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Preliminary Reconnaissance Survey for Thorium, Uranium, and Rare-Earth Oxides, Bear Lodge Mountains, Crook County, Wyoming

By V. R. Wilmarth and D. H. Johnson

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Trace Elements Investigations Report 172

UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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Geology and Mineralogy

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PRELIMINARY RECONNAISSANCE SURVEY FOR THORIUM, URANIUM, AND RARE-EARTH OXIDES, BEAR LODGE MOUNTAINS, CROOK COUNTY, WYOMING

By

V. R. Wilmarth and D. H. Johnson

April 1953

Trace Elements Investigations Report 172

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

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PRELIMINARY RECONNAISSANCE SURVEY FOR THORIUM, URANIUM, AND RARE-EARTH OXIDES, BEAR LODGE MOUNTAINS, CROOK COUNTY, WYOMING

By

V. R. Wilmarth and D. H. Johnson

ABSTRACT

An area about 6 miles north of Sundance, in the Bear Lodge Mountains, in Crook County, Wyo., was examined during August 1950 for thorium, uranium, and rare-earth oxides and samples were collected.

Uranium is known to occur in fluorite veins and iron-manganese veins and in the igneous rocks of Tertiary age that compose the core of the Bear Lodge Mountains. The uranium content of the samples ranges from 0.001 to 0.015 percent in those from the fluorite veins, from 0.005 to 0.018 percent in those from the iron-manganese veins, and from 0.001 to 0.017 percent in those from the igneous rocks. The radioactivity of the samples is more than that expected from the uranium content. Thorium accounts for most of this discrepancy. The thorium oxide content of samples ranges from 0.04 to 0.25 percent in those from the iron-manganese veins and from 0.07 to 0.39 percent in those from the sedimentary rocks, and from 0.04 to 0.30 in those from the igneous rocks.

Rare-earth oxides occur in iron-manganese veins and in zones of altered igneous rocks. The veins contain from 0.16 to 12.99 percent

rare-earth oxides, and the igneous rocks, except for two localities, contain from 0.01 to 0.42 percent rare-earth oxides. Inclusions of metamorphosed sedimentary rocks in the intrusive rocks contain from 0.07 to 2.01 percent rare-earth oxides.

INTRODUCTION

Deposits that contain thorium, uranium, and rare-earth oxides were discovered near Warren Peaks in the Bear Lodge Mountains, northeastern Wyoming, in September 1949 by A. J. Katches, engineer for the Telmor Engineering Company of Chicago, Ill. In March 1950, samples of radioactive fluorite from the Bear Lodge Mountains, that contain as much as 0.015 percent uranium, were submitted to the U. S. Geological Survey by F. Mischand of Custer, S. Dak. As the association of fluorite with radioactive material is apparently of widespread occurrence, the writers spent 2 weeks in August 1950 examining the uranium-bearing fluorite and rare-earth deposits. The purpose of this reconnaissance was to obtain information on the mode of occurrence, extent, and reserves of these deposits. This work was done on behalf of the Division of Raw Materials of the Atomic Energy Commission.

Location and accessibility

The thorium, uranium, and rare-earth deposits are in the southern part of the Bear Lodge Mountains, approximately 6 miles north of Sundance, Crook County, Wyo. (fig. 1). The majority of the known

