TWO URANIUM-BEARING PEGMATITE BODIES IN SAN BERNARDINO COUNTY, CALIFORNIA*

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Abstract

Two uranium-bearing pegmatite bodies have been discovered recently in San Bernardino County, California. Examination shows that each one contains small amounts of some uncommon minerals that are composed largely of titanium, niobium, and uranium. However, the mineral assemblages are different for each. One body, in the Cady Mountains, contains, in addition to the common feldspars and quartz, the rare minerals betafite, niobian anatase, and cyrtolite. This is the first known occurrence of betafite in California. From the Pb^{206}/U^{238} ratio of betafite, the geologic age of the pegmatite has been determined as 155 million years or Middle Jurassic.

The other pegmatite body, at Pomona Tile quarry near Rock Corral, 40 miles southwest of the one in the Cady Mountains, contains euxenite and an unidentified uranium-bearing mineral, as well as the rare-earth minerals monazite and allanite and several common minerals. Euxenite is described for the first time from California. According to the lead-uranium ratio of the euxenite the age of this pegmatite is 150 million years or Middle Jurassic. The isotopic composition of lead in the euxenite has not yet been determined, so the amount of original lead is unknown.

Introduction

As a result of the widespread interest in uranium and thorium many persons, mostly prospectors and amateur mineralogists, are searching the Mojave Desert for radioactive minerals, and some have been successful. The Cady Mountains pegmatite was brought to the attention of D. F. Hewett by Oscar Hoerner, who lives 6 miles southeast of Newberry Station on the Atchison, Topeka & Santa Fe Railroad, and by Ralph W. Ross, of South Pasadena. These two were very helpful in guiding Hewett to the pegmatite during February 1950. The Pomona Tile Quarry pegmatite was found by Hewett in February 1951 during a reconnaissance in the Rock Corral area.

The descriptions of the geologic features and relations of both pegmatite bodies presented here are based on field work by D. F. Hewett, who collected numerous specimens. The minerals were determined by Jewell J. Glass, who also organized the laboratory work. Spectroscopic analyses of the numerous specimens were made by K. J. Murata; *x*-ray work was done by J. M. Axelrod and F. A. Hildebrand; all are members of the staff of the U. S. Geological Survey.

Locality and Accessibility

The Cady Mountains pegmatite here named is at the top of one of the

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highest peaks of the Cady Mountains (Fig. 1), a rugged area that lies about 35 miles east of Barstow, between the Union Pacific Railway and U. S. Highway 91 on the north, and the Atchison, Topeka and Sante Fe Railroad and U. S. Highway 66 on the south. It is accessible from Hector, on the Santa Fe Railroad, by a fairly good desert road, as follows:

1. From Hector, N. 20° E., about 2 miles.
2. Due east on section line about 4 miles.
3. Northeast up wash into canyon about $2\frac{1}{2}$ miles.
4. Northwest up wash to base of mountain about half a mile.
5. From this point a trail leads westward up the mountain slope to the pegmatite, which lies about 750 feet above the wash.

