SOME RARE-EARTH MINERAL DEPOSITS IN MOHAVE COUNTY, ARIZONA

by

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Department of Mineralogy
The University of Michigan

THE ARIZONA BUREAU OF MINES

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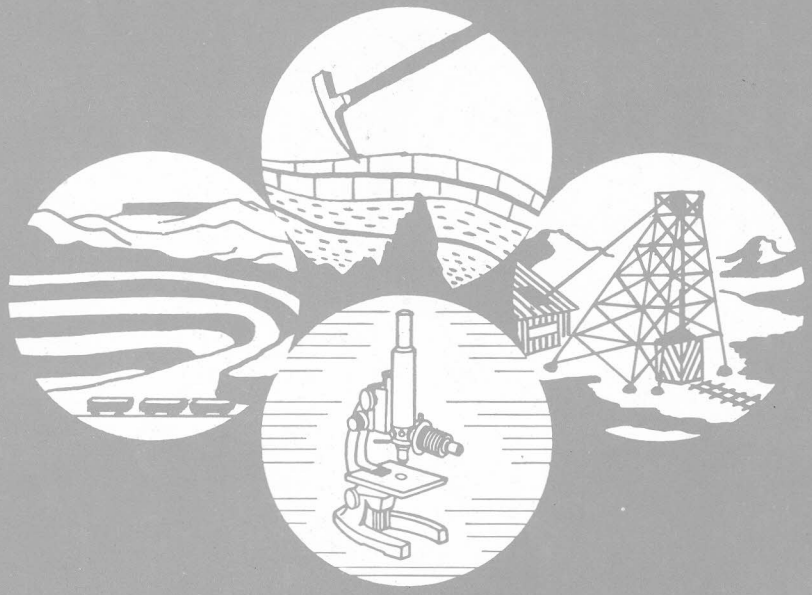

THE UNIVERSITY OF ARIZONA
TUCSON

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FOREWORD

Bulletin 167, titled: Some Rare-Earth Mineral Deposits in Mohave County, Arizona, by E. William Heinrich, was published originally by the Arizona Bureau of Mines in 1960. Because of the contemporary and continuing interest that comes for the information contained in the bulletin, it now has been reprinted in 1967.

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J. D. Forrester, Director
Arizona Bureau of Mines
October, 1967

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GENERAL INFORMATION

DURING LATE SUMMER, 1955, the writer spent a week in the western part of Arizona examining rare-earth mineral deposits in Mohave County. Occurrences of rare-earth minerals long have been reported from several pegmatite deposits in the Cerbat and Aquarius Ranges, north and southeast of Kingman, respectively. Galbraith (1947) reports chevkinite from the Aquarius Range (p. 90); gadolinite from near Kingman, ". . . and in the northern part of the county, in sand dunes" (p. 87); euxenite in the Cerbat Range ". . . as scattered masses up to 50 pounds weight in pegmatite, Kingman Feldspar mine," and east of Big Sandy River, south of Burro Creek (p. 90); samarskite in the Aquarius Range with allanite (p. 40); and allanite in the Aquarius Range with gadolinite and at the Kingman Feldspar Mine (p. 89). Moore (1953) reports that gadolinite has been mined from pegmatites in the Aquarius Range, 30 miles south of Hackberry (p. 8); samarskite has been found in pegmatites in the Aquarius Range associated with allanite (p. 23); euxenite in masses up to 50 pounds has been found in the Kingman Feldspar Mine, Cerbat Range (p. 23); fergusonite has been produced by L. L. Edgerton from the Aquarius Range (p. 23), and allanite occurs at the Kingman Feldspar Mine (p. 26). Collections of the Smithsonian Institution in Washington, D. C., contain gadolinite from the Black Beauty Claim, 20 miles south of Hackberry, Arizona, and fergusonite from the Peacock Mining District near Kingman.

These numerous and somewhat confusing reports, in summary, indicated two main localities with a variety of species allegedly present: 1)Kingman Feldspar Mine, Cerbat Range; gadolinite, euxenite, allanite; 2) Aquarius Range; chevkinite, samarskite, allanite, gadolinite, fergusonite. This report represents the results of an attempt to establish the identities of the reported rare-earth minerals.

The writer is indebted to L. L. Edgerton of Kingman for guiding him to several of the deposits, and to James Howell, former manager of the Consolidated Feldspar Corporation plant in Kingman, for permission to examine the Kingman deposit. Dr. A. A. Giardini assisted in the laboratory studies, which were a part of a general investigation of rare-earth minerals supported by Michigan Memorial-Phoenix Project 150.

1

KINGMAN FELDSPAR MINE

LOCATION AND OWNERSHIP

The Kingman Feldspar Mine is in sec. 26, R. 17 W., T. 22 N., Sixth Standard Parallel North, about 5 air-miles north of Kingman. A good dirt road branches north-northwest from U.S. 66 from near the northeast edge of Kingman, continuing for about five miles toward Stocton Hill, with a tributary mine road extending west to the quarry. The deposit, which is readily visible from the start of the mine road, lies near the base of the east flank of the Cerbat Range near its southern termination. The Cerbat Range is a relatively low but rugged range that extends from near Kingman for about 25 miles in a generally northwest direction. Outcrops are excellent; there are no trees and only scant small vegetation.