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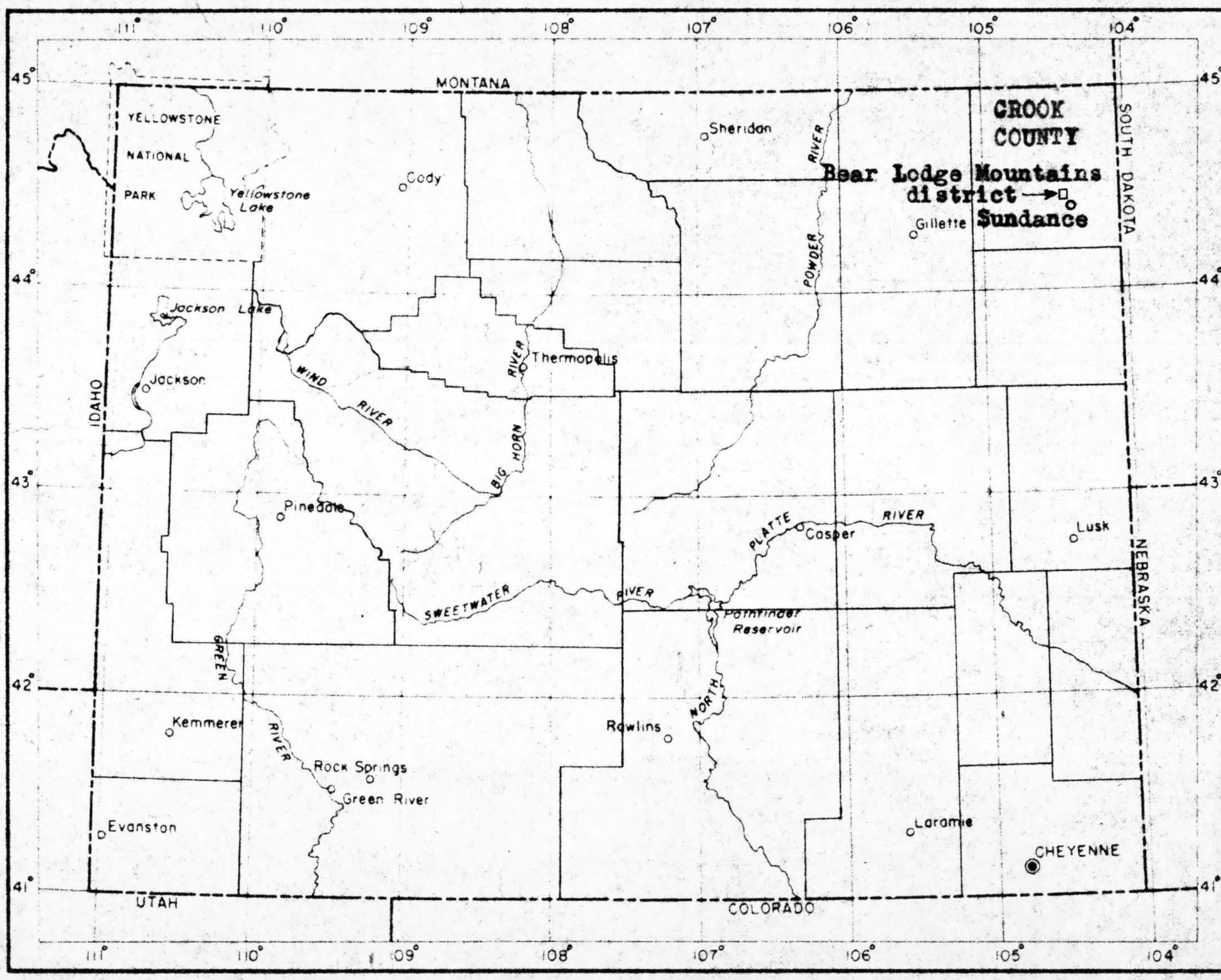

Figure 1. - Index map of Wyoming, showing location of the Bear Lodge Mountains district.

deposits are in Tps. 51 and 52 N., Rs. 63 and 64 W., 6th principal meridian, and are accessible from Sundance over the Forest Service access road from Sundance to Alva, Wyo. The roads from Sundance to the deposits commonly are closed by snow during the winter months. Sundance is on U. S. Highway 85 about 29 miles north of Upton, Wyo., the nearest railhead on the Chicago, Burlington, and Quincy railroad.

History

The early prospectors in the Bear Lodge Mountains were interested in gold and silver, and evidence of their placer and underground mining can be found in the region. Prior to 1900, the Bond Mining Company produced gold and silver from two mines just south of Warren Peaks. Fluorite deposits in the area have been known since 1914, but it was not until 1943 that an attempt was made to develop them. Such development has been carried on principally by the Wyoming Fluorspar Company and F. W. Peterson of Sundance, Wyo., and E. W. Peterson of Tacoma, Wash. No large tonnage of fluorspar has been produced, and no mines are operating in 1953. Extensive prospecting for manganese was carried on at the Black Rock mine during the early part of 1942, but little if any manganese ore was obtained.