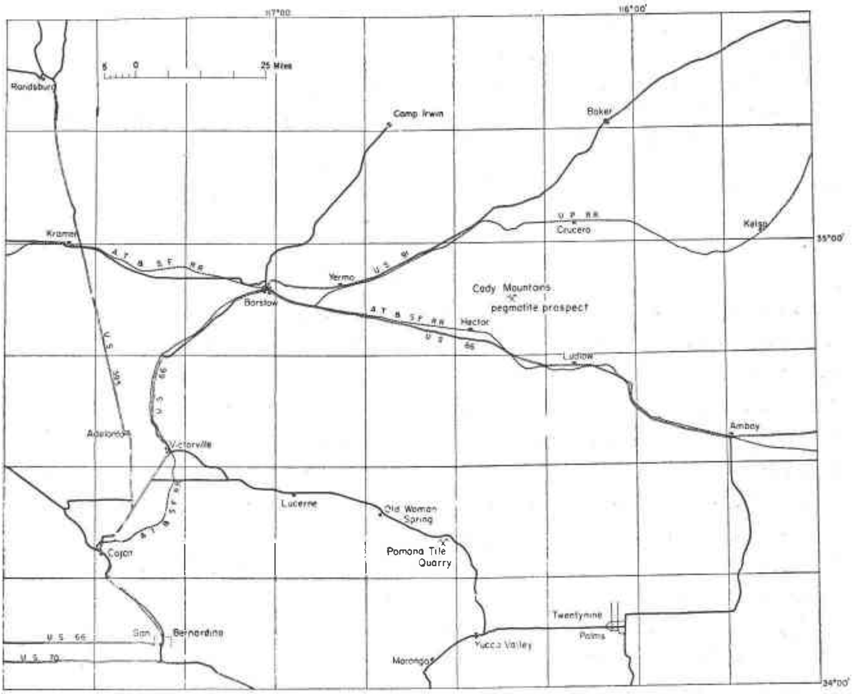

FIG. 1. Sketch map of part of San Bernardino County, California, showing location of pegmatite prospects.

The Pomona Tile Quarry pegmatite here named is about 19 miles northwest of Yucca Valley, a settlement on the paved State highway that extends from the vicinity of Whitewater, on U. S. Highway 70-60-99, up Morongo Valley to Twentynine Palms. From a point on this highway a mile east of Yucca Valley, a graded desert road leads northwest 16 miles to a spur that extends to Rancho Roqueño. The Pomona Tile

Co. quarry road from this spur turns west 1.8 miles from the junction with the road from Yucca Valley. The Pomona Tile Co. quarry lies on the crest of a prominent ridge $2\frac{1}{2}$ miles from the Yucca Valley road. Rock Corral, a well-known watering trough, is 2 miles west of the quarry. The Pomona Tile Co. quarry is about 40 miles S. 10° W. from the Cady Mountains pegmatite.

Geology of the Cady Mountains Pegmatite Area

The host rock of the pegmatite body is a type of quartz monzonite that is common in the eastern Mojave Desert. There is no record that more than a small part of the rocks of the Cady Mountains has ever been studied or mapped. During 1930–31 Dion L. Gardner (1940) mapped about two-thirds of the area between longitude 116° and 117° W. and latitude 34°30′ and 35°00′ N. Gardner, however, did not study or map the rocks of the Cady Mountains. In 1945 Cordell Durell (1953) mapped the eastern part of the Cady Mountains in connection with a study of the celestite deposits along the south slope. Durell has been kind enough to give a copy of his map to the writers. This map shows that the southeastern part of the Cady Mountains is wholly Tertiary volcanic rocks; there are basalt flows at the base of the section, overlain by andesite flows, and these by rhyolite tuffs and playa deposits, which contain the beds of celestite. The map shows a small area of granite (monzonite) in the saddle that separates the main mass of the Cady Mountains from the lower hills to the southeast. This granite (monzonite) appears to form most of the higher part of the Cady Mountains in which the pegmatite is found.

Near the Cady Mountains pegmatite body, the monzonite is coarsely crystalline; the feldspar crystals range from 3 mm to 1 cm in diameter; the grains of quartz and biotite are smaller. Thin sections show orthoclase and microcline, about 35 per cent; plagioclase (andesine), 25 per cent. In the vicinity of the pegmatite are numerous dikes of similar rock of finer grain. A thin section shows orthoclase and microcline, 30 per cent; plagioclase and microperthite, 25 per cent; quartz, 35 per cent; magnetite, 5 per cent; biotite, 3 per cent; and sphene, 2 per cent. These dikes trend northwest roughly parallel to the trend of the pegmatite. The monzonite lacks any layering or foliation, but several systems of joints are present.

Gardner's map shows large bodies of such monzonite, to which he assigned a Late Jurassic age, in the mountains that are 10 to 25 miles east, southwest, and west of the Cady Mountains. Also, this monzonite closely resembles the Cactus granite of Vaughan (1922) mapped by Gardner in the eastern part of the Newberry Mountains. The type locality of

Vaughan's Cactus granite is Cactus Flat, on the north slope of the San Bernardino Mountains, 60 miles south of the Cady Mountains.

The Cady Mountains pegmatite body is small and is simple in form and structure. It is in the central part of a large mass of quartz monzonite that underlies the Cady Mountains. In addition to orthoclase, quartz, and albite, which form most of the pegmatite, it contains small masses within which the following minerals have been found; biotite, muscovite, albite, betafite, cyrtolite, and niobian anatase.