The deposit, which is owned and mined by the Consolidated Feldspar Corporation, a subsidiary of International Minerals Corporation, has been quarried since 1924. Potash feldspar (microcline) is the chief product, although quartz ("silica") also is produced. The Corporation operates a feldspar and quartz-grinding mill that is situated along the tracks of the Atcheson, Topeka, and Santa Fe Railroad about one mile northeast of Kingman. The Kingman Feldspar Mine is the largest and most continuous commercial pegmatite operation in Arizona, having yielded more than 100,000 tons of crude and ground feldspar since its opening.

GEOLOGY

GENERAL

The deposit consists of a large pegmatite that has been intruded into a medium-grained gray granite, which locally has a well-developed gneissoid texture and in other places is porphyritic with phenocrysts of potash feldspar as much as one-half inch long. Here and there in the granite are large xenoliths or roof pendants of gneissic metamorphic rocks that are strongly injected. In the northernmost cut, a nearly horizontal dike of diabase, six inches to two feet thick, transects the pegmatite. South and southeast of the deposit, granite hills are capped unconformably by lavas of probable Tertiary Age. Thus the sequence of rock units in the southern end of the Cerbat Range is:

Quaternary (and Recent): Alluvium
Tertiary: Volcanic rocks
Pre-Cambrian: Diabase
Pegmatite
Granite
Gneisses

PEGMATITE GEOLOGY

The mine has been developed in a large pegmatite, apparently sill-like in structure, which strikes N. 50–65° E. and dips 60–75° NW. Locally the contacts with the wall rocks, chiefly granite, diverge somewhat from this general attitude.

Two main groups of openings have been used to explore the deposits:

1. The northern or Number 1 cut, the only one being worked in 1955, 250 feet long, 200 feet wide, 60–90 feet deep at the face (Figure 1).
2. The southern group (Number 2), which begins about 900 feet southwest of the northern cut.
   a) A narrow curving cut, northernmost of this group, which trends S. 65° W. and curves to the south, is 450 feet long, including a 300 foot-long entrance that is 20–40 feet deep. This cut opens into a bulbous quarry about 100 × 100 feet in plan and 60–80 feet high at the south face.
   b) Cut 2a has an upper bench which opens to the southeast about 80 feet above the floor. This cut is 150 feet long, 60 feet wide, and 20 feet high.
   c) Southwest of cut 2b is another curving cut that trends southwestward. It appears to be the oldest quarry opening and is about 400 feet long, 20–40 feet wide and 60–80 feet deep.

The total strike length of pegmatite exposed is between 1200–1500 ft.

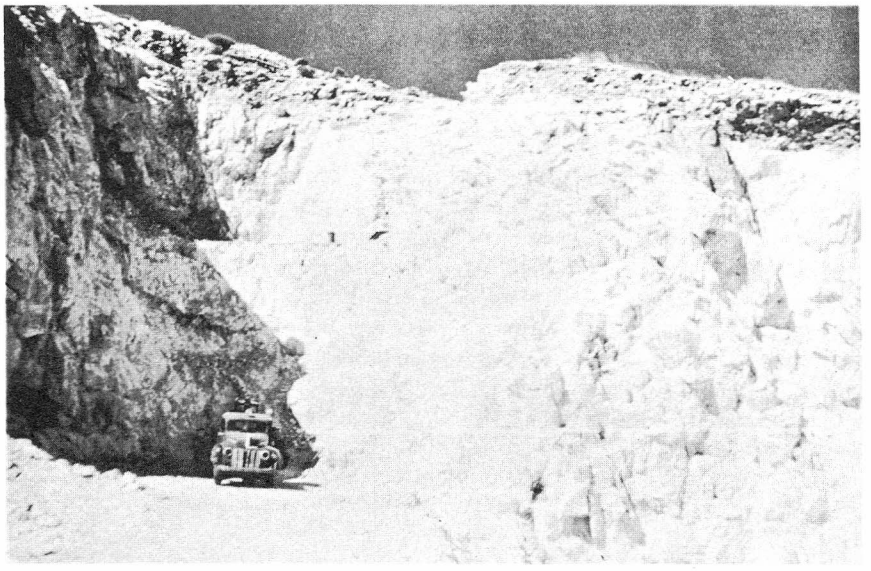

Figure 1. Feldspar mining in northern (No. 1) cut, Kingman Feldspar pegmatite, Cerbat Range, Arizona.

The pegmatite ranges in thickness from about 50 to over 200 feet, widening to the northeast. Contacts with wall rocks are sharply defined. Normally the wall rock is granite, but biotite gneiss is prominently exposed in the upper face of cut 2a where the pegmatite branches around gneissic roof pendants.

The pegmatite is characterized by a well-defined internal structure:

1. Core or central unit: 40–200 feet thick, composed chiefly of masses of white microcline up to 10–12 feet across and subordinate pods of gray quartz as large as 5×6×15 feet (Figure 1). Locally, especially on the face of cut 2a, these pods extend long stringers up to one foot thick that transect the feldspar masses of the core. These veins have a general northeast trend with the attitude of the pegmatite as a whole, and likewise dip at a moderate to steep angle to the northwest (Figure 2).
2. The wall zone: 10–20 feet thick, composed of a medium-grained (1–3 inches) aggregate of gray quartz, white feldspar and biotite, locally some muscovite, garnet, magnetite, and pods of allanite. Some quartz and feldspar are graphically intergrown. Much of the wall zone has a streaky, gneissoid texture which is oriented parallel with the wall rock contacts (Figure 3). Locally thin quartz veinlets, 1–2 inches thick, cut across the wall zone. This unit also shows well-defined joints that strike northeast, dipping at moderate angles northwest.
3. A border zone: 1–2 feet thick, white and aplitic in texture, composed of fine-grained quartz and feldspar (Figure 3).

