BASTNAESITE, AN ACCESSORY MINERAL IN THE REDSTONE GRANITE FROM WESTERLY, RHODE ISLAND*

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Abstract

Bastnaesite, $CeFCO_3$, has been found in the Redstone granite of Martin (1925), which is one of the granites of the Sterling batholith near Westerly, R. I. It has not previously been recorded as an accessory mineral in granite. *X*-ray diffraction powder patterns of the bastnaesite compare closely with a pattern obtained from bastnaesite from Mountain Pass, Calif. The three strongest diffraction lines are: 2.88 Å, 3.56 Å, and 1.895 Å. A mean index of refraction measured on fine-grained material is 1.71. Spectrographic analysis showed a major amount of cerium and minor amounts of lanthanum, neodymium, calcium, and fluorine.

Introduction

The Redstone granite of Martin (1925) is a phase of the Sterling granite gneiss and is one of the last differentiates of the Sterling batholith. The Sterling batholith, underlying the greater part of the state of Rhode Island and extending into Connecticut and Massachusetts (Hawkins, 1918), is of Pennsylvanian age (Loughlin, 1910). The Redstone granite of Martin (1925) occurs as sheets roughly parallel to the southern margin of the batholith and intrudes the flow-banded Sterling granite gneiss and a metamorphic complex known as the ancient schists. The granites of the Sterling batholith are rich in accessory minerals, several having a high rare-earth content.

In a heavy-mineral study of Martin's Redstone granite, a mineral resembling a finely granular xenotime was found. Martin (1925) menmentioned a rare "rust producing" crystal as probably allanite. Kemp (1899) noted these rust blemishes in the Westerly granites spreading from a dark nucleus and staining quartz and feldspar, and he considered the mineral to be altered allanite, adding that it was a poor petrographic subject. Iddings and Cross (1885) described allanite in Westerly granites. Allanite occurs in the monumental granite at Westerly (Quinn, 1943); however, the writers found no allanite in the Redstone granite of Martin (1925). Derby (1891) described monazite in the Redstone granite, and the writers also have noted the presence of monazite. Xenotime is described as present in the Westerly gray granite (Kemp, 1899), however none was found in the Redstone. Young (1938) found keilhauite, a sphene rich in rare earths, in the Sterling granite gneiss. The small

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amount of sphene present in the Redstone granite and in the monumental stone at Westerly (Quinn, 1943) is normal.

Optical, spectographic, and *x*-ray analyses clearly establish the "rust producing" mineral in the Redstone granite of Martin (1925) to be bastnaesite, a fluocarbonate of cerium earth minerals. Its occurrence in coarse-grained granite, free of pegmatite or inclusions, and its intimate association with monazite suggest that it is a primary constituent of the rock. Bastnaesite has not previously been described as an accessory mineral in granite other than in contact metamorphic zones or pegmatites.

At Mountain Pass, Calif., bastnaesite occurs in carbonate rock associated with potassium-rich intrusives (Olson et al., 1955). It is present in skarn at Bastnäs, Vastmanland, Sweden (Geijer, 1920). It has also been reported in contact zones at Kychtym, Russia (Silberminz, 1929); in the Torendrika-Ifasino region of Madgascar (Koechlin, 1912); and at Jamestown, Colo. (Goddard and Glass, 1940). At Pikes Peak, Colo., bastnaesite is found with tysonite in granite pegmatite (Allen and Comstock, 1880). Glass and Smalley (1945) describe bastnaesite as being present in a brecciated zone near the contact of igneous rock with metamorphosed sediments, in the Gallinas Mountains, New Mexico.

Sample Location

At Westerly, R. I., the Redstone granite of Martin (1925) makes up a ridge half a mile wide and two miles long north of Chapman Road. The specimen studied was obtained from the Redstone quarry, shown on the Ashaway (Conn.-R.I.) quadrangle north of the New York, New Haven, and Hartford railroad tracks, half a mile northeast of Westerly. Commerically this granite is known as the "Westerly Red" and should not be confused with the "Westerly monumental granite." The sample collected for study was coarse-grained granite obtained near the center of the body and was free of inclusions and pegmatite.

Mineral Separation

A 10-kg. sample of the granite was crushed to pass a 40-mesh screen. The 80- to 200-mesh fraction of the product of the rolls crusher was separated by means of a hand magnet, bromoform, methylene iodide, and a Frantz isodynamic magnetic separator. Bastnaesite has a specific gravity greater than methylene iodide and separates on the Frantz isodynamic separator between 0.4 and 0.7 amp. at cross and longitudinal settings of 10°. A few grains of bastnaesite remained nonmagnetic up to 1.0 amp. Several grams of bastnaestite were concentrated.

Optical and *X*-Ray Examination

The bastnaesite occurs in the rock in two forms, as prismatic crystals measuring 0.05×0.15 mm. and as irregular aggregates averaging 0.1 mm. in diameter. Both forms are finely granular. The mineral is reddish brown as seen under the petrographic microscope. In immersion liquids an intermediate index of 1.71 can be determined where the coating (probably cerium oxide) has been partly removed by tartaric acid. Dana (Ford, 1932) describes bastnaesite as uniaxal (+), $\omega=1.717$; $\epsilon=1.818$.