The recent discovery of radioactive material and rare-earth oxides has stimulated prospecting in this region and has resulted in the filing of many claims on much of the open land in the vicinity of Warren Peaks. The Telmor Engineering Company of Chicago, Ill., and a group of independent operators are currently developing and exploring approximately 100 claims for thorium, uranium, and rare-earth oxide ores.

Geologic investigations

The complex geology of the Bear Lodge Mountains has been described by Scott (1897), Ward (1899, p. 521-946), Richardson (1903, p. 365-393), Darton (1905, 1909), and by Pierce, Hanna, and Girard (1944). In 1944 the U. S. Bureau of Mines (Dunham, 1946) investigated the Bear Lodge fluorite property as part of the strategic minerals program; the geology was described by Cox (written communication 1945). In 1944, during a brief examination of the Bear Lodge Mountains for radioactive materials, abnormal radioactivity was detected in the igneous rocks north and east of Warren Peaks (Slaughter and Nelson, written communication 1945, ~~p. 3~~). The results of analysis of samples from this area indicate that the greater part of the radioactivity was caused by thorium.

In March 1950, the U. S. Bureau of Mines began a diamond-drilling program to investigate the rare-earth deposits on claims owned by the Telmor Engineering Company. In August 1950, the writers examined the fluorite and rare-earth deposits in the Bear Lodge Mountains as part of an investigation of the association of fluorite with radioactive materials. A comprehensive study of the geology of this area was not possible at the time; therefore, a preliminary sampling program was undertaken to delimit the thorium, uranium, and rare-earth metal occurrences. Preliminary traverses for radioactivity of all the accessible roads were made with carborne equipment, and detailed radiometric traverses of bulldozer trenches and pits were completed. Samples were collected for rare-earth, thorium, and uranium analysis.

A. J. Katches of the Telmor Engineering Company and C. A. Baker and J. Guidinger, both of Sundance, Wyo., provided claim maps and guided the field party through the area.

GEOLOGY

The Bear Lodge Mountains, 15 miles long and 3 miles wide, trend northwest, and form an elongate dome-shaped uplift with a central core of granite of pre-Cambrian age and monzonite and syenite porphyries of Tertiary age. Upturned beds of sedimentary rocks ranging in age from Cambrian to Tertiary flank the central core.

Igneous rocks

The largest exposure of pre-Cambrian granite is east of Warren Peaks where a mass nearly 3 miles long and half a mile wide roughly parallels the eastern contact of the igneous rocks with the sedimentary rocks. Smaller bodies of granite, not more than a quarter of a mile across, crop out west of Warren Peaks. The granite is a fine-grained, light-gray rock that consists essentially of orthoclase, biotite, quartz, muscovite, and magnetite. Locally the granite has a pegmatitic texture.

The Tertiary monzonite and syenite porphyries are yellow, red, or gray and generally are greatly altered. The fresher porphyry is fine-grained and contains augite, biotite, brown to green amphibole, oligoclase, and orthoclase, but locally quartz constitutes as much as 15 percent of the rock. The altered porphyry varies within a few feet from rock that contains abundant phenocrysts to rock with few phenocrysts. The phenocrysts are orthoclase, commonly rimmed with oligoclase and sanidine. The groundmass is a fine-grained trachytic felt of oligoclase with minor augite and biotite. The chief alteration products are sericite, kaolin, and hydrous iron oxides.

In thin sections the porphyritic texture of the Tertiary igneous rocks is evident. Some orthoclase phenocrysts as much as a quarter of an inch long are replaced in part by later feldspars, clay, and hematite. Commonly small irregular masses of anhedral plagioclase have replaced the orthoclase of the phenocrysts. The groundmass is composed of very fine-grained plagioclase and quartz. Quartz grains constitute as much as 15 percent of the rock locally but average less than 10 percent. Hematite, which occurs as irregular masses, narrow veins, and pseudomorphs after pyrite cubes, commonly makes up 10 percent of the rock. Jarosite and limonite are abundant locally.