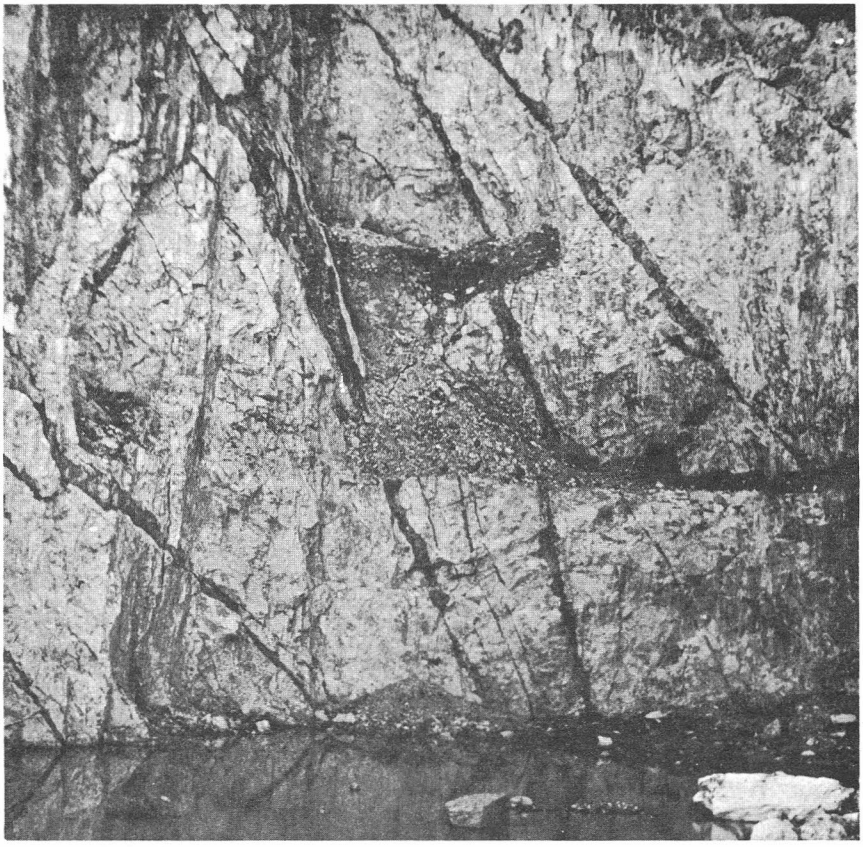

Figure 2. Quartz veins transecting feldspathic core, Cut 2a, Kingman Feldspar pegmatite, Cerbat Range, Arizona.

MINERALOGY

Because of the long confusion over its identity, the allanite was the mineral of chief interest. It was first found by the writer in pieces in slide material on the floor at the face of cut 2a, mixed with blocks of wall-zone rock. It also was abundantly exposed in cut 2b in both the footwall and hanging parts of the wall zone in pods ranging in length from less than an inch to 10 inches. In this cut, grains and pods of the mineral were exposed along the footwall side for a distance of about 80 feet and along the hanging wall side for nearly 40 feet, along which distance it was conservatively estimated that four dozen pods of the mineral appeared. In cut 2c, the mineral was exposed in pods, 1–8 inches long, on the footwall side for about 40 feet, and pieces on the cut floor indicated that some was present in the hanging-wall zone as well.

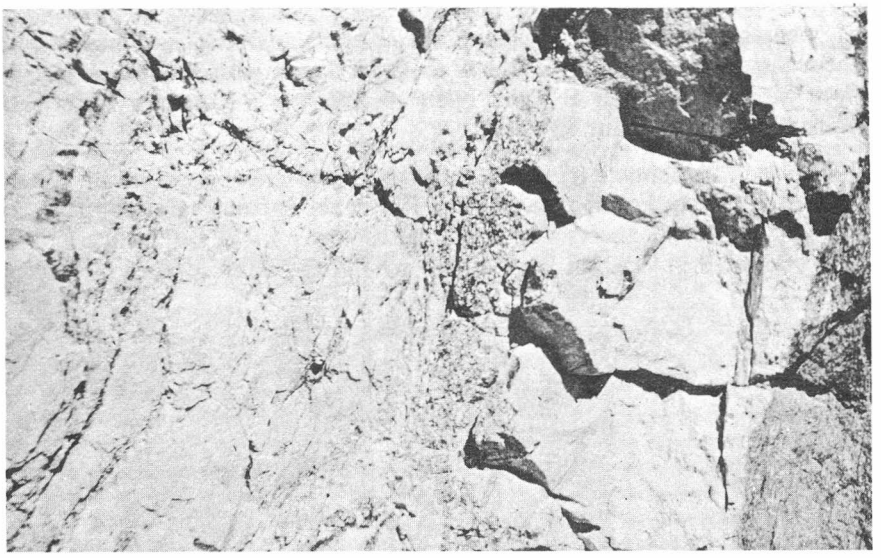

Figure 3. Zoning in outer part of Kingman Feldspar pegmatite. Grayish gneissoid rock from left to center is wall zone; white, well-jointed rock to right of center is aplitic border zone; lower extreme right dark rock is gneissic granite.

No specimens of allanite were observed in cut 1, but this may be because of the very limited exposures of wall-zone rock in this quarry. The observed distribution of the mineral indicates that it is widely and uniformly disseminated throughout the inner part of the wall zone on both flanks of the core, probably along much of the exposed length of the pegmatite.