Cady Mountains Pegmatite Body

As there is no cover of vegetation, the borders and extent of the pegmatite are well exposed. In plan, the body is roughly elliptical, about 100 feet long and 25 feet wide at the widest part. The contact that separates the pegmatite from the enclosing monzonite is definite and sharp. The longer axis of the pegmatite strikes about N. 10° W. and the body seems to dip about 65° W. The ends are distinctly round rather than wedge-shaped. The internal arrangement and relations of the minerals that make up the pegmatite are well shown in an open cut on the east slope of the peak; it is about 40 feet long, about 10 feet deep, and the face is 15 feet high.

Mineral arrangements. As exposed in the open cut, the pegmatite is roughly separable into two parts or longitudinal zones. The lower or eastern zone is about 12 feet thick and is made up largely of light reddish-brown feldspar, minor amounts of quartz, magnetite, and pale greenish mica. This zone shows a faint layering, which is not noticeable in the upper zone. The upper zone, also about 12 feet thick, contains large irregular masses of white quartz; these masses of quartz seem to replace the feldspar.

Coarsely crystalline, pale reddish-brown orthoclase is the most abundant mineral in the lower zone. No terminated crystals were found but some cleavage faces are several inches in diameter. This feldspar is replaced sporadically by large areas of feathery white albite. There are also small pipelike bodies of clear, glassy quartz whose longer axes are normal to the footwall; these are a few inches in diameter and 6 to 15 inches long. The reddish orthoclase of the lower zone also contains isolated small rounded lumps of magnetite, as much as 2 inches long; these show no radioactivity, therefore contain no inclusions of uranium-bearing minerals.

Within the lower zone there are several round masses of loosely coherent material, pale yellowish green in color; one of these is a few inches in diameter and 10 inches long. This material disintegrates readily in water, and after the coarse fragments of feldspar are panned and screened out the residue is composed of three minerals—flakes of pale greenish mica (muscovite), small crystals of quartz, and flat tetragonal crystals of niobian anatase. This residue shows slight radioactivity. Nothing resembling these masses is found in the upper zone. In the lower zone, also, there are a few rosettes of biotite plates 15 to 20 inches in diameter; thin plates of biotite 5 to 8 inches long radiate outward from centers. The plates of biotite contain sparse, small crystals of cyrtolite.

The upper zone contains much more quartz than feldspar, which it seems to replace. The masses of quartz do not contain any other minerals. A single lens of dark minerals about 36 inches long and about 20 inches thick occurs with the reddish-brown orthoclase. The lens is made up of thin plates of biotite 1.5 mm to 3 mm thick and as much as 6 inches long; between these biotite plates, layers 6 mm to 2.5 cm thick composed of magnetite, reddish orthoclase, and albite have formed. Pseudohexagonal crystals of cyrtolite (metamict zircon) occur on the borders of the biotite zone; and octahedrons of betafite are found enclosed in the magnetite masses and in the feldspar. After some 25 pounds of the dark minerals from the lens were crushed and examined carefully, about 25 grams of betafite crystals were recovered. It is possible that the entire lens would yield about 100 grams of this mineral.

The common and abundant minerals that make up the pegmatite are orthoclase, microcline, plagioclase (albite), microperthite, quartz, magnetite, biotite, and muscovite. Only the uncommon and relatively sparse minerals betafite, cyrtolite, and anatase are here described in detail.

Betafite. Betafite is a niobate and titanate of uranium. Special interest is attached to this mineral because it seems to be very uncommon in American pegmatites. A sufficient amount of the mineral has been recovered from the pegmatite here described to permit the determination of its age. Except for a few grains observed in the midst of albitized orthoclase, this mineral forms perfect octahedrons. Most of the crystals are either embedded in the magnetite or lie between plates of magnetite and feldspar that are themselves enclosed within layers of biotite. Thus far, the largest crystal found is about 6 mm in diameter, but most of the crystals range from 2 to 4 mm in diameter. All of the crystals of betafite show an outer zone of pale yellowish, fine-grained material, the nature of which has not been determined. It probably represents an alteration of the betafite that forms the core of each crystal. The unaltered core of betafite is pale yellowish brown, in part slightly greenish, is transparent, and the luster ranges from vitreous to resinous. It shows conchoidal fracture but no cleavage; hardness is about 3. Immersed in index media, the fragments are pale greenish yellow, isotropic, and have an average index of refraction of 1.910. The shell or alteration product is too fine-grained to be determined.

Table 1 presents spectrographic analyses of betafite, cyrtolite, and niobian anatase.