The intrusive igneous rocks near WarrenPeaks are in general altered. Locally, as at the Inum No. 2 claim (fig. 2) they are completely altered, resulting in a whitish-green to salmon-pink, hard, vuggy porcellanite. The vugs are in part filled by botryoidal hematite, clay minerals, orthoclase, and chalcedony. A thin section from sample W-81 shows the rock to be composed almost entirely of clay minerals and chalcedonic quartz. Clear, glassy orthoclase crystals are common in the vugs. The rare-earth oxide content of this sample is 9.24 percent.

Sedimentary rocks

The sedimentary rocks in the Bear Lodge Mountains range in age from Cambrian to Tertiary. All the deposits from which fluorspar has been produced are in the Pahasapa limestone of Mississippian age. A generalized stratigraphic column for the Bear Lodge Mountains is given in table 1.

ORE DEPOSITS

The ore deposits of the Bear Lodge Mountains have been described briefly by Darton (1905). Small quantities of gold have been produced from quartz fissure veins in the Tertiary intrusive rock near Warren Peaks and from placer deposits in the lower quartzites and conglomerates of the Deadwood formation in Rudy Canyon near Sundance.

Approximately a mile north of Warren Peaks, (fig. 2), cuprite and malachite occur as coatings on fracture surfaces in the altered igneous rock; however, only a few tons of relatively rich copper ore has been produced. Several tons of fluorite was mined from the Pahasapa limestone that crops out along the southern part of the Bear Lodge uplift.

Table 1. - Generalized stratigraphic section, Bear Lodge Mountains, Wyoming.

Formation	Thickness (feet)	Description
Tertiary		
Sand and gravels	25-150	----------
——Unconformity——		
Upper Cretaceous		
Carlile shale	350	Gray, thin-bedded shale and thin-bedded sandstone.
Greenhorn limestone	40	Gray, thin-bedded limestone.
Graneros shale	1,000	Dark-gray shale, light to dark-gray, hard sandy shale grading to a sandstone near bottom of formation.
Dakota sandstone	40-100	Reddish-brown, massive, cliff-forming sandstone.
Lower Cretaceous		
Fuson shale	10-40	Gray to red sandstone and shale; forms steep slopes.
Lakota sandstone	150-300	Gray to buff, massive cliff-forming, cross-bedded sandstone with coal and conglomerate near base.
Morrison formation	125-150	Gray, buff pale-green shale, and gray, thin bedded sandstone; forms steep slopes.
——Unconformity——		
Jurassic		
Sundance formation	325	Buff sandstone; green fossiliferous shale; reddish, shaly sandstone, and buff sandstone.

Table 1. - Generalized stratigraphic section, Bear Lodge Mountains, Wyoming - Continued.

Formation	Thickness (feet)	Description
Unconformity		
<u>Triassic</u>		
Spearfish formation	500-600	Red sandy shale and sandstone, with gypsum beds.
<u>Permian</u>		
Minnekahta limestone	40	Gray, thin-bedded, cliff-forming limestone.
Opeche formation	60-80	Red sandy shale and sandstone.
<u>Pennsylvanian</u>		
Minnelusa sandstone	500-600	White, massive sandstone, buff to brown, limy sandstone, and red shale.
<u>Mississippian</u>		
Pahasapa limestone	600	Light-gray, massive limestone; forms cliffs.
Englewood limestone	50	Pink, thin-bedded limestone.
Unconformity		
<u>Ordovician</u>		
Whitewood limestone	80	Pinkish, massive cliff-forming limestone.
<u>Cambrian</u>		
Deadwood formation	100-300	Shale and limestone breccia; sandstone and quartzite.

Radioactive fluorite deposits

The fluorite deposits in the Bear Lodge Mountains are in narrow veins in the Tertiary intrusive rocks and in veins and replacement bodies in the Pahasapa limestone of Mississippian age. The known radioactive fluorite deposits, at the Sunrise Lode and the Home Fire No. 43 claim, occur as veins in the igneous rocks; samples from these deposits contain from 0.003 to 0.015 percent uranium. Examination for radioactivity of 14 fluorite deposits in the limestone did not disclose significant radioactivity. Samples from 9 of these fluorite deposits contain from 0.001 to 0.003 percent uranium.