About 350 pounds of the mineral were available in sacks at the mill of the Consolidated Feldspar Corporation in Kingman; approximately 10 pounds were found by the writer in dumps and the cuts; and perhaps 50 pounds were in place on cut walls. It has been reported that a carload (20 tons) was shipped to an unknown buyer about 1944, but Mr. Howell was unable to verify this claim.

The allanite is black, with a brilliant pitchy luster. Pieces are coated by a distinctive red-brown, ferriferous oxidation crust, very similar to that on allanite specimens from the famous deposit at Little Friar Mountain, Amherst County, Virginia. It appears typically in anhedral, somewhat elongated pods, markedly fractured.

The allanite is in large part metamict and microscopically shows considerable variation in color from dark brown and somewhat pleochroic to dirty olive brown, non-pleochroic; in birefringence from $y - a = 0.011$ to nil; and in $B = 1.725$ to 1.760. X-ray studies confirm the identity of the species and also indicate that the bulk of the mineral is strongly damaged structurally (Table 2, Column 1). Heating brings about a partial structural restoration (Table 2, Columns 2 and 3).

A partial analysis of the allanite, made by means of X-ray fluorescence, is presented in Table 1, Column A. In comparison with a California allanite (Table 1, Column B) and other allanites, the Kingman material is unusually high in Y for an allanite.

Table 1. Percentage of rare earths and radioactive elements in allanite from Kingman Feldspar pegmatite, Kingman, Arizona (Column A). For comparison, an analysis of these percentages for a California allanite is presented in Column B. Analysis is by X-ray fluorescence.

	A	B
Y	= 1.3	0.34
La	= 4.4	4.73
Ce	= 8.1	10.4
Pr	= 1.0	1.12
Nd	= 4.2	4.28
Sm	= 0.95	0.59
Gd	= 0.7	0.21
Dy	= 0.13	....
Th	= 2.7	0.95
U	= 0.14	0.03

It had been hoped that the radioactive rare-earth mineral might be gadolinite, but with verification of its identity as allanite, the occurrence becomes primarily of scientific, rather than of commercial, interest. The deposit continues to be an important feldspar producer, with large reserves. The feldspar is a very high quality microcline, a very light grayish-white in color, exceptionally low in iron, and free of quartz and other impurities.

Table 2. X-ray Data on Rare-Earth Minerals from Arizona.

1		2		3		4		5		6	
d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I
						9.20	20			3.65	vw
						8.05	20			3.28	vw
						7.96	20	2.99	s	2.99	vs
						5.09	10	2.90	m	2.90	w
						5.01	10	2.80	vw	2.77	w
						4.87	5	2.62	m	2.60	w
						4.69	20	2.43	vw	2.43B	vw
						3.78	10	2.20	vw	2.19	vw
						3.59	10	1.99	vw	2.10	vw
		3.50	w			3.52	40	1.95	vw	1.94	w
				3.17	m	3.30	10	1.85B	w	1.90	vw
				3.11	mw	3.23	20	1.83B	w	1.83	m
				3.08	vvw	2.92	90			1.80	vw
2.96B	vvw	2.92	s	2.84	w	2.91	100	1.78	vw	1.78	vw
				2.78	w	2.86	50	1.74	vw	1.73	vw
		2.82	w	2.72	w	2.82	10	1.69	vw	1.64	w
		2.70	w	2.67	m	2.68	40			1.61	vw
		2.66	w	2.50	ms	2.62	40	1.57B	w	1.56	vw
2.58B	vvw	2.59	w			2.51	20	1.54B	vw	1.54	vw
		2.53	w			2.50B	10	1.51B	vw	1.49	mw
		2.47	vw			2.33B	10			1.44	vw
		2.32	vw	2.19	vw	2.20	10			1.34	vw
						2.18B	20	1.20	vw	1.19B	vw
		2.15	m			2.15	10	1.17	vw	1.16	vw
		2.12	m			2.14	10				
						2.10B	2				
		2.04B	vw			2.05B	2				
				1.95	m	1.91B	2				
1.59B	vvw	1.89B	m	1.92	s	1.89B	20				
				1.85	m	1.78B	2				
1.66B	vvw			1.83	m	1.67B	10				
				1.81	w	1.65B	10				
		1.64	m	1.78	vw	1.64B	20				
		1.61B	vw	1.76	ms	1.56B	20				
		1.59B	vw	1.73B	vw	1.12B	2				
		1.55B	vw	1.69	ms						
		1.47B	mw	1.66	vvw						
		1.41B	mw	1.64B	ms						
		1.27B	w	1.59	vvw						
				1.54	vvw						
				1.52	vw						
				1.48	ms						
				1.46	vw						
				and many others							

1. Allanite, metamict, not heated. Kingman Feldspar pegmatite, Kingman, Arizona.
2. Allanite, recrystallized by heating in air for one and one-half hours between 725-775 C. Kingman Feldspar pegmatite, Kingman, Arizona.
3. Allanite, recrystallized and decomposed by heating in air for four hours between 950-1000 C. Kingman Feldspar pegmatite, Kingman, Arizona.
4. Allanite, not metamict. Berman, 1955. Compare with Column 2.
5. Yttrotantalite, Rare Metals pegmatite, Aquarius Range, Arizona.
6. Yttrotantalite. Skuleboda pegmatite, Ryrs station, Uddevalla, Sweden.

