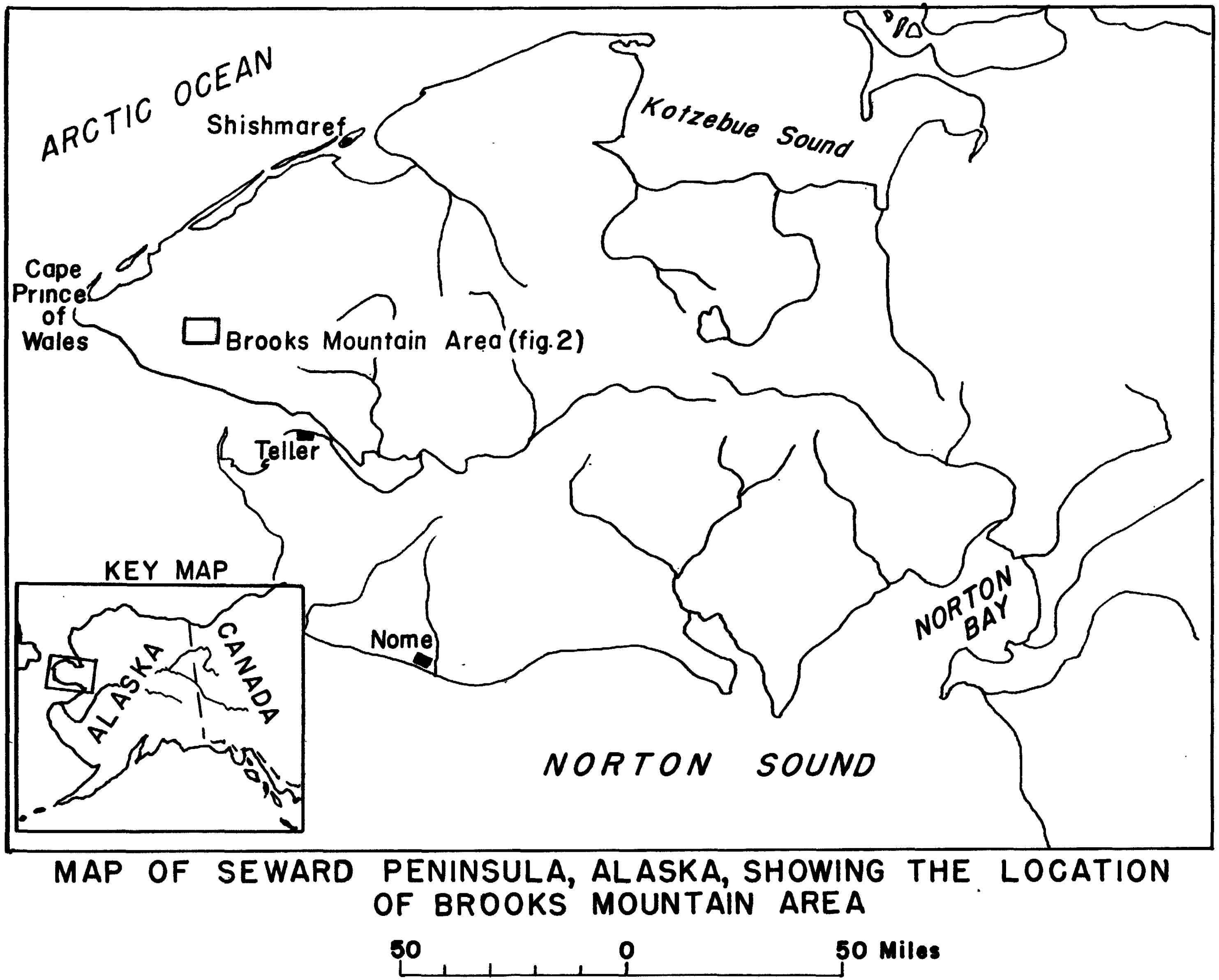
FIGURE 1



MAP OF SEWARD PENINSULA, ALASKA, SHOWING THE LOCATION OF BROOKS MOUNTAIN AREA

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investigation of the Brooks Mountain area including several bedrock claims, which were being prospected for uranium by the United States Smelting Refining and Mining Company on the southwest slope of the mountain, was made during the latter part of July and August 1951. Some of these claims were owned by the company and the remainder were leased by it from Mr. George Hellerich of Fairbanks and associated from elsewhere in Alaska. The investigation was made by Walter S. West and Max G. White, geologists, and Fred Freitag, Arthur E. Nessett, and Eugene A. Hainze, field assistants. This work was done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