X-ray powder diffraction patterns were made of the concentrates of bastnaesite that separated magnetically on the Frantz isodynamic separator at 0.5, 0.7, and 1.0 amp. These concentrates were mostly the aggregate form of the mineral. In each of the photographs the bastnaesite pattern occurred with a very faint monazite pattern. Monazite had not yet been identified as a component mineral, and it was considered that the monazite and bastnaesite could be intergrown. Monazite subsequently was identified in immersions and separated by hand-picking the sample.

Hand-picked separates of pure bastnaesite of the aggregate variety, magnetic at 0.5 amp., and of the prismatic variety, magnetic at 0.7 amp., were photographed. Both varieties showed bastnaesite powder patterns without the monazite lines. There is no difference between the powder patterns of the prismatic and the aggregate forms of the mineral.

In Table 1 the *x*-ray powder diffraction pattern of the bastnaesite from the Redstone granite of Martin (1925) is compared with that for bastnaesite from Mountain Pass, Calif. The three strongest diffraction lines of the Redstone granite bastnaesite are 2.88 Å, 3.56 Å, and 1.895 Å. These are in close agreement with the three strongest diffraction lines of the Mountain Pass mineral.

Both the aggregate and prismatic forms of the bastnaesite from the Redstone granite of Martin (1925) are composed of minute crystallites and as a result the patterns produced are faint and diffuse. The measurements were made from the centers of the diffuse lines.

Composition of the Bastnaesite

Qualitative spectrographic analysis of the bastnaesite shows cerium to be the only major element. Lanthanum, neodymium, calcium, and fluorine occur as minor components. Aside from detectable contaminants, thorium showed as a minor component. Upon heating the sample, however, the *x*-ray powder pattern showed the presence of uranoan thorianite; this indicates that thorium is present in other minerals and is not only a substitution for one of the rare earths in the bastnaesite. Chemical

TABLE 1. *X*-RAY-DIFFRACTION POWDER-PATTERN MEASUREMENTS OF BASTNAESITE FROM MOUNTAIN PASS, CALIF., AND WESTERLY, R. I. (CuKα RADIATION)

Mountain Pass, Calif. (Film no. 255)		Westerly, R. I. (Film no. 4889)	
d(Å)	*I*	*d*(Å)	*I*
4.85	M	4.87	W
3.55	S	3.56	S
2.87	S	2.88	M
2.44	F	2.45	VF
2.06	S	2.06	M
2.01	S	2.01	M
1.895	S	1.895	M
1.784	M	1.784	W
1.672	S	1.670	W
1.575	M	1.578	F
1.482	M	1.482	F
1.439	M	1.441	F
1.347	M	1.347	F
1.301	S	1.299	W
1.280	W		VF
1.204	W		VF
1.191	W		VF
1.181	M	1.183	F
1.158	M	1.157	F

The error in measurements is $\pm 0.05°$, 2θ.

analysis by Alexander Sherwood of the Geological Survey shows the ThO_2 content of the bastnaesite alone to be 0.39 per cent, uranium to be 0.0045 per cent. Phosphorus occurs as a minor constituent and cannot be accounted for by contamination. Phosphorus, however, has a normal affinity for the rare earths as does fluorine (Rankama and Sahama, 1950).

Semiquantitative spectrographic analysis for the trace elements shows yttrium to be present from 0.1 to 0.5 per cent and scandium to be present from 0.01 to 0.05 per cent.

The rare earths are distributed as follows:

>10.	per cent	Ce				
1.–5.	per cent	La	Nd			
0.1 –0.5	per cent	Pr	Gd	Sm		
0.01 –0.05	per cent	Dy	Er	Eu	Lu	Tb
0.005–0.01	per cent	Ho	Yb			

Of the Ce-earth metals, $Ce > La \geqq Nd > Pr \geqq Sm > Eu$.
Of the Y-earth metals, $Gd > Dy \geqq Er \geqq Lu \geqq Tb > Ho > Yb$.

This bastnaesite is thus intermediate between the apatite assemblage of Goldschmidt and Thomassen (1924) where $Ce \geqq Nd > Sm \geqq Gd \geqq Dy \geqq Er \geqq Yb$, and the allanite-monazite type (Rankama and Sahama, 1950), which is predominantly Ce earths, $Ce > Nd > Sm \geqq Gd$ but impoverished of the Y earths.

Petrography

The Redstone granite of Martin (1925) is a coarse-grained red granite. Pink orthoclase feldspar comprises about 45 per cent of the rock. The other major components are approximately: plagioclase 30, smoky quartz 20, and biotite 5 per cent. The plagioclase feldspar was determined by Martin (1925) to be oligoclase with oligoclase-albite rims. Separates were made of the accessory minerals, and the following percentages were estimated for the whole rock:

Magnetite and ilmenite	0.13
Apatite	0.05
Bastnaesite	0.02
Pyrite	0.005
Monazite	0.002
Sphene	0.001
Zircon	0.001
Uranoan thorianite	0.001
Allanite	none
Xenotime	none
Garnet	none

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