2

THE RARE METALS MINE, AQUARIUS RANGE

LOCATION

The Rare Metals pegmatite Mine, owned and intermittently operated by L. L. Edgerton, is about 55 miles by road southeast of Kingman, on the west side of the Aquarius Range. As located by Mr. Edgerton, the deposit is in sec. 21, R. 12 W. T. 17 N., 5th Standard Parallel North. The Aquarius Range is a north-south trending range that lies on the east side of Big Sandy Wash, along the eastern edge of Mohave County. The deposit lies at an elevation of about 4000 feet. Mr. Edgerton has held the property under claim for about 10 years.

GEOLOGY

The western flanks of the Aquarius Range in the vicinity of the Rare Metals pegmatite are underlain by pre-Cambrian granite which is cut by exceedingly numerous parallel to subparallel pegmatites, ranging from about a foot to 40 feet thick. Many are about 6–10 feet across.

The Rare Metals pegmatite, which crops out along the north side of a west-trending tributary to Big Sandy Wash, is about 600 feet long along its explored length, strikes N. 85° E., and dips 30–40° NE. It ranges in thickness from a few feet near its western end to about 40 feet in the main workings. Numerous other parallel pegmatites crop out on the hillside above and below the Rare Metals pegmatite (Figure 4).

The deposit is well-zoned with a conspicuous quartz core pod as much as 20 feet thick and about 60 feet long. Some masses of microcline occur marginally in this core. Both east and west of this main core pod, the dike contains other core units of massive quartz and flesh-colored block microcline, 3–6 feet thick. The contacts with the granite are poorly exposed, but the main outer unit of the dike is a wall zone consisting of a medium-grained aggregate of quartz, feldspar, muscovite and garnet. This zone is as much as 12 feet thick in the thickest part of the pegmatite. Marginal to both sides of the core are pods of muscovite in 1–4 inch flakes and scattered beryl crystals.

The main workings consist of an eastern cut across the pegmatite (No. 2) 40 feet long, 8–10 feet wide and 25 feet high at the face and a closely adjacent western longitudinal open cut (No. 1), 60 feet long, along the pegmatite (Figure 5). This has been extended as a shallow incline beneath the quartz core. Several prospect pits dot the dike west of these main workings, and about 50 feet east of the main cuts another small pit (Number 3) is in pegmatite. The discovery cut (No. 4), which is east of the boundary fence and probably in the same pegmatite, was made for bismuth minerals and antedates Mr. Edgerton's work.

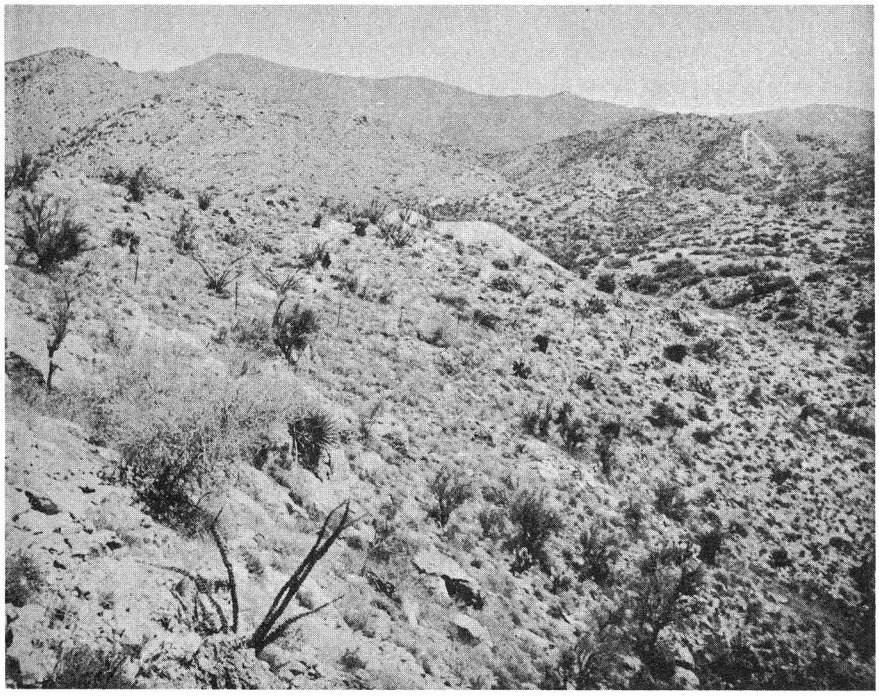

Figure 4. General eastward view of western side of Aquarius Range, Arizona, showing Rare Metals pegmatite (left center, extending to dump in center) and other parallel dikes (right center).

Although where the granite-pegmatite contacts are exposed no significant reaction between the rocks is visible, the pegmatite locally was found to contain a few blocky xenoliths of altered granite, several inches to eight inches across. These rocks are granular aggregates containing chiefly gray-green muscovite (about 70 per cent) in one-eighth inch, randomly oriented flakes, quartz, feldspar, and minute grains of purple fluorite. Conspicuous are minute vugs containing muscovite platelets and in a few cases also some purple fluorite grains.

MINERALOGY AND PARAGENESIS

The rare-earth minerals were found in several places in the pegmatite, but concentrations apparently are confined to an unusual, discontinuous petrologic unit that is restricted to the footwall side of the quartz core, where the core is relatively thick (Figure 6). This unit is exposed in openings 1, 2, and 3, but does not appear in any of the outcrops between the workings.