GEOLOGY

Brooks Mountain is composed of igneous, sedimentary, and metamorphic rocks. The various rock types are represented by a granite mass and felsic and mafic dikes of Mesozoic(?) age which intrude a black slate formation of Cambrian or pre-Cambrian age and the Port Clarence limestone of Ordovician, Silurian, and Devonian age (fig. 2).

Description of rock types

Slate

The black carbonaceous slate at Brooks Mountain has an exceedingly fine-grained texture and a platy structure. Quartz and mica are common constituents. In contact with the granite and for several hundred feet away from the contact the slate has been altered to a dense, compact brown mass which shows faint banding. It has lost its original platy character and the mineral grains are slightly coarser.

Limestone

The limestone on Brooks Mountain which has not been subjected to contact metamorphic alteration varies from thin-bedded rock with brown to black shaly partings to pure gray granular rock in beds averaging about 3 ft in thickness. However, the limestone has in places been highly metamorphosed, as for example at the Foggy Day prospect, where it has been changed to a coarse-grained white marble traversed by seams of silicates and veins and veinlets of other minerals. A green mica zone at the granite-limestone contact in the Foggy Day claim is probably the result of alteration of the limestone.

Granite

A small stock of granite is exposed over an area of about 1-3/4 sq mi on the south flank of Brooks Mountain (fig. 2).

There are at least two facies of the granite; one is a coarse-grained porphyritic granite with phenocrysts of orthoclase as much as 3 in. in length but averaging about 1½ in.; the other is a medium-grained granite. Although the evidence is not conclusive, it appears that the coarse-grained granite forms the main body of the mass, and the medium-grained rock may be a chilled border phase of the granite. Mineral constituents common to both facies of granite include orthoclase, plagioclase, biotite, smoky quartz, glassy quartz, and black tourmaline. The accessory minerals are monazite, zircon, xenotime, anatase, magnetite, and ilmenite.

A possible correlation may be made between the Brooks Mountain granite and other granite masses in the York district, particularly those on Cassiterite and Tin Creeks in the Lost River area, and at Cape and Ear Mountains. This correlation is based not only on similarity of composition but also on the occurrence of tin minerals in or near all the granite masses. In addition the granite masses all intrude the Port Clarence limestone, and the contact metamorphism of the limestone adjacent to the granite at all the masses is similar.

Dikes

Several granite and aplite dikes, one dacite porphyry dike, and one pegmatite dike are known to crop out on Brooks Mountain (fig. 2). The granite and aplite are found in the slate, limestone, and granite; the dacite porphyry dike cuts both limestone and slate; and the pegmatite dike is in limestone. All of the dikes are believed to be genetically related to the granite.

Structure

The Paleozoic sedimentary rocks, which strike northeast along the northwest side of the granite at Brooks Mountain, appear to lie in an overturned anticline with the axis of the fold dipping northwest. The nature of the contact between the sedimentary rocks and the granite is poorly defined; it was observed only in a few isolated outcrops and is inferred mostly from float and talus. The contact is probably a normal intrusive contact, although the sedimentary rocks may have been thrust faulted against the granite by compressive stresses from the northwest. However, if such faulting has taken place, it has been localized at the contact, there being no evidence of faulting in the sedimentary rocks to the southwest of the area under consideration here.

One major and two minor joint fracture systems are present in the granite. The major joint fractures trend northwest and at many points are occupied by narrow quartz-tourmaline veins. The valley at the head of the Mint River fork that drains the area is a cirque. Erosion of the strongly jointed granite at the head of the cirque has formed high, sharp pinnacles, some of which are 200 ft high.

Hydrothermal alteration of sedimentary rocks and granite

The sedimentary rocks and granite at Brooks Mountain have been hydrothermally altered, particularly along the limestone-granite contact on the southwest flank of the mountain (fig. 2).

