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DOVERITE, A POSSIBLE NEW YTTRIUM FLUOCARBONATE FROM DOVER, MORRIS COUNTY, NEW JERSEY*

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ABSTRACT

Doverite, a possible new yttrium fluocarbonate, was found at the Scrub Oaks iron mine at Dover, Morris County, New Jersey. The mineral occurs in brownish-red aggregates mixed with xenotime, hematite, and quartz. The aggregates are irregular—some of them as large as 1 inch in diameter—and most of them have rims of bastnaesite.

In parts of the mine, the doverite aggregate constitutes several per cent of the gangue. The aggregate has indices of refraction in the range from 1.700 to 1.685. It is physically inseparable from the other components of the aggregate. Hematite and doverite were leached from the aggregate leaving a residue of quartz and xenotime. From the x-ray powder data, doverite is suggested to be an yttrian analogue of synchisite and to have a general formula $YFCO_3 \cdot CaCO_3$, the Y in the formula including several elements of the rare-earth group.

The x-ray powder pattern of doverite bears a marked similarity to that of synchisite. The powder pattern of synchisite was indexed in terms of a pseudo-orthorhombic C-centered cell with $a=4.10$, $b=7.10$, and $c=9.12$ Å. From these data the cell constants of doverite were calculated to be $a=4.07$, $b=7.06$, and $c=9.12$ Å.

Inasmuch as doverite has not been satisfactorily purified from the aggregate, the possibility remains that doverite may be an yttrium-bearing synchisite. Until it can be proven to be an end-member of a series, its status as a new species is tentative.

INTRODUCTION

Ore containing the possible new mineral was found in 1951 in the course of a study of the paragenesis of the ore minerals at Scrub Oaks mine, Dover, New Jersey, by W. L. Smith. It was recognized as an unknown radioactive mineral. In the summer of 1954, Harry Klemic, of the U. S. Geological Survey, collected some of the same material from the Scrub Oaks mine. Analysis of this sample by spectrographic methods showed a high rare-earth content and prompted further studies. The two senior authors visited the deposit in the fall of 1954 to collect more samples and study its geological environment. A preliminary description of doverite was published (Smith and others, 1955).

The brownish-red aggregate containing doverite was found to comprise several per cent of the gangue in some areas of the mine and to occur at several levels. The brownish-red aggregate subsequently has been determined to be a microscopic mixture of doverite, hematite, xenotime, and quartz; some aggregates have rims of bastnaesite, some containing admixed leucoxene. The aggregates are associated with

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hematite, magnetite, quartz, apatite, albite, zircon, bastnaesite, and rutile. Elsewhere in the mine siderite, calcite, biotite, muscovite, epidote, hornblende, tremolite, sericite, pyrite, chalcopyrite, and bornite were found. Monazite, tourmaline, anatase, sphene, spinel, pumpellyite, chevkinite, garnet, and pyrrhotite have been reported as present in the deposit.

The Scrub Oaks mine of the Alan Wood Steel Company is located at Mine Hill, 2½ miles west of Dover, off U. S. route 46. The geology of the Scrub Oaks deposit is described by Roche and Crockett (1933), and Sims (1953, 1958). The deposit lies in the west-central region of the New Jersey highlands. The magnetite body is described by Sims (1953) as an irregular tabular body consisting of several shoots of disseminated ore in albite-oligoclase granite. The granite and ore are of Precambrian age. The doverite aggregates are intimately associated with the ore minerals in the coarser-grained and pegmatitic phases of the ore rather than with the host rock.

MINERALOGY

Separation method

The ore containing the doverite aggregate was crushed by hand rather than by machine to avoid contamination. Because of some inclusions of quartz and iron ores in the mineral fragments, the aggregate concentrates had to be purified by hand picking. Particles greater than 100-mesh size were often attached grains. For ease of handling, the crushed ore was sized in 100- and 200-mesh sieves.

Heavy-liquid separations were made with methylene iodide (sp. gr. 3.33), which produced a light fraction composed primarily of quartz and traces of feldspar and apatite, and a heavy fraction containing the doverite aggregate with attached bastnaesite, magnetite, specular hematite, and zircon. The magnetite was removed from the concentrate by means of a hand magnet. The specular hematite and zircon were removed on a Frantz isodynamic magnetic separator. The doverite aggregate separates on the Frantz separator between 0.30 and 0.45 amp. at horizontal and longitudinal settings of 10°. The magnetic property of the aggregate may be due partly to its rare-earth composition as well as to its hematite component. Hematite occurs both free and as a component of the aggregate. Several grams of the aggregate were concentrated. A 1-gram sample of the purified material was obtained for chemical analysis.