The Sunrise Lode in the NW 1/4 sec. 22, T. 52 N., R. 63 W., 6th principal meridian, Crook County, Wyo., owned by C. A. Baker and associates of Sundance, Wyo., has been developed by several shallow prospect pits on a 6- to 12-inch wide fluorite vein at the contact of Tertiary monzonite porphyry and the quartzite of the lower Deadwood formation of Cambrian age. The vein strikes N. 20° W., dips 40° S., and can be followed for 150 feet along the strike. Readings of 1.7 mr/hr on a Geiger-Muller counter were noted on the fluorite vein. Two grab samples, C-12 and W-85, (table 2) contain 0.015 and 0.006 percent uranium respectively.

In thin sections of specimens from the vein, fluorite, fragments of sedimentary and igneous rocks, euhedral to subhedral quartz grains, and minor quantities of calcite, wad, and hematite were noted. The included igneous rock fragments have been partly altered to clay.

Table 2. - Analyses of samples from fluorite deposits, Bear Lodge Mountains, Crook County, Wyoming. [1]

Sample number	Property	Description	Equivalent uranium (percent)	Uranium (percent)
C-2	May lode	Granular purple fluorite cut by calcite veinlets	0.001	
C-3	Bear Lodge lode	Purple fluorite with clay and quartz	.002	
C-4	Bear Lodge lode	Pale-purple to black fluorite in limestone breccia	.002	
C-5	James Walter claim	Purple fluorite veinlets and calcite	.002	
C-6	Nichols No. 1 lode	Purple fluorite cut by iron-stained calcite vein	.002	
C-7	Baker lode	Crystals of purple fluorite in iron-stained quartzite	.002	
C-8	Nichols lode	Purple fluorite and calcite	.002	
C-9	Blue Bell lode	Pale-purple to white fluorite with clay veinlets	.001	
C-10	McCoy No. 3 lode	Purple fluorite with iron-stained clay	.003	
C-11	May B lode	Dark fluorite with quartz, clay, and limonite	.003	
C-12	Sunrise lode	Dark-purple, crystalline fluorite in quartzite	.015	0.015
W-85	Sunrise lode	Dark-purple, crystalline in quartzite	.043	.006
W-86	Peterson No. 1 claim	Dark-purple, massive fluorite with calcite	.004	.003
W-87	Home Fire No. 43 claim	Dark-purple fluorite and wad	.013	.003
C-1	Home Fire No. 43 claim	Dark-purple crystalline fluorite with limonite	.010	.010

[1] Analysis by Trace Elements Section, Geochemistry and Petrology Branch, Denver, Colo.

Small pods of rounded quartz grains in the vein probably represent inclusions of the quartzite from the Deadwood formation. Locally fluorite embays and replaces the cement along the quartz grain boundaries. Dark-purple, finely crystalline fluorite, the most abundant mineral in the vein, is interstitial to the quartz grains and rock fragments. A coarsely crystalline variety of dark-purple fluorite that is later than the finely crystalline fluorite occurs as narrow veins and commonly as thin crusts in small vugs in the finer-grained fluorite.

The Home Fire No. 43 claim, formerly known as the Old Clark Lode, is owned by C. A. Baker and associates of Sundance, Wyo. The claim is in the NE 1/4 sec. 28, T. 52 N., R. 63 W., 6th principal meridian, Crook County, Wyo. A 15-foot vertical shaft was dug to explore narrow fluorite veinlets in altered Tertiary monzonite porphyry. The fluorite veinlets average 3 inches in width and fill fractures in the wall rock. Readings of 4 to 6 divisions on the 0.2 scale of a Geiger-Muller counter were observed from the fluorite veinlets, whereas only 0.5 to 1.0 divisions on the 0.2 scale were noted from the altered monzonite porphyry. Two grab samples of fluorite contained 0.010 and 0.003 percent uranium respectively.