The fine-grained, aplitic rock consists chiefly of quartz, sugary albite, and muscovite. Most of the small mica flakes are concentrated in bands one-half to one inch across, which alternate with thicker albite-rich bands in a curving, scalloped pattern (Figure 7). This unit strongly resembles some of the rhythmically banded aplitic rocks ("line rock") that have been reported from several other pegmatite districts in the United States (summarized in Jahns, 1955). Locally this unit is at least six feet thick.

The rare-earth minerals identified in the Rare Metals pegmatite are: yttrotantalite, euxenite, gadolinite, and monazite. Fergusonite may also be present in very small amounts. A few small grains of a black, pitchy, radioactive mineral gave an X-ray pattern, upon ignition, which resembles that of fergusonite. Descriptions of these are given in Table 3. Of these

Figure 5. No. 1 cut, along footwall side of quartz core, Rare Metals pegmatite, Aquarius Range, Arizona.

Table 3. Rare-earth Minerals in the Rare Metals Pegmatite.

Species	*Composition*	*Description*	*Occurrence*
Monazite	$(Ce,La)PO_4$	Red brown, subhedral crystals as much as 1½ inches across. Strongly radioactive	In unaltered wall zone with muscovite and quartz
Euxenite	$(Y,Ce,U)(Nb,Ta)_2O_6$	Black; submetallic, mirror-like luster; anhedral grains as much as ⅜ inch across, surrounded by radial fracture system and reddish halo. Very strongly radioactive and metamict	In albitized parts of wall zone. Usually in albite
Gadolinite	$Be_2FeY_2Si_2O_{10}$	Resinous luster; very deep olive brown in color. Moderately radioactive. Not metamict. $y = 1.78, \alpha\text{-}\gamma = 0.013. 2V = 80°$, (+) $r < v$ strong. Weakly pleochroic from neutral to pale grayish green	In "line rock" unit as relicts(?), some overgrown by yttrotantalite
Yttrotantalite	$(Fe,Y,U)(Nb,Ta,Ti)O_4$	Bladed to fan-shaped aggregates as much as an inch long. Clove brown, resinous. Completely metamict. Strongly radioactive	Scattered through "line rock" unit

yttrotantalite is the species that has been obtained in the largest amounts. The identity of this rare species (previously thought to represent a new mineral and referred to as "edgertonite") is confirmed by the X-ray data (Table 2, Columns 5 and 6) and was further checked by means of X-ray fluorescence analysis (Table 4). Yttrotantalite has been regarded as an exceedingly rare mineral of the radioactive multiple oxide group (Palache et al., 1944, pp 763–764). Since that time numerous other foreign occurrences have been recorded (Heinrich, 1958), but its discovery at the Rare Metals deposit represents the first authenticated occurrence in the United States. This is doubtless the mineral referred to by Moore (1953, p. 23) as fergusonite.

Figure 6. "Line rock" unit rich in yttrotantalite (lower left) along footwall contact of quartz core. Timbers (left center and lower right) mark contact between the two units. Rare Metals pegmatite, Aquarius Range, Arizona.

According to Mr. Edgerton, the deposit has yielded seven to eight tons of yttrotantalite ore, six tons of beryl, some bismuth minerals, and small amounts of monazite and gadolinite. No gadolinite was found in place, but Mr. Edgerton reports that curved masses of gadolinite up to 12 pounds in weight have been found in the "line rock" unit. A small specimen provided by him proved to consist of gadolinite with a crust of yttrotantalite blades.

The partial analysis of a gadolinite made by Chase Palmer (Galbraith, 1947, p 87) on material from ". . . pegmatite veins of the Aquarius Range, 30 miles south of Hackberry, from which several tons of the mineral have been mined," may well refer to the mineral from the Rare Metals deposit.

Table 4. Composition of Yttrotantalite, Rare Metals Pegmatite, Arizona

Elements Contained:

Major elements:	Y, Nb, Ta, Fe, Ti; Ta: Nb 2:1
Minor elements:	U, Th
Subordinate rare earths:	Gd, Dy, Ho
Minor rare earths:	Ce, Nd, Sm, Tb, Er
Absent, rare earths:	La, Pr, Eu, Tm, Yb, Lu
Absent, other elements:	Zr, Hf, Mn

PERCENTAGE COMPOSITION:

Ye_2O_3, etc.	38.86
Ce_2O_3, etc.	11.50
BeO	11.50
FeO	11.56
SiO_2	24.21
	95.83

Bismutite, of probable supergene origin, has been found in relative abundance; one mass allegedly weighed 700 pounds. Several pieces were found in Cut 2, where the mineral is associated with foot-long pods of rusty brown chalcedony. Other pieces were found near the discovery cut. No relicts of the parent mineral were found. The identity was checked by means of X-rays.

