

A re-examination of cheralite

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SUMMARY. A new analysis of the type material of cheralite specifies the individual rare earth elements. Unit cell contents are: $(REE)_{1.58}Th_{1.15}Ca_{1.03}Pb_{0.05}U_{0.15})_{3.96}(P_{3.67}Si_{0.33})_{4.01}O_{16}$. Refinement of the cell parameters based on new XRD data shows that $a = 6.7515 \pm 0.0005 \text{ \AA}$, $b = 6.9625 \pm 0.0005$, $c = 6.468 \pm 0.0005$, $\beta = 103^\circ 53'$, giving a cell volume of 295.2 \AA^3 . Space group $P2_1/n$.

CONTINUED work by the authors on other rare earth phosphates has led to a re-examination of the type material (MI 28881)* of the mineral cheralite as described by Bowie and Horne (1953) from Kuttakuzhi, Travancore (now in Kerala State), India. Instrumental improvements during the last quarter century permit us to give new and better quality data for cheralite to improve the specification of the type material whilst in no way detracting from the value of the original description.

Cheralite $(REE,Th,Ca,U)(P,Si)O_4$, is part of an isostructural series of monoclinic minerals of the general form ABO_4 where $A = REE, Th, U, Ca$ and $B = P, Si$, Monazite $(REEPO_4)$ —Breithaupt, 1829) and huttonite $(ThSiO_4)$ —Pabst, 1950) are prominent end-members of this series.

Microprobe analysis. The original analysis of cheralite (Bowie and Horne, 1953) and subsequent analyses (Finney and Nagaraja Rao, 1967; Aplonov and Petrova, 1965) have not separated the individual rare earth elements beyond giving results for Ce_2O_3 and La_2O_3 or $(La,Pr,Nd,Y)_2O_3$. The present analysis using a Cambridge Scientific Instruments Microscan 5 electron microprobe has permitted all the rare earth elements to be identified.

This analysis for 26 elements is given in Table I and has been obtained using the techniques and

* Numbers preceded by MI refer to specimens in the Mineral Inventory, Institute of Geological Sciences Collection.

standards described by Bowles (1975, 1978) with additional standards from Drake and Weill (1972) and Smellie *et al.* (1978). Full ZAF correction of the results has been obtained using a version of the Mason-Frost-Reed (1969) program expanded to consider a sufficient number of elements.

The analysis of the type material shows that the cell contents are: $(REE)_{1.58}Th_{1.15}Ca_{1.03}Pb_{0.05}U_{0.15})_{3.96}(P_{3.67}Si_{0.33})_{4.01}O_{16}$.

The distribution of rare earth elements in cheralite is similar to that shown by monazite, especially monazite from granitic pegmatites (fig. 1). This is not surprising since the cheralite type material is from a granitic pegmatite and there is structural similarity between monazite and cheralite.

X-ray data. The d -spacings (Table II) were determined from diffractometer charts taken with $Cu-K\alpha$ radiation at room temperature (around $22^\circ C$) and a scanning speed of $\frac{1}{8}^\circ 2\theta/\text{min}$. Quartz ($a = 4.91331 \text{ \AA}$, $c = 5.40488 \text{ \AA}$, at $25^\circ C$) was used as an internal standard. The intensities are relative peak heights. The powder data were provisionally indexed by comparison with published data (Bowie and Horne, 1953) and were refined using the least-squares program (BA 1.0) developed by the late Dr R. J. Davis, Department of Mineralogy, British Museum (Natural History), for the refinement of cell dimensions and enumeration of all possible d -spacings. This refinement gave cell dimensions $a = 6.7515 \pm 0.0005 \text{ \AA}$, $b = 6.9625 \pm 0.0005 \text{ \AA}$, $c = 6.468 \pm 0.0005 \text{ \AA}$, $\beta = 103^\circ 53'$, space group $P2_1/n$. Other workers have obtained lower values for the cell parameters of cheralite from the same locality (Table III). The present work confirms the higher values obtained by Bowie and Horne.