A narrow zone of tactite(?), composed essentially of green mica, fluorite, and calcite was observed in the workings of the Foggy Day prospect (fig. 2) which lie mainly in granite at the limestone-granite contact on the southwest flank of the mountain. The metamorphosed limestone on the southwest flank of the mountain, from the Pageite claim on the south to the Iron Cap No. 10 claim on the north (fig. 2), contains a large variety of minerals including idocrase, diopside, grossularite, augite, hedenbergite, scapolite, chrondrodite, phlogopite, siderophyllite, tourmaline, fluorite, scheelite, arsenopyrite, ludwigite, pyrite, pyrrhotite, magnetite, hematite, limonite, galena, cerussite, sphalerite, chalcopyrite, chalcocite, bornite, azurite, malachite, hulsite, and paigeite. These minerals, with the exception of those that are of secondary origin, appear to have been formed from solutions introducing fluorine, chlorine, boron, silica, aluminum, magnesium, tungsten, arsenic, sulphur, iron, lead, zinc, copper, and tin, which penetrated the limestone through fissures, joints, and bedding planes. Little or no alteration took place along the eastern part of the granite-limestone contact.

Minerals introduced in the granite are hematite, limonite, siderite, pyrrhotite, arsenopyrite, fluorite, scheelite, chalcopyrite, azurite, malachite, tetrahedrite, cassiterite, bismuth, and zeunerite, and the quartz and tourmaline that occupy joint fractures in the granite. Some of these minerals from which the uranium in the zeunerite has been derived may have been deposited in the granite.

As most of the minerals formed by hydrothermal alteration occur near the limestone-granite contact, it is probable the contact was the principal path along which the mineralizing solutions moved. The solutions apparently were more effective in causing deposition and replacement in the limestone than in the granite, possibly because the granite was less favorable than interaction with the solutions at the time that they passed through it.

The alteration of the rocks at Brooks Mountain appears to have been produced in part by solutions from the granite magma at the time that it came in contact with the limestone and in part at a later time by hot solutions which may either have been released from the granite during the process of cooling or from some deep-seated source after the granite had solidified, as was the case in the Lost River area (White and West, 1952).

MINERAL DEPOSITS AND RADIOACTIVITY STUDIES

Uranium in the form of zeunerite, a hydrous copper-uranium arsenate, was found concentrated at two localities and in trace amounts at three other places on Brooks Mountain. Other radioactive minerals are also present in the granite. Equivalent uranium and uranium analyses of pertinent Brooks Mountain samples are given in table 1. Sample locations are shown on figure 2.

As preliminary uranium analyses of samples from the zeunerite occurrences at Brooks Mountain closely paralleled the equivalent uranium analyses on the same samples it was believed that for the present investigation equivalent uranium analyses would be sufficient to indicate the amount of radioactive material present. Most analyses were made in the Geological Survey Trace Elements Section Washington Laboratory; some equivalent uranium analyses were

Table 1.--Analyses of selected samples from Brooks Mountain, Seward Peninsula, Alaska

Sample no.	Location	Type of sample	Description	Raw sample Percent eU 1/	Raw sample Percent U	Concentrate Percent eU 1/
4200	Foggy Day prospect	20 ft N-S channel	From south limestone contact to 6 ft north of pegmatitic lens, 3 ft below surface	0.01	--	--
4282	-do-	8 ft channel	Across pegmatitic lens, 4½ ft below surface	0.08	0.075	--
4278	-do-	18 ft N-S channel	From south limestone contact to 6 ft north of pegmatitic lens, 6 ft below surface	0.02	--	--
4434	-do-	2 ft channel	Central part of pegmatitic lens, 7½ ft below surface	0.25	0.22	--
4283	-do-	4 ft channel	Across pegmatitic lens, 9 ft below surface	0.06	--	--
4435	-do-	3.8 ft channel	Across pegmatitic lens, 11 ft below surface	0.12	0.09	--
4284	-do-	-do-	Across pegmatitic lens, 12 ft below surface	0.10	--	--
4436	-do-	-do-	Across pegmatitic lens, 14 ft below surface	0.16	--	--
4285	-do-	3.6 ft channel	Across pegmatitic lens, 15 ft below surface	0.12	--	--
4309	-do-	2 ft channel	Across pegmatitic lens, 18 ft below surface	0.028	--	--
3854	-do-	Float	Pegmatitic lens material	2.144	2.25	--
4012	-do-	Grab	-do-	0.068	0.04	--
4013	-do-	-do-	-do-	0.02	0.02	--
4016	-do-	-do-	-do-	0.27	0.2	--
4197	-do-	-do-	Limonite at north border of pegmatitic lens	0.23	--	--
4198	-do-	-do-	Pegmatitic lens material	0.014	--	--
4305	-do-	-do-	Black 1 in. seam in pegmatitic lens	0.31	--	--
4130	-do-	0.9 ft channel	Across small lens 5 ft south of pegmatitic lens, 6 ft below surface	0.2	--	--