Examination of fluorite deposits at the Peterson No. 1, Baker lode, Bear Lodge lode, Blue Bell lode, McCoy No. 3 lode, May B lode, James Walter, Nichols lode, Nichols No. 1 lode, May, Custer, Custer No. 1, Bear Lodge No. 2, and Wright No. 1 claims indicated no significant anomalous radioactivity. These deposits are in the Pahasapa limestone near its contact with the Tertiary intrusive rocks. The fluorite occurs as discontinuous fissure veins that parallel or nearly parallel the bedding, and as discontinuous replacement bodies. The veins range from 2 inches to a foot in width and from 6 inches to 6 feet in length. Replacement fluorite bodies vary from a few widely disseminated fluorite crystals to masses as much as 2 feet wide and 10 feet long. The fluorspar generally is fine-grained, granular to massive, dark-purple to colorless fluorite associated with calcite, quartz, and limestone fragments. The vein-fluorite is coarsely crystalline and most commonly consists of cubes and octahedra, as much as 5 mm across. Fluorite crystals characterized by alternating bands of dark-purple and colorless fluorite line the vein walls. Colorless calcite occurs as interstitial vein filling. Colorless euhedral to anhedral quartz crystals fill the interstices between fluorite grains and locally replace the fluorite along cleavage planes. Growth rings found in many of the large quartz crystals may represent clay minerals deposited contemporaneously with the quartz. Psilomelane and hydrous iron oxides commonly coat fractures in the fluorite and were the last minerals to be deposited. Ten samples of fluorite from some of these deposits range from 0.001 to 0.003 percent equivalent uranium (table 2).

The results of spectrographic analysis of selected samples of dark purple radioactive fluorite (W-85B) from the vein at the Sunrise lode and the dark purple non-radioactive fluorite (W-86B) from the replacement deposit in limestone at the Peterson No. 1 claim are given in table 3. These samples were analyzed to determine the variations in minor element content between the radioactive fluorite in veins and the non-radioactive fluorite from the replacement deposit. As shown in table 3, the vein fluorite contains 0.X percent thorium, which explains the higher percent equivalent uranium in this sample. In general, the vein fluorite contains greater quantities of the elements listed in table 3 than does the fluorite from the replacement deposits. The color of the fluorite appears to be independent of the quantity of radioactive material.

Thorium and rare-earth deposits

The two areas in the Bear Lodge Mountains (fig. 2) that have been prospected extensively for uranium and rare-earth minerals are a west-trending zone that includes most of the Inum group of claims, just north of Warren Peaks, and a northeast-trending zone through the Climax group of claims, especially the Climax No. 8 and No. 10 claims. Results of analyses of samples from these zones indicate that the thorium, uranium, and rare-earth oxides occur for the most part in iron-manganese veins that fill fractures in the monzonite and syenite porphyries and in zones of intensely altered igneous rocks.

No ore has been produced from these deposits, although parts of the deposits contain uranium and rare-earth oxide of commercial grade.

Iron-manganese veins

Iron-manganese veins that contain thorium, uranium, and rare-earth

Table 3. – Semiquantitative spectrographic analyses of fluorite from Sunrise lode and Peterson No. 1 claim, Crook County, Wyoming. 1/

Sample number	Description	Pb	Be	Ca	Al	Ti	Ba	Sr	Y	La	Ag	Zr	Th	Cu	Mn	Cr	Sc	V	Mg	Sn
W-85B	Dark-purple crystalline fluorite from vein on Sunrise lode	0.0X	0.00X	XX.0	X.0	0.0X	0.0X	0.0X	0.0X	0.0X	0.0X	0.0X	0.X	0.0X	0.00X	0.000X	Trace.	0.X	0.00X	0.00X
W-86B	Dark-purple fluorite from replacement body in limestone on Peterson No. 1 claim	0.00X	0.000X	XX.0	0.X	0.00X	0.00X	0.00X	0.00X	0.000X	0.00X	0.00X	–	0.00X	0.0X	0.00X	–	0.0X	0.00X	Trace.

Looked for but not found: Ni, Co

1/ Analysis by Survey Library ~~Trace Elements section, Geochemistry and Petrology Branch~~, Denver, Colorado.

oxides are notably abundant in the area covered by the Inum and Climax group of claims. The veins range in width from one inch to as much as 2 feet and are exposed along strike for as much as 300 feet; the average length of 12 veins is approximately 50 feet. The veins trend predominantly northwest and dip 12° to 30° NE.; a complementary set of veins trends northeast and dips 60° to 85° NW.