The density of cheralite corresponding to the unit-cell contents (Table I) and the above dimensions is 5.39 g cm^{-3} , compared with the measured value of 5.3 g cm^{-3} (Bowie and Horne, 1953).

Infra-red and absorption spectra. The infra-red spectra of cheralite and a monazite from Skardalen

TABLE I. Analyses and unit cell contents of cheralite from Kuttakuzhi, India

	Wt %		Molecular proportions recalculated to 16 oxygen atoms				
	1	2	1		2		
Ce ₂ O ₃	14.21	12.12	Ce ³⁺	0.836	0.710	} 3.96	
La ₂ O ₃	}	5.19	La ³⁺	}	0.306		
Pr ₂ O ₃		1.20	Pr ³⁺		0.070		
Nd ₂ O ₃		5.91	Nd ³⁺		0.338		
Sm ₂ O ₃		1.81	Sm ³⁺		0.100		
Eu ₂ O ₃		0.25	Eu ³⁺		0.014		
Gd ₂ O ₃		0.45	Gd ³⁺		0.024		
Tb ₂ O ₃		13.35	0.05		Tb ³⁺		0.003
Dy ₂ O ₃		0.06	Dy ³⁺		0.003		
Ho ₂ O ₃		0.01	Ho ³⁺		0.001		
Er ₂ O ₃		0.03	Er ³⁺		0.002		
Tm ₂ O ₃	0.12	Tm ³⁺	0.006				
Y ₂ O ₃	0.08	Y ³⁺	0.007				
Al ₂ O ₃	tr.	—	Al ³⁺	—			
Fe ₂ O ₃	tr.	—	Fe ³⁺	—			
CaO	6.30	5.99	Ca ²⁺	1.084	1.027		
PbO	0.92	1.15	Pb ²⁺	0.040	0.050		
ThO ₂	31.50	31.64	Th ⁴⁺	1.151	1.153		
U ₃ O ₈	4.05	4.33	U ^{4+,6+}	0.139	0.148		
P ₂ O ₅	26.80	27.10	P ⁵⁺	3.642	3.673		
SiO ₂	2.10	2.08	Si ⁴⁺	0.337	0.333		
H ₂ O ⁺	0.06	—					
	99.29	99.57					

Analyses: 1—Bowie and Horne (1953); 2—Present work, Yb₂O₃, Lu₂O₃, Hf₂O₃, Al₂O₃, Fe₂O₃, MnO, TiO₂ not detected (< 0.01 %).