1/ eU - equivalent uranium

Table 1.--Analyses of selected samples from Brooks Mountain, Seward Peninsula, Alaska--Continued

4108	Tourmaline No. 2 claim	Grab	Hematitic coating on tourmaline vein	1.0	--	--
4139	-do-	-do-	Tourmaline vein material	0.052	--	--
4163	-do-	-do-	Granite between tourmaline veins	0.005	--	--
4165	-do-	12 ft channel	Across tourmaline veins and granite	0.007	--	--
4166	-do-	Grab	Tourmaline vein material	0.054	--	--
4135	-do-	9.5 ft channel	Across tourmaline veins and granite	0.007	--	--
4185	S of Tourmaline No. 2 claim	Grab	Weathered tourmaline vein	0.013	--	--
4109	-do-	-do-	-do-	0.02	--	--
4235	-do-	-do-	Weathered granite	--	--	0.038a 2/
4117	Near SE corner of Midnight Sun claim and NE corner of Square Zero claim	-do-	-do-	0.006	--	--
4118	-do-	-do-	Granite dike	0.009	--	--
4320	Near isolated limestone outcrop on Iron Cap No. 5 claim	-do-	Weathered granite	0.012	--	--
4266	Pit S of Read prospect	-do-	-do-	0.005	--	--
4275	Paigeite claim	-do-	Aplite dike	--	--	0.005a
4288	N part of granite mass	-do-	Granite	--	--	0.016a
4101	75 ft N of Foggy Day prospect	-do-	Granite wash material	0.006	--	0.015a
4105	80 ft W of sample 4101	-do-	-do-	0.007	--	0.013b
4111	E of Foggy Day prospect	-do-	Granite	0.004	--	--
4113	West central part of Iron Cap No. 9 claim	-do-	-do-	0.007	--	0.10a
4115	Central part of Iron Cap No. 5 claim	-do-	-do-	0.004	--	0.17a
4116	E of sample 4115	-do-	-do-	0.005	--	0.20a
4240	North central part of Sunny Day claim	-do-	Oxidized granite	--	--	0.19a
4119	South slope above Crystal Creek-Anderson Creek saddle	-do-	Granite	0.005	--	--
4185	North slope above Crystal Creek-Anderson Creek saddle	-do-	Granite dike	0.007	--	--

2/ Crushed raw sample material which has been concentrated by screening, sliming, and methylene-iodide separation is shown by an a after the analysis; raw sample material concentrated by panning and methylene-iodide separation is shown by a b after the analysis.

made in the Fairbanks Laboratory of the Alaskan Trace Elements Unit.

Foggy Day Prospect

The largest concentration of zeunerite on Brooks Mountain was found at the Foggy Day prospect which is situated on the Foggy Day, Iron Cap, and Iron Cap No. 8 claims (fig. 2). This prospect is in granite adjacent to a contact with an altered marmorized limestone and consists of an open-cut about 20 ft deep which was excavated by the United States Smelting Refining and Mining Company during the summer of 1951. The zeunerite at this prospect occurs in a lens-shaped body of granite rock, about 15 ft in diameter and 4 or 5 ft thick. Both the zeunerite-bearing granitic lens and the adjacent granite are highly oxidized and weathered, though permanently frozen. The material in the lens appears to be a pegmatitic phase of the coarse-grained granite. An interpretation of the relation of lens rock to the surrounding granite is difficult because of the degree of decomposition of the rock. The pegmatite rock is porous and vuggy. The zeunerite occurs in tabular crystals up to $\frac{1}{4}$ in. in diameter embedded in bright red hematite, which usually fills the openings and vugs in the lens of pegmatitic rocks. The remaining space is generally occupied by clear ice, which in some cases has large crystals of zeunerite suspended in it. Zeunerite is found in minor to trace amounts in the openings and cracks in the granite rock that encloses the lens and in a very small granitic lens about 5 ft south of the larger lens. Considerable amounts of purple fluorite, black tourmaline, and smoky quartz occur in the pegmatitic phase. The minerals present in heavy mineral fractions (those greater than 3.3 sp gr) of two typical high- and low-grade samples from the lens are as follows:

Sample 4432

Minerals	Estimated percent
Zeunerite	70
Zircon	9
Hematite	9
Tourmaline	4
Limonite	3
Arsenopyrite	2
Fluorite	1
Scheelite	1
Chalcopyrite	1
Magnetite	trace

Sample 4198

Minerals	Estimated percent
Hematite	70
Limonite	20
Zircon	3
Zeunerite	2
Pyrrhotite	2
Fluorite	2
Scheelite	1
Arsenopyrite	trace
Magnetite	trace
Tourmaline	trace

Careful studies of the minerals in the lens disclosed that the only radioactive mineral other than zeunerite is hematite, although some of the other minerals contain minor amounts of uranium as revealed by flux tests. No primary uranium minerals were found in either the lens material or the surrounding granite. Radiometric data indicates that the pegmatitic lens material probably averages between 0.1 and 0.2 percent equivalent uranium. A few high-grade float specimens and localized concentrations in the lens have been found to contain as high as 2.1 percent equivalent uranium. The overall average of the lens rock and the surrounding zeunerite-bearing granite is about 0.07 percent equivalent uranium.

No radioactivity was found in the limestone near the Foggy Day prospect nor in the base metal veinlets in the limestone.

By the end of August, exploration at the Foggy Day prospect had almost completely removed the pegmatitic lens. At the bottom of the cut and the base of the lens, hematitic stringers were observed in a zone about 8 in. wide. These stringers may represent feeder channels coming out of the granite. If so, the zeunerite and hematite may have been deposited by solutions which followed these channels from a primary deposit at greater depths in the granite. However, it is also possible to account for the source of the zeunerite by assuming that at one time primary minerals including a uranium mineral filled the vugs in the porous granite and that the zeunerite and hematite are the remaining decomposition products.

Tourmaline No. 2 claim

Another locality where a concentration of uranium was found on Brooks Mountain is on the Tourmaline No. 2 claim approximately 700 ft southeast of the Luther prospect and a little over 500 ft from the nearest point along the granite-limestone contact (fig. 2). On this claim, networks of quartz-tourmaline veins ranging in width from a fraction of an inch to 4 in. occur in joint fractures in the granite. Zeunerite and brown scaly hematite are found as coatings on some of the vein surfaces and wall rocks. The concentration of radioactive material is restricted to the open veins. Tourmaline veins which completely fill the joint fractures contain no zeunerite or hematite. In August 1951 exploration by the United States Smelting Refining and Mining Company exposed some of the zeunerite-bearing tourmaline veins in several shallow pits and trenches. The veins were not traced for any great distance because of talus cover. Although a few pieces of high-grade vein rock contain as much as 1.0 percent equivalent uranium, the average content of the vein material is about 0.05 percent equivalent uranium. Also in this vicinity are several radioactive hematite-bearing tourmaline veins that contain no zeunerite, probably because of leaching.

Minor occurrences of zeunerite

Zeunerite, in trace amounts, was identified in samples from three other localities on Brooks Mountain as follows:

1) In weathered granite a short distance southeast of the Midnight Sun claim and the northeast corner of the Square Zero claim (sample 4117, fig. 2).

2) In slightly weathered granite at the northern boundary of the small isolated, paigeite-bearing limestone mass on Iron Cap No. 5 claim (sample 4320, fig. 2).

3) On the ore dump of the Cameron prospect (sample 4260, fig. 2).