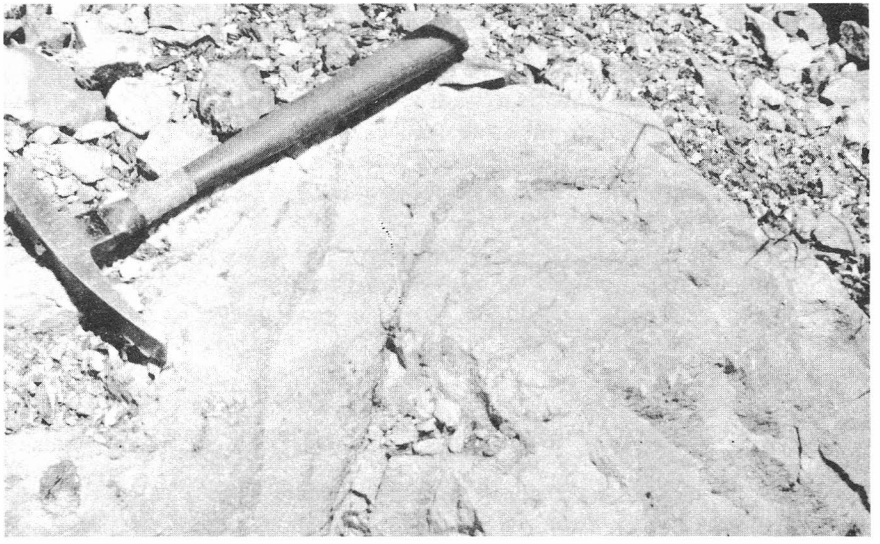

Figure 7. Scallopy-banded "line rock" (referred to locally as "boleros"). Banded muscovite-sugary albite-quartz-yttrotantalite replacement unit, Rare Metals pegmatite, Aquarius Range, Arizona.

Table 5. Paragenesis of the Rare-Metals Pegmatite, Aquarius Range, Arizona

	Wall Zone	Core Margin Zone	Core	"Line Rock"
Stage 1	Quartz, microcline, sodic plagioclase, muscovite, garnet, monazite			
Stage 2		Microcline, muscovite, beryl, unknown Bi mineral		
Stage 3	Albite, euxenite, fergusonite(?)		Quartz	
Stage 4	Hematite			Ablite, muscovite, gadolinite, yttrotantalite
Stage 5 (supergene)		Bismutite, chalcedony		

The complete paragenesis of the pegmatite is given in Table 5.

The sequence of formation of the rare-earth minerals is:

1. Monazite (in non-albitized wall-zone pegmatite)
2. Euxenite (in slightly albitized wall-zone pegmatite)
3. Gadolinite (in "line rock")
4. Yttrotantalite (in "line rock," with some of it forming crusts on gadolinite)

The geochemical progressions involved in this sequence are:

	Older Minerals	Younger Minerals
1.	Ce group rare earths	Y group rare earths
2.	Nb	Ta
3.	Fe poor	Fe rich

OTHER PEGMATITES IN THE AQUARIUS RANGE

About one and one-half miles south of the Rare Metals pegmatite, two small pegmatites have been mined to very shallow depths for beryl, of which about 400 lbs. were obtained. The poorly exposed parallel dikes are six feet or less thick, at least several score feet long, and about 200 feet apart. They strike generally east-west and contain small cores rich

in microcline. The following accessory mineral assemblage was noted: 1) blue beryl in subhedral crystals, some of which show bending and are segmented by transverse quartz veinlets; 2) light brown garnet; 3) small stubby gray apatite crystals; 4) grains of magnetite; 5) euhedra of colorless, partly sericitized topaz, as much as two and one-half inches long; 6) small pods of glassy, pale green, cryptocrystalline sericite; 7) a few minute bladed aggregates of dark green clinozosite.

About two miles southwest of the Rare Earth mine, two small poorly exposed pegmatites have been prospected by means of several shallow pits (Columbite prospect). The dikes are indistinctly zoned, containing small quartzose core pods. From the northern of these, several hundred pounds of columbite reportedly have been obtained. A few beryl crystals occur in the southern dike. Small vugs with yellow sericite masses also are present. The dumps at one deposit contain specimens with allanite blades several inches long, associated with minor amounts of monazite, which forms anhedral grains 0.2 inches long in quartz pods. The other dike contains a few crystals of reddish xenotime as much as an inch across (checked optically and by means of X-rays).

The accessory mineralogy of these deposits offers a remarkable contrast with that of the nearby Rare Metals dike:

Rare Metals Mine		Columbite Prospects	
Monazite	(Ce phosphate)	Monazite	(Ce phosphate)
		Xenotime	(Y phosphate)
Euxenite	(Fe,Y,Ce,Nb,Ta,Ti multiple oxides)	Columbite	(Fe,Nb multiple oxide)
Yttrotantalite			
Gadolinite	(Fe,Y, Be silicate)	Allanite	(Ca,Ce,Al,Fe silicate)

Other reported occurrences of rare-earth (or radioactive minerals) in the Aquarius Range are:

1. Frank Kayser deposit on Bolo Creek, a tributary of Trout Creek, which is a tributary of Big Sandy Wash. Reportedly in sec. 14, R. 11 W., T. 18 N. near crest of Aquarius Range. Reported to contain gadolinite. Specimens believed to be from this deposit were examined and found to consist of metamict allanite and a few lustrous marginal grains of a species that is properly euxenite.

2. A poorly located occurrence of chevkinite (Kauffman and Jaffe, 1946, p 582) in a dike ". . . in the Aquarius Range, Mohave County, Arizona." The identity of the species is confirmed by X-ray data and a chemical analysis. Associated are monazite, sphene, apatite, cronstedtite, and quartz. Locality was sought but could not be found.

SUMMARY

Pegmatites in the Aquarius Range, Mohave County, Arizona contain a variety of radioactive rare-earth minerals. Authenticated species are: monazite, xenotime, euxenite, yttrotantalite, gadolinite, and allanite. Fergusonite also may be present. The occurrence of yttrotantalite, several tons of which have been produced, is the first that has been established for the United States. Within one pegmatite, the sequence of rare-earth minerals is accompanied by an increase in Y rare earths and Ta in younger minerals at the expense of Ce rare earths and Nb in older species. The variation in mineralogy among deposits shows that even in a relatively small area between apparently comagmatic dikes, Y earths may be combined in one case chiefly with 0 and SiO_2 (euxenite, yttrotantalite, and gadolinite), and in another mainly with PO_4 (xenotime) and that similarly, whereas one deposit will contain Ce earths chiefly as the phosphate (monazite), in another, Ce earths are combined mainly with SiO_2 to form allanite and to only a very minor extent with PO_4. In each of the pegmatites, the two subgroups of rare earths do not form minerals of the same chemical class, i.e., the phosphates xenotime and monazite are mutually exclusive as are the silicates gadolinite and allanite.