TABLE 1. QUALITATIVE SPECTROGRAPHIC ANALYSES OF BETAFITE, CYRTOLITE (METAMICT ZIRCON), AND NIOBIAN ANATASE FROM CADY MOUNTAINS, SAN BERNARDINO COUNTY, CALIFORNIA

K. J. Murata, analyst

Percentage	Constituents		
	Betafite	Cyrtolite (metamict zircon)	Niobian anatase
>5	Nb, U, Ti	Zr, Si	Ti
1–5	Ca	Th	Fe, Si
0.X	La, Fe, Si, Ba, Sr, Ta, Th	U, Y, Fe, Ti, La, Nb	Nb, Ta, Mn, La
0.0X	Pb, Mn, Zr, Y, Sn, B, (As?)	Ca, Ba	Pb, Al, Zr, Y, Ca, Sn, Ba
0.00X	Be, Al	Be, Pb, Mn, Cu, Al, B	V, Cu
0.000X	—	Sr	Be
Not found in sample	Cu, V	V, As, Ta, Sn	U, Sr, Th, B, As, Sn

Not found in any sample: Ag, Bi, Mo, Sb, Ga, W, Ge, Zn, Cd, In, Tl, Ni, Co, Cr, P, and Na.

In order to determine the age of betafite, the unaltered portions were separated and submitted to Harry Levine, of the U. S. Geological Survey, for analysis for uranium, thorium, and lead. The results obtained are as follows: U 10.68 per cent, ThO_2 4.22 per cent, and PbO 0.63 per cent. In addition, the lead present in betafite was separated and subjected to isotopic analysis. We are indebted to Lorin Stieff, U. S. Geological Survey, for the following calculations of age based on the chemical and isotopic analyses:

"The lead extracted from the betafite was prepared as the iodide. This iodide was analyzed by the Assay Laboratory Department, Carbide and Carbon Chemicals Co., Y-12 Plant, Oak Ridge, Tennessee. The abundance of the lead isotopes in atom per cent in the betafite is given below:

Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}
0.717	50.691	13.095	35.495

"Four separate age calculations on the betafite have been made. These ages are shown in the following table.

Calculated ages of betafite to nearest 5 million years

Pb^{206}/U^{238}	Pb^{207}/U^{235}	Pb^{207}/Pb^{206}	Pb^{208}/Th
155	165	300	285

Isotopic analysis of the lead for the betafite indicated that the sample contained approximately 52 per cent original lead. In the absence of any isotopic analyses of lead from the Cady Mountains we have assumed that the original lead in the betafite is similar in isotopic composition to lead from vanadinite from the Tucson Mountains in Arizona, analyzed by Nier (1938).

"Of the four ages the Pb^{206}/U^{238} (155) is probably the nearest to the actual age of the betafite. The relatively high Pb^{207}/Pb^{206} age of 300 million years probably reflects the errors introduced by assuming the original lead in the betafite to be similar to the lead from the Tucson Mountains. An analysis of common lead from the vicinity of the Cady Mountains would undoubtedly permit a more accurate age determination. In addition, a Pb^{207}/Pb^{206} age is not very reliable in the 0–500 million year range. The similarity between the thorium age and the Pb^{207}/Pb^{206} age is probably fortuitous. A more judicious choice of common lead might lower the thorium age, and the Pb^{207}/Pb^{206} age would be expected to drop radically. A selective loss of thorium from the sample would not be expected but might possibly account for the older thorium age. A selective loss of lead from the sample does not seem probable because the uranium ages are younger than the thorium ages."

Cyrtolite (metamict zircon). Cyrtolite is a name applied by some authors to metamict zircon. Crystals of this mineral are very common in the large lens of magnetite, feldspar, and biotite in the upper zone of the pegmatite and are less common in the rosettes of biotite in the lower zone. Most of the crystals range from 2 to 3 mm in diameter. The color is pale grayish red. A few crystals show tetragonal symmetry, but most of them are flattened or otherwise distorted; some are roughly triangular or pseudohexagonal in outline. The hardness is about 7; the luster is vitreous. In the large magnetite lens, the crystals are concentrated in the layers of biotite.

In thin section the mineral is transparent, but it contains minute grains of hematite that may account for the pale reddish color. The central part of the crystals is isotropic, that is, the mineral is metamict, and has an index of refraction of about 1.825. The borders of the crystals are anisotropic and are deeply stained; no optical figure could be obtained. The mean index of refraction is about 1.890.