Sample 4117 is in the tourmaline vein area and has a comparatively close proximity to the Tourmaline No. 2 claim deposits. Therefore, the minor amount of zeunerite at this site may have been derived from the same source as that on the Tourmaline No. 2 claim. The zeunerite in samples 4320 and 4260 is probably related in source to that of the Foggy Day prospect because of the nearness to this deposit. Several highly oxidized hematitic zones in granite, geologically similar to the Foggy Day occurrence, on Iron Cap No. 3, Sunny Day, and Iron Cap No. 9 claims contain no zeunerite although the hematite is slightly radioactive. There is no evidence of any large scale leaching of zeunerite in these deposits, if zeunerite was ever present. The hematite, although earthy, is generally more compact than at the Foggy Day prospect. The Cameron prospect, which has mineral assemblages similar to the Read and Luther prospects, is the only base metal prospect that is slightly radioactive. As stated above, its radioactivity is probably related in source to the Foggy Day deposit.

Radioactivity of the granite

The Brooks Mountain granite as a whole is slightly radioactive. The radioactivity is caused by zircon, monazite and xenotime, which are primary accessory minerals in the granite. The principal radioactive element in these minerals is probably thorium. The amount of radioactivity at any given place on the granite mass is directly proportional to the quantity of these accessory minerals present. The average equivalent uranium content of the granite is about 0.005 percent.

CONCLUSIONS

Zeunerite is the major uranium-bearing mineral at the surface in the Brooks Mountain area. Traces of uranium occur as an impurity in some of the fluorite, tourmaline, smoky quartz, hematite, limonite, siderite, malachite, azurite, tetrahedrite, arsenopyrite, biotite, muscovite, sericite, and a secondary bismuth mineral. Zircon, monazite, and xenotime are also radioactive, but the radioactivity of these minerals is probably due mainly to thorium.

The principal points of uranium mineralization are at two localities on Brooks Mountain although trace amounts of zeunerite have been found at three other places, which are probably structurally related to the two main zeunerite occurrences. Numerous other sites, geologically similar to the two main zeunerite-bearing sites, do not contain zeunerite. Consequently, most of the quartz-tourmaline veins on the mountain contain only a very small amount of radioactive material, and no other red oxidized zones in the granite are more than slightly radioactive. The marked restriction of principal zeunerite mineralization to the two localities indicates that uranium may have been derived from one or possibly two local primary sources within the granite. Radiometric examination of the granite mass and laboratory studies of the granite samples failed to disclose the presence of a primary uranium mineral from which the uranium in the zeunerite could have been derived.

Whereas surface evidence does not indicate the occurrence of a commercial uranium deposit at the Foggy Day prospect, this deposit differs from most known uranium deposits. It is probably of pre-glacial origin and has remained frozen below the permafrost table at least since the inception of the present period of permanently frozen ground conditions. Even though this condition would tend to preserve the deposit as it was before freezing, a considerable portion of it may have been eroded away by glacial action. If it is assumed that this zeunerite deposit is of secondary, water-borne origin, by being frozen, no enlargement of it was possible, as was the case in similar secondary deposits in temperate climates. For this reason, a total elimination of this deposit from consideration is probably not wise solely on the basis of poor surface showing, because, by so doing, comparison is being made with deposits in warmer climates that probably were never frozen or frozen for only a comparatively short period of time.

RECOMMENDATIONS FOR PROSPECTING

Further discoveries of surficial occurrences of zeunerite similar to the Foggy Day prospect and Tourmaline No. 2 claim would probably not contribute much to the present knowledge of the origin of the uranium minerals at Brooks Mountain, as the known occurrences have been rather comprehensively investigated by both Survey and United States Smelting, Refining, and Mining Company geologists. Consequently, further exploration of this uranium occurrence should be directed toward testing the hypothesis of a primary uranium oxide source for the uranium in the zeunerite. It is believed that the best method of testing this hypothesis is by diamond drilling close to the surface workings at the Foggy Day prospect in an attempt to intersect the uraniferous zone at shallow depths, with the objective of determining whether any significant changes in mineral content occur at 25, 50, 100, 150, and 200 ft below the surface. The main significant change to be sought is the introduction of uraninite or pitchblende into the mineral assemblage of the deposit. The shallower holes should of course be drilled first as very little is known of the subsurface attitude of the deposit, if such exists.

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