The identity of the abundant rare-earth mineral in the Kingman Feldspar pegmatite is established as allanite.

GLOSSARY*

Allanite—A calcium (Ca) iron (Fe) aluminum (Al) rare-earth silicate.
Apatite—A calcium phosphate.
Beryl—A beryllium (Be) aluminum silicate.
Chevkinite or Tscheffkinite—A titanium (Ti) silicate mainly of cerium and iron.
Clinozoisite—A hydrous calcium aluminum silicate.
Columbite—An oxide of iron (Fe), manganese (Mn), and columbium (Niobium, Nb).
Comagmatic—Derived from the same magma.
Cronstedite—A hydrous iron silicate.
Cryptocrystalline—Formed of crystals too fine to be seen.
Diabase—An igneous instrusive rock of basaltic composition.
Euxenite—A complex oxide of calcium, tantalum (Ta), titanium, yttrium, cerium, niobium, erbium, and ytterbium.
Fergusonite—A complex oxide of niobium, titanium, and rare earths.
Gadolinite—A silicate of beryllium, iron, and rare earths.
Gneiss—A foliated or layered metamorphic rock.
Metamict—Formerly crystalline, but now amorphous due to radioactive emanations.
Monazite—A phosphate of cerium, lanthanum, yttrium, and thorium(Th).
Paragenesis—The origin, association, and sequence of minerals.
Pegmatite—A coarse-grained igneous rock, characteristically occurring as dikes.
Rare earths—A series of 16 elements: Lanthanum (La), cerium (Ce), Praesodymium (Pr), Neodymium (Nd), Illinium (Il), Samarium (Sa), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Yttrium (Y), Erbium (Er), Thullium (Tm), Ytterbium (Yb), and Lutecium (Lu).
Samarskite—An oxide of calcium, iron, uranium (U); thorium, rare earths, niobium, and tantalum.
Sphene or titanite—A calcium-titanium silicate.
Yttrotantalite—An oxide of iron, yttrium, uranium, niobium, tantalum, and titanium.
Xenolith—Inclusion.
Xenotime—An yttrium phosphate.

**See also*—Moore, Richard T., Minerals and Metals of Increasing Interest, Rare and Radioactive Minerals: Univ. Ariz., Ariz. Bur. Mines Bull. No. 163 (1953); Butler, G. M., Petrology: Univ. Ariz., Ariz. Bur. Mines Bull. No. 166 (1959).

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The ARIZONA BUREAU OF MINES was created and placed under the authority of the Arizona Board of Regents in 1915 by an act of the State legislature. The Bureau is directly charged with developing, maintaining, and disseminating to the people of Arizona information relating to geology, mining, metallurgy, and earth sciences generally. The Bureau's primary functions, therefore, are scientific investigation and public service activities comparable to those conducted by geological survey agencies and mineral experiment stations in other states. These primary functions are achieved through the following continuing programs:

1. Prepare and publish bulletins and circulars containing authoritative information on a wide range of topics of interest to prospectors, miners, and others concerned with the development of Arizona's mineral resources and industries. The bulletins are distributed free of charge to residents and at cost to nonresidents of Arizona upon request.

2. Classify mineral and rock specimens. Besides identifying rocks and giving the composition of minerals, the Bureau makes qualititative tests for important elements and answers inquiries concerning the probable market for and the economic value of material similar to samples submitted. This service is furnished free of charge providing the specimens originate within the State of Arizona; a charge of $1 per specimen is made for samples submitted from outside the State. Spectrographic analyses and detailed microscopic determinations are furnished at established rates, a schedule of which will be submitted on request.

3. Conduct laboratory and pilot-plant metallurgical testing of mineral substances in cooperation with industries and individual mine operators in the State. Such tests are conducted on the basis of nominal charges to compensate for wear and depreciation of equipment needed in the experimentation.

4. Make geologic investigations and compile geologic maps and reports. Geologic maps of each county, on a scale of 1:375,000, have been issued and geologic reports on numerous mining districts have been made available as bulletins. In addition to maps and reports on counties and mining districts, comprehensive studies of basic problems in the geology of Arizona are being carried out in order that the maximum benefits may be derived by the people of the State by having a more complete knowledge of its geologic setting.

5. Maintain a working file of statistical records of mineral production in Arizona.

6. Develop well-log storage facilities and a library of data pertaining to oil and water wells drilled in Arizona.

7. Conduct state-wide commodity studies as to modes of occurrence and potential industrial value of various mineral materials.

8. Collect and file items relating to Arizona mines and minerals that appear in Arizona newspapers and in many technical periodicals.

The basic philosophy which obtains in the operation of the Arizona Bureau of Mines is that of providing for the people of Arizona educational services in the earth sciences which cannot be readily secured elsewhere, and furnishing advice and service about mineral occurrences which cannot be obtained conveniently from commercial sources.

An inquiry addressed to: Director, Arizona Bureau of Mines, University of Arizona, Tucson, AZ 85721, will bring a prompt response if further information is desired about the services which are available.

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