The metamictic condition of the Cady Mountains uranium- and thorium-bearing cyrtolite may be explained (Table 1) on the basis of work on zircon and cyrtolite by Kostyleva (1946) establishing the conclusion that metamictic disintegration is the result of the destruction of bonds in the lattice produced by alpha-radiation from the radioactive elements present.

Niobian anatase (octahedrite). This mineral forms myriads of perfect tetragonal crystals of pyramidal habit, few of which are as much as 0.5 mm in diameter. They are included in the small masses of muscovite that occur in the lower zone of the pegmatite. Some of the crystals show a combination of pyramid, prism and base. The masses of muscovite, quartz, and anatase disintegrate readily in water.

The crystals are transparent and deep green in transmitted light; thin fragments are pale yellowish green. The mineral is uniaxial negative; ϵ is near 2.45. Interference colors in thin section are sapphire blue, purple, and reddish yellow; hardness is about 5. Spectrographic analysis of the mineral is shown in Table 1.

Geology of the Pomona Tile Quarry Pegmatite Area

The general geology of the area between Rancho Roqueño and Rock Corral, within which the Pomona Tile Quarry body is found, has been studied and mapped by Vaughan (1922). Later Woodford (Woodford and Harris, 1928) restudied a part of the area near Blackhawk Canyon and revised some of Vaughan's conclusions. In the northeastern part of the San Bernardino Mountains, Vaughan recognized three major geologic units: 1) heterogeneous plutonic rocks; 2) Cactus granite (thought by Woodford to be nearer to quartz monzonite) intrusive into the older plutonic rocks; 3) undifferentiated schists into which the foregoing rocks were intruded.

A reconnaissance of several square miles around the Pomona Tile Quarry pegmatite indicates that the three major rock units recognized by Vaughan are present. Probably the most abundant rock in this area is a light-colored quartz monzonite (Cactus granite of Vaughan) in which the pegmatite is found. This intrudes a darker gneissic granite, abundant near Rock Corral, in which large white orthoclase crystals are embedded in a dark matrix, largely quartz and biotite. Several miles east of the pegmatite body, the young quartz monzonite (Vaughan's Cactus granite) intrudes an earlier quartz monzonite that is characterized by large, flat crystals of orthoclase. The third group of rocks in this area includes sporadic blocks of dark rocks that range from several tens of feet to several hundreds of feet in diameter; most of these blocks have flat bases and rest on the above-described intrusive rocks. All of these blocks show foliation, now in diverse attitudes. The dark color of these blocks is due largely to abundant biotite. Some specimens show small amounts of quartz and orthoclase; several contain abundant cordierite and sillimanite. These blocks of dark foliated rocks are regarded as remnants of roof pendants on the underlying intrusive rocks. Almost all of the blocks examined show noticeable radioactivity, which seems to be due to thorium-bearing cyrtolite (metamict zircon).

Pomona Tile Quarry

Pegmatite body. Six open cuts and trenches reveal several flat-lying tabular bodies of pegmatite within an area of several acres along the crest of a prominent ridge. The uppermost and largest body strikes about N. 70° E. and dips 5 to 10° NW. and is 10 to 15 feet thick. This body has yielded all of the uncommon minerals that are described herein. Four other open cuts show masses of gray glassy quartz and pale reddish coarsely crystalline feldspar,—orthoclase, and microcline. These explorations do not show the exact shape or size of any pegmatite body. The explored bodies seem to be tabular lenses that form a zone in the quartz monzonite.

The largest trench on the crest of the ridge shows one large and several small concentrations of uncommon minerals in the midst of the feldspar and quartz that form most of the tabular body. In this, as in other lenses of pegmatite on the ridge, there seems to be no simple form of the masses of quartz and feldspar, nor any simple arrangement of the masses. There is no layering or zoning whatsoever.

The largest concentration of uncommon minerals is in and around the border of a nucleus of quartz from which thin plates of ilmenite 1 to 5 mm thick radiate outward as much as 3 feet. In the nucleus the plates are wholly embedded in gray glassy quartz, but beyond the nucleus they are wholly in reddish microcline. The other uncommon minerals are dispersed as grains and crystals in or near the nucleus of quartz; none is found in the outer zone of ilmenite plates. Two other small areas of radiating plates of ilmenite lie about 50 and 75 feet southwest of the largest body, but these contain only very small amounts of the uncommon minerals.