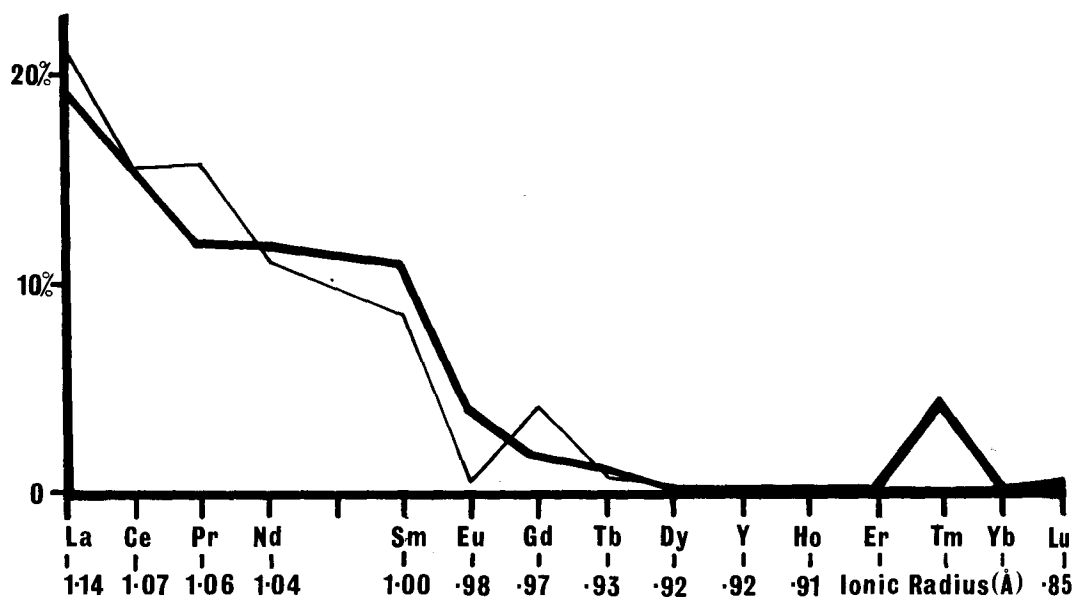


FIG. 1. The rare earth pattern of cheralite (heavy line) compared with the average composition of 104 monazites (thin line) from granitic pegmatites (Fleischer and Altshuler, 1969). The vertical axis shows the rare earth composition expressed as a ratio of the rare earth concentration in average chondritic meteorites and normalized to 100% Rare Earth + Yttrium.

TABLE II. X-ray powder data for cheralite from Kuttakuzhi, India

I/I_1	d_{obs}	d_{calc}	hkl	I/I_1	d_{obs}	d_{calc}	hkl
10	5.20 Å	5.200 Å	$\bar{1}01$			1.868 Å	103
6	4.77	4.772	110	14	1.867 Å	1.866	$\bar{1}32$
20	4.664	4.663	011			1.866	032
25	4.167	4.166	$\bar{1}11$	6	1.851	1.851	320
12	4.073	4.072	101	4	1.794	1.794	023
10	3.515	3.515	111	5	1.757	1.758	222
30	3.481	3.481	020			1.731	132
58	3.277	3.277	200	18	1.731	1.730	$\bar{2}23$
3	3.139	3.139	002			1.682	140
100	3.074	3.074	120	10	1.6820	1.682	$\bar{3}13$
12	2.965	2.965	210	2	1.638	1.639	400
			$\bar{1}12$	2	1.621	1.621	402
65	2.862 _s	{ 2.862	012			1.595	410
		2.862		4b	1.594	1.591	330
8	2.600	2.600	$\bar{2}02$			1.575	$\bar{1}14$
			$\bar{2}12$	3	1.575	1.575	$\bar{1}14$
12	2.435 _s	{ 2.436	$\bar{2}12$			1.534	$\bar{2}41$
		2.435	112	5b	1.533	1.532	$\bar{2}14$
4	2.386	2.386	220			1.467	$\bar{1}24$
			$\bar{1}22$	2	1.467	1.466	411
2	2.331 _s	{ 2.332	022				
		2.331					
1	2.237	2.237	$\bar{3}01$	2	1.455		
22	2.177	2.177	031	2	1.374 _s		
12	2.149	2.149	103	2	1.362		
14	2.130	2.130	$\bar{3}11$	3	1.339		
14	2.111	2.111	221	5	1.327		
1	2.016	2.016	131	2	1.301		
16	1.954	1.954	212	4	1.273		
2	1.925	1.925	301	4	1.228		
8	1.887	1.887	$\bar{2}31$				

b = broad.