Physical properties

The doverite aggregate is a finely crystalline mixture which may show a platy character. The aggregates range in size from microscopic specks to some approximately 1 inch in diameter. They are irregular, rounded, nodular masses in external form. Doverite is physically inseparable from the other components of the aggregate. Doverite constitutes the more abundant component of the aggregates which have a nometallic luster, are brownish red resembling jasper or red hematite, have a brownish streak, are brittle, and break with an uneven to subconchoidal fracture. The aggregates are somewhat variable in composition, some having appreciably more quartz or hematite than others, and in some the bastnaesite is absent. The hardness of the aggregate is 6.5 and the specific gravity ranges from 3.89 to 4.1+ as the composition of the aggregate varies, as determined by suspension in Clerici solution and checked by pycnometer. Assuming average specific gravities for the other components, the density of doverite was calculated to be in the range of 3.61 to 3.72. The aggregates are moderately radioactive with an equivalent uranium content of 0.5 to 0.6 per cent.

X-ray diffraction data

X-ray powder patterns show the aggregates to be a mixture of doverite, xenotime, hematite, quartz, and in some samples, bastnaesite. The pattern obtained from a sample leached with hot acid shows only xenotime and quartz. A bastnaesite pattern was obtained on a sample of the aggregate rim. The powder pattern of doverite has a marked similarity to that of synchisite. The powder pattern of synchisite was indexed in terms of pseudo-orthorhomic C-centered cell with $a=4.10$, $b=7.10$, and $c=9.12$ Å (Donnay and Donnay, 1953). On the basis of these data, the cell constants of doverite were calculated to be $a=4.07 \pm 0.02$, $b=7.06\pm 0.02$, $c=9.12\pm 0.03$ Å. The spacings of the two powder patterns are listed for comparison in Table 1. The cell volume calculated from the constants previously given is 262.1 A^3. If the yttrium end-member were assumed to be $2(YFCO_3 \cdot CaCO_3)$, the calculated density would be 3.40.

Because of the complexity of the doverite pattern, and because of its close similarity to that of synchisite, uncertainty still exists as to the validity of doverite as a new species. It would be expected that an yttrium analogue would have a cell size considerably smaller than the one proposed for doverite. Unless more conclusive evidence can be obtained, it may be that doverite is actually an yttrium-rich synchisite.

Optical properties

The doverite aggregate is brownish red in thin section and in immersions of high-index oils and shows variations in translucency which give the material a streaked or blotchy character. The individual crystal

Table 1. Comparison of Powder Data for Doverite Aggregate, $YFCO_3 \cdot CaCO_3$, and Synchisite, $CeFCO_3 \cdot CaCO_3$

(CuKα radiation, $\lambda = 1.5418$, nickel filter, camera diameter 114.6 mm.)

Doverite aggregate, Dover, N. J. (film T 6391)				Synchisite, Quincy, Mass. (film 6668)	
I	d_{hkl} (Å) (meas.)	d_{hkl} (Å) (calc.)	*hkl*	*I*	d_{hkl} (Å) (meas.)
s	9.1	9.12	001	s	9.1
m	4.55*	4.56	002	m	4.55
s	3.53	3.53	110	s	3.56
		3.53	020		
s	3.45	xenotime		vf	3.49
wb	3.30	3.29	111	m	3.31
		3.29	021		
wb	3.05	3.04	003	w	3.07
				w	3.04
s	2.80	2.79	112	s	2.81
		2.79	022		
vvf	2.75	xenotime			
fb	2.69	hematite			
mw	2.57	xenotime			
vf	2.52	hematite			
w	2.44	xenotime		vvf	2.42
vf	2.30	2.30	113	w	2.31
		2.30	023		
wb	2.28*	2.28	004	w	2.28
vfb	2.21	hematite		vf	2.23
wb	2.15	xenotime		vf	2.15
ms	2.04	2.04	200	ms	2.05
		2.04	130		
vvf	1.995	1.988	131	w	2.002
		1.986	201		
vf	1.935	xenotime			
ms	1.916	1.915	024	m	1.918
		1.915	114		
m	1.863	1.860	132	ms	1.870
		1.858	202		
vfb	1.839	1.824	005	vf	1.821
vf	1.819	xenotime			
m	1.772	1.765	040	w	1.781
		1.763	220		
f	1.768	xenotime			
		1.733	041		
f	1.727	1.731	221	w	1.749

* Lines occur on both xenotime and doverite patterns. s = strong; ms = medium strong; m = medium; mw = medium weak; w = weak; f = faint; vf = very faint; vvf = very very faint; b = broad line.