The following minerals have been found in the Pomona Tile Quarry pegmatite: albite, allanite, epidote, biotite, hematite, magnetite, monazite, rutile, sphene, euxenite, and an unidentified uranium-bearing mineral; other minerals, probably products of weathering of some of the minerals listed above, are: kaolinite, leucoxene, limonite, manganese oxide, and fluorescent hyalite. Only the uranium-bearing minerals will be described.

Euxenite. Euxenite is a niobate and titanate of yttrium, erbium, cerium, and uranium. Numerous small tabular crystals, dark brown in color, 3 to 8 mm in maximum diameter were found wholly in the reddish feldspar near the nucleus of the pegmatite body; these crystals are shown by spectrographic analysis to be euxenite (Table 2). This analysis was confirmed by *x*-ray determination made by F. A. Hildebrand. The mineral is isotropic (metamict), has a mean index of refraction of 2.25, and a hardness of about 6.

TABLE 2. QUALITATIVE SPECTROGRAPHIC ANALYSIS OF TWO METAMICT EUXENITES FROM POMONA TILE QUARRY PEGMATITE, SAN BERNARDINO COUNTY, CALIFORNIA

K. J. Murata, analyst

Percentage	Constituents
>10	Nb, Ti, Y
1–10	U, Fe, Th, Yb
0.X	Ta, Ca, Pb, Mn, La
0.0X	Mg, Si, Al, Sc

Not found in samples: B, Be, As, Sb, Sn, Bi, Cu, Ag, Ge, Ga, Tl, In, Zn, Cd, Mo, W, Cr, V, Co, Ni, Sr, Ba, Na, Pt, P.

The analysis above applies to both samples.

Lead, uranium, and thorium determinations on euxenite from Pomona Tile Quarry pegmatite were made by Paul Scott, Rivers A. Powell, and Glen Edgington, analysts on the staff of the U. S. Geological Survey. The percentage determinations are U=13.9, 14.5; Pb=0.30, 0.30, 0.29; and Th=2.51. These values were used in calculating the geologic age of the Pomona Tile Quarry pegmatite.

Computations for the age determination were made by Dr. John Putnam Marble, Chairman, Committee on measurement of geologic time, National Research Council. A summary of his report is quoted below:

"Using the simplest age formula:

$\text{Age} = 7600 \left[\frac{\text{Pb}}{\text{U} + 0.36\text{Th}} \right]$ million years, which is good enough for the present purposes, especially in view of the spread in the U determinations quoted, the age works out to be 149.7 million years. The data do not really indicate anything closer than, say, 145–155 million years.

"The calculations are summarized as follows:

Average per cent Pb=0.297; U=14.2; Th=2.51

$0.297/14.2+0.36\times 2.51=0.297/14.2+0.90=0.297/15.10=0.0197$

$0.0197\times 7600=149.7$."

The lead from euxenite has not yet been analyzed isotopically, so the amount of ordinary lead is not known. Therefore the age obtained above by means of the simplest age formula may be subject to some revision when the results of the isotopic analysis become available.

An unidentified uranium-bearing mineral. A few grains of a highly splendent black mineral occur in the feldspar remote from the quartz nucleus. The material has been analyzed spectrographically (Table 3). The composition is similar to that of davidite (Bannister and Horne, 1950). An *x*-ray powder diffraction pattern obtained by F. A. Hildebrand shows an unidentified mineral. Some similar grains of this mineral were

TABLE 3. QUALITATIVE SPECTROGRAPHIC ANALYSIS OF AN UNIDENTIFIED URANIUM-BEARING MINERAL FROM POMONA TILE QUARRY PEGMATITE, SAN BERNARDINO COUNTY, CALIFORNIA

K. J. Murata, Analyst

Percentage	Constituents
>10	Ti, Fe
6–10	U
1–5	Th, Si, Y, Ca
0.X	Nb, Yb, La, Zr
0.0X	Mg, Al, Ba, V, Pb
0.00X	B

Not found: Cu, Bi, Ag, Au, Pt, Mo, W, As, Sb, Sn, Cd, Ga, In, Tl, Co, Ni, Cr, Sc, Na, P, Be, Zn, and Sr.

found in the midst of masses of microcline unaccompanied by any of the other minerals found near the nucleus of the pegmatite body, as much as 25 feet distant from the largest concentration of the rare minerals. This mineral attracted attention because it exhibits unusually strong radioactivity.

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