The vein material is dark reddish-brown to black and relatively soft and porous, although locally, as at the Climax No. 10 claim, the veins, because of abundant jasper, are hard and siliceous. There are all gradations from the highly siliceous to the soft and porous vein rock. Thin sections show that the typical vein contains hematite and limonite (40 percent), psilomelane and other manganese oxides (20 percent), orthoclase (15 percent), chalcedony (10 percent), and jarosite, clay, and fragments of igneous rocks (15 percent). Hematite occurs as botryoidal masses, commonly having a fibrous structure, intermixed with hydrous iron oxides and minor quantities of secondary black manganese minerals. The maximum manganese content of the veins is 15 percent, but the average is approximately 10 percent. Euhedral to anhedral orthoclase crystals, as much as one-fourth inch in length, commonly are replaced along crystal boundaries by clay, hematite, and limonite. Fragments of syenite porphyry, partly altered to clay, constitute approximately 10 percent of the vein material, although locally the veins contain as much as 50 percent igneous rock fragments. Chalcedony occurs as vug and fracture fillings in the vein material. No discrete minerals that are known to contain uranium or rare-earth oxides have been identified.

The analytical results of 6 samples (W-77, -90, -92, -94, -102, and -105) of oxidized vein material are given in table 4. The uranium content of these samples ranges from 0.005 to 0.018 percent and the rare-earth oxide content ranges from 0.20 to 12.99 percent. As shown in table 4, the percent equivalent uranium of these samples ranges from 0.020 to 0.075, whereas the uranium content is much lower; this discrepancy is due largely to thorium. The thorium oxide content of these samples is approximately 10 times greater than the uranium content. Spectrographic analyses (table 4) of these 6 samples of oxidized vein material indicate that bismuth, lead, tin, zinc, niobium, and the cerium-earth metals are generally more abundant in the iron-manganese veins than in the samples of igneous rocks from the area shown in figure 2 that have been analyzed.

Although no rare-earth minerals have been identified, some of the veins contain abundant rare-earth oxides. Sample W-77, for example, contains 12.68 percent rare-earth oxides. In thin section this rock contains hematite intermixed with hydrous iron oxides and psilomelane (65 percent), chalcedony (20 percent), and partially altered orthoclase (15 percent). According to Rankama and Sahama (1950, p. 529), manganiferous limonitic ores in Virginia contain thin coatings of weinschenkite, a hydrous, rare-earth-bearing phosphate. Although no phosphate minerals were identified in thin sections of the vein material, a finely-divided secondary rare-earth mineral, possibly weinschenkite, was obscured in the iron and manganese minerals. Heavy-liquid separations of samples W-94 and W-105 were made to determine the niobium and rare-earth oxide distribution in the separates. The results of spectrographic analyses are given in the following table:

Sample no.	Description	Ce	La	Nd	Y	Nb
W-94	Bulk sample	0.X	0.X	--	0.00X	0.X
W-94A	Fraction < 2.8 sp. gr.	0.X	0.X	--	0.0X	0.0X
W-94B	Fraction > 2.8 sp. gr.	0.X	0.X	--	0.0X	0.X
W-105	Bulk sample	X.0	X.0	--	0.X	0.0X
W-105A	Fraction < 2.8 sp. gr.	X.0	X.0	--	0.0X	--
W-105B	Fraction > 2.8, < 3.3 sp. gr.	XX.0	X.0	X.0	0.0X	--
W-105C	Fraction > 3.3 sp. gr.	XX.0	X.0	X.0	0.X	--

Microscopic examination of the separate fractions of sample W-94 shows that sample W-94A consists predominantly of a soft, white material, presumably clay, with minor quantities of quartz, orthoclase, calcite, and mica. Fraction W-94B consists primarily of hematite, hydrous iron oxide, psilomelane, wad, and minor quantities of altered orthoclase. In samples W-94A and B the Ce, La, and Y content in the separate fractions is nearly equal, suggesting that they are equally as well concentrated in the clay minerals as in the iron and manganese oxides. In samples W-105A, B, and C, there is greater concentration of cerium and yttrium-earth metals in the heavier fractions. Sample W-105C contains only manganite, psilomelane, and wad and contains greater quantities of Ce and Y. Sample W-105B which is composed mainly of orthoclase in part altered to clay, hematite, and limonite, contains less yttrium. The main constituent of sample W-105A is unaltered orthoclase, and in this fraction the Ce, La, and Y content is less than the other two fractions. In general then, the above results suggest that the Ce, La, and Y content of the vein material is concentrated in the clay minerals and in the iron and manganese oxides.