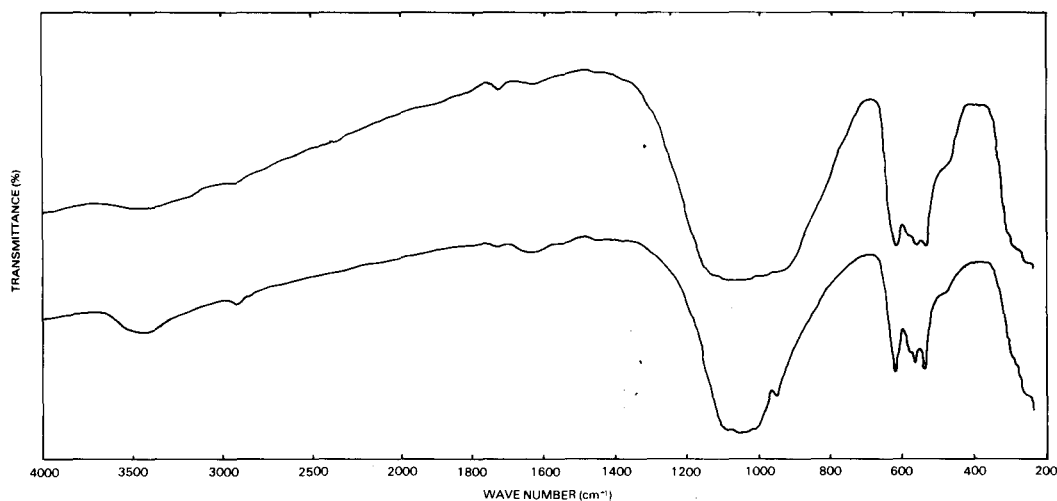


FIG. 2. Infra-red spectra of cheralite (above) from Kuttakuzhi, southern India, compared with monazite, Skardalen, Evje, Norway.

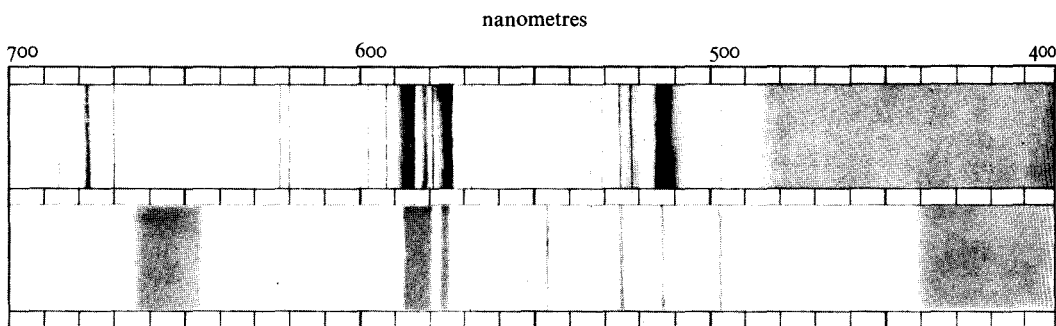


FIG. 3. Absorption spectra of cheralite (*below*) from Kuttakuzhi, southern India, and of red gem monazite from Sri Lanka.

TABLE III. Unit cell parameters of cheralite

	1	2	3	4
a (Å)	6.70	6.717 ± 0.005	6.74	$6.751_5 \pm 0.0005$
b (Å)	6.87	6.920 ± 0.005	7.00	$6.962_5 \pm 0.0005$
c (Å)	6.39	6.434 ± 0.005	6.43	6.468 ± 0.0005
β	$103^\circ 24'$	$103^\circ 50' \pm 5'$	$104^\circ 36'$	$103^\circ 53'$
V (Å ³)	286	290.4	294	295.2

1—Khubchandani (1956), 2—Nagaraja Rao and Finney (1965), 3—Bowie and Horne (1953), 4—Present work.

Quarry, Evje, Norway (MI 31156) for comparison, were run on a Perkin Elmer 457 spectrophotometer using the KBr disc technique. The traces (fig. 2) are very similar, but the band in the 950 cm^{-1} region was not observed in the cheralite.

The absorption spectrum of the cheralite as seen through a Beck wavelength prism spectroscopie is compared in fig. 3 with that of a red gem monazite from Sri Lanka described by Jobbins *et al.* (1977). The bands in the 570–80 nm and 525 nm regions are similar and have been ascribed to rare earths, notably neodymium. A broad band in the cheralite in the 640–60 nm region is not present in the monazite. It may be due to the significant presence of uranium (4.33% U_3O_8) in the cheralite as opposed to 0.4% U_3O_8 in the monazite; the thulium present (and ? holmium) may contribute to this broad band.

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