TABLE 1 (*continued*)

Doverite aggregate, Dover, N. J. (film T 6391)				Synchisite, Quincy, Mass. (film 6668)	
I	d_{hkl} (Å) (meas.)	d_{hkl} (Å) (calc.)	*hkl*	*I*	d_{hkl} (Å) (meas.)
		1.693	133		
f	1.689	1.691	203	w	1.704
w	1.647	1.646	042	m	1.658
		1.645	222		
f	1.544	xenotime			
		1.520	006		
w	1.512	1.518	204		
		1.518	134		
vf	1.487	hematite			
vf	1.457	hematite			
f	1.431	xenotime			
		1.396	116		
		1.396	026		
wb	1.395	1.395	224		
vvfb	1.341	xenotime			
wb	1.282*	1.280	242		
		1.279	312		
fb	1.236	xenotime			
		1.220	313		
fb	1.216	1.218	206		
		1.218	136		
wb	1.153	xenotime			

components of the aggregates are extremely fine grained, approaching the limits of resolution and making detailed optical examination impossible. The doverite aggregate, as distinguished from the other components, is anisotropic and shows indices of refraction in the range from 1.700 to 1.685. The indices of the immersion liquids were measured at the time of examination on an Abbe refractometer. The lighter colored rims around the doverite aggregates, identified to be bastnaesite, are often mixed with leucoxene. Bastnaesite was determined petrographically to approximate ten per cent of the aggregate.

CHEMISTRY

The aggregate, at first thought to be a single mineral species, and subsequently found to be a mixture of doverite, quartz, xenotime, and hematite, rimmed with bastnaesite and leucoxene, was chemically

TABLE 2. CHEMICAL ANALYSIS OF THE DOVERITE AGGREGATE

[Analysts: Harry Levine and Robert Meyrowitz, U. S. Geological Survey]

Constituent	Per cent	Constituent	Per cent
RE oxides*	44.36	TiO_2	0.75
ThO_2	1.62	MgO	0.53
SiO_2	9.70	H_2O (total)	1.35
Fe_2O_3	8.90	CO_2	11.75
CaO	9.80	F	2.87
P_2O_5	8.75		
Al_2O_3	0.54		101.14
UO_3	0.22	$-(O=2F)$	1.21
		Total	99.93

* Includes $Ce_2O_3=7.40$.

analyzed (Tables 2 and 3), and the analysis of the aggregate was computed (table 4).

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TABLE 3. SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSIS OF THE DOVERITE AGGREGATE, IN PER CENT

[Analyst: Katherine V. Hazel, U. S. Geological Survey]

Over 10	Y
5 –10	Ca Ce Fe
1 – 5	Si P La Th Gd
0.5 – 1	Dy Er Yb Nd Pr
0.1 –0.5	Ti Al Lu Mg Ho Na
0.05– 0.1	Mn Tm
0.01– 0.05	Ba B Eu Pb Sc Sr

TABLE 4. COMPUTATION OF ANALYSIS OF AGGREGATE, IN PER CENT

Constituent	1	Deduct 2	Deduct 3	4 (=1-2-3)	5[a]
Ce_2O_3, etc.	12.48[b]	—	7.5[c]	5.0	12.1[d]
Y_2O_3, etc.	31.88[b]	17.50[e]	—	14.4	34.8
CaO	9.80	—	—	9.8	23.7
CO_2	11.75	—	1.8[c]	10.0	24.1
F	2.87	—	0.7[c]	2.2	5.3
SiO_2	9.70	9.70[f]	—	—	—
Fe_2O_3	8.90	8.90[g]	—	—	—
P_2O_5	8.75	8.75[e]	—	—	—
TiO_2	0.75	0.75[h]	—	—	—
ThO_2	1.62	1.62[i]	—	—	—
UO_3	0.22	0.22[i]	—	—	—
Al_2O_3	0.54	0.54[i]	—	—	—
MgO	0.53	0.53[i]	—	—	—
H_2O	1.35	1.35[i]	—	—	—
	101.14			41.4	100.0
$-(O=2F)$	1.21				
	99.93				

[a] Column 4 calculated to 100%.

[b] Column 1 is the analysis of Table 2 with values for Ce earths and Y earths calculated from the averages of the ranges given in Table 3.

[c] Deducting 10% bastnaesite.

[d] Analysis indicates a Y_2O_3 to Ce_2O_3 ratio of approximately 3 to 1.

[e] Deducted as xenotime.

[f] Deducted as quartz.

[g] Deducted as hematite.

[h] Deducted as leucoxene.

[i] Deducted; manner of occurrence unknown. It would be more logical to distribute UO_3 and ThO_2 among bastnaesite, xenotime, and doverite, but the amounts are too small to warrant this refinement.

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