Sedimentary and igneous rocks

The monzonite and syenite porphyries which form the core of the Bear Lodge Mountains contain numerous inclusions of altered and metamorphosed sandstone, shale, and limestone (fig. 2). These inclusions range from 3 to 50 feet in width and from a few to 500 feet in length. The results of analysis of 6 samples, W-79, -84, -101, -123, -130, -132, of sedimentary rocks from these inclusions in the igneous rocks are given in table 4. The equivalent uranium content of these samples ranges from 0.000 to 0.067 percent; the uranium content from 0.001 to 0.005 and the rare-earth oxide content from 0.07 to 2.01 percent. Thorium oxide was found in only two samples. In general, the total rare-earth oxide content of the limestones is greater than that for the quartzites and shales (table 4).

Samples of the igneous rocks contain from 0.001 to 0.017 percent uranium and from 0.07 to 10.76 percent rare-earth oxides. Of the 47 samples of igneous rock analyzed, 10 contain less than 0.1 percent, 34 contain from 0.10 to 0.50 percent, 2 contain from 0.50 to 5.0 percent and 2 contain more than 5 percent rare-earth oxide. According to Rankama and Sahama (1950, P. 528), some granites and syenites contain from 0.016 to 0.02 percent cerium-earth metals, and Goldschmidt (1937, p. 655) reports that the lanthanum content of one sample of granite is nearly 0.2 percent. Thus the majority of the samples analyzed contain more rare-earth oxides than average granites and syenites.

The samples of igneous rocks that contain appreciable quantities of rare-earth oxides are W-81 and W-137. Sample W-81 contains 9.24 percent rare-earth oxide and is a completely altered igneous rock from the pit at the Inum no. 2 claim. The principal minerals are clays and chalcedonic quartz. Although this type of rock contains rare-earth oxides in potentially commercial quantities more development work is necessary to determine the size and distribution of this rock.

A grab sample (W-137) of partly altered monzonite porphyry contains 10.76 percent rare-earth oxides. Heavy-liquid separations were made of this sample; the spectrographic results are shown below.

Sample no.	Description	Ce	La	Nd	Y
W-137	Bulk sample	X.0	X.0	-	0.0X
W-137A	Fraction >3.3 sp. gr.	XX.0	XX.0	XX.0	0.0X
W-137B	Fraction >2.8 <3.3 sp. gr.	XX.0	XX.0	XX.0	0.0X
W-137C	Fraction <2.8 sp. gr.	0.X	0.X	0.X	0.00X

In general these results show that the material that contains the concentration of rare-earth oxides occurs in the heavier fractions. Although no discrete minerals were identified in the separate fraction, an X-ray powder diffraction pattern on the sample W-137A showed monazite to be present.

CONCLUSIONS

The results of this investigation for thorium, uranium, [illegible], and rare-earth oxides in the Bear Lodge Mountains, Wyo., are as follows:

1) The percentage of uranium in the fluorite veins ranges from a 0.001 to 0.015, in the igneous rocks from 0.001 to 0.017, and in the iron-manganese veins from 0.005 to 0.018.

2) Most of the radioactivity results from thorium; the thorium oxide content of the material analyzed ranges from 0.03 to 0.39 percent.

3) The rare-earth oxide content of the iron-manganese veins ranges from 0.20 to 12.99 percent, but because of the limited size of the veins and the high cost of mining, commercial production of rare-earth ore from the veins under present conditions would be prohibitive.

4) At all but two localities the rare-earth oxide content of the igneous rock samples is too low to be of economic significance at this time. At these two localities further development and detailed sampling are necessary to determine the size and shape of the zone enriched in rare-earth oxides.

5) Although monazite was detected by X-ray analysis, discrete thorium, uranium, or rare-earth minerals were not found, and it is

believed that these elements are concentrated in the clay minerals or in the iron and manganese oxides.

6) Additional deposits of thorium and rare-earth oxides are most likely to be found in the areas in the intrusive rocks that contain abundant iron-manganese veins.

LITERATURE CITED

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