AN X-RAY STUDY OF NATURAL MONAZITE

II. Single Crystal Data on Indian Monazite Mineral

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INTRODUCTION

IN a previous communication[1] from this laboratory data obtained from a powder pattern on monazite were presented. It was shown that naturally occurring monazite containing thorium was metamict and that the order could be restored by heating at about 1100° C. for 24 hours, as evidenced by the greater sharpness of the powder pattern and the change in the density and refractive index of the heated sample. Work has now been extended to single crystal study of natural monazite and the present communication gives the cell dimensions and indices of reflecting planes obtained from the rotation and Weissenberg photographs.

The earliest X-ray study of monazite appears to have been reported in Klochmann's *Lehrbuch der Minerologie*.[2] Gliszczynski[3] studied the rotation and oscillation photographs of a single crystal of turnerite ($CePO_4$) and employed the data of Klochmann in indexing the planes. Parrish[4] used the thorium-free monazite, found by analysis to correspond to $La_4Ce_4Y(PO_4)_9$, for an independent determination of its unit cell and the space group from Weissenberg photographs. It is noteworthy that both the above single crystal studies have been made on material free from thorium.

EXPERIMENTAL

Monazite is found to occur abundantly amongst the minerals in the beach sand of Travancore in South India. It is in the form of fine golden yellow grains. Several thousand particles were carefully examined under the microscope but none showed any faces or edges. A massive piece of monazite rock weighing several grams was supplied to the authors by the Raw Materials Division* of the Department of Atomic Energy, New Delhi. It looked quite homogeneous. It was a dull brown piece showing the following faces:—

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$$(\bar{1}\ 0\ 1),\ (\bar{1}\ \bar{1}\ 1),\ (\bar{1}\ 0\ 0),\ (\bar{1}\ \bar{1}\ 0)$$

$$(1\ \bar{1}\ 0),\ (1\ \bar{1}\ \bar{1}),\ (1\ 0\ 0),\ (1\ 0\ \bar{1})$$

A piece was carefully cut and used for single crystal work. A portion was used for powder pattern and some for chemical and spectroscopic analysis. The portion used for mounting was about 2 mm $\times$ 1 mm $\times$ 0·5 mm. The following photographs were taken:—

b-axis (i) oscillation (Fig. 1).
(ii) Weissenberg zero layer (Fig. 3).
(iii) Weissenberg 1st layer (Fig. 4) and 2nd layer by equi-inclination method.

a-axis (i) Rotation (Fig. 2).
(ii) Weissenberg zero layer, 1st layer equi-inclination.

From the photographs given in the figures the following cell dimensions were calculated:—

$$a_0 = 6\cdot66\ \text{Å}$$
$$b_0 = 6\cdot98\ \text{Å}$$
$$c_0 = 6\cdot32\ \text{Å}$$
$$\beta = 76°\ 38'$$

The density of the sample was experimentally determined with a pyknometer as 5·23 gm./c.c.

Table I gives the comparative values of the cell parameters for the thorium-bearing monazite used here and the thorium-free monazite used by previous workers.

TABLE I

	Th-bearing	Turnerite $CePO_4$ (Gliszczynski)	Th-free monazite $La_4Ce_4Y(PO_4)_9$ Parrish
a_0	6·66	6·78	6·76
b_0	6·98	6·99	7·00
c_0	6·32	6·44	6·42
β	76° 38′	76° 22′	76° 50′
ρ	5·23	5·217	5·17

The reflecting planes indexed from the Weissenberg photographs together with the visual estimates of their intensities are collected together in Table II.

TABLE II

hkl	I/I_0	*hkl*	I/I_0	*hkl*	I/I_0	*hkl*	I/I_0
2 0 0	v.s.	4 0 2	v.s.	0 1 7	v.s.	1 2 0	s.
4 0 0	v.s.	$\bar{4}$ 0 2	v.w.	0 1 8	v.s.	1 4 0	v.s.
6 0 0	w.	$\bar{4}$ 0 4	w.	0 2 1	v.v.w.	1 6 0	v.s.
0 2 0	v.w.	4 0 6	v.s.	0 2 2	v.v.w.	1 1 1	v.v.w.
0 4 0	s.	5 0 1	v.w.	0 2 4	v.v.w.	1 1 3	w.
0 6 0	s.	$\bar{5}$ 0 1	v.s.	0 2 5	v.s.	1 1 5	w.
0 8 0	s.	5 0 3	m.s.	0 2 6	v.s.	1 1 6	w.
0 0 2	s.	$\bar{5}$ 0 3	w.	0 2 7	v.s.	1 1 7	m.s.
0 0 4	v.s.	5 0 5	w.	0 4 1	m.s.	1 2 1	v.w.
0 0 6	v.s.	5 0 7	m.s.	0 4 2	v.v.w.	1 2 4	w.
0 0 8	s.	6 0 2	v.s.	0 4 4	v.v.w.	1 2 5	v.v.w.
1 0 1	w.	6 0 4	w.	0 4 5	s.	1 2 7	v.v.w.
$\bar{1}$ 0 1	m.s.	6 0 6	v.s.	0 4 6	v.s.	1 2 8	m.s.
1 0 3	m.s.	7 0 1	m.s.	0 4 7	s.	1 3 2	s.
$\bar{1}$ 0 3	s.	7 0 3	m.s.	0 5 1	m.s.	1 3 6	w.
1 0 5	w.	$\bar{7}$ 0 3	m.s.	0 5 3	m.s.	1 3 8	m.s.
1 0 7	m.s.	7 0 5	v.s.	0 5 5	w.	1 4 1	w.
$\bar{1}$ 0 7	v.s.	$\bar{7}$ 0 5	v.s.	0 5 7	v.s.	1 4 3	w.
2 0 2	s.	$\bar{7}$ 0 7	w.	0 6 1	s.	1 4 5	w.
$\bar{2}$ 0 2	s.	$\bar{7}$ 0 9	v.s.	0 6 2	w.	1 4 7	w.
2 0 4	m.s.	8 0 2	v.s.	0 6 3	v.w.	1 4 8	m.s.
$\bar{2}$ 0 4	s.	8 0 4	v.s.	0 6 4	m.s.	1 5 2	s.
2 0 6	v.s.	0 1 3	s.	0 6 5	v.s.	1 5 5	m.s.
3 0 1	m.s.	0 1 4	m.s.	0 6 6	v.s.	1 5 7	m.s.
$\bar{3}$ 0 1	v.s.	0 1 5	v.v.w.	0 7 2	s.	1 6 2	w.
3 0 3	m.s.	0 1 6	w.	0 7 3	m.s.	1 6 5	s.
$\bar{3}$ 0 3	v.s.			0 7 4	v.s.	1 7 1	m.s.
3 0 5	w.					1 7 2	s.
$\bar{3}$ 0 5	v.s.					1 7 5	w.
3 0 7	w.					1 8 1	m.s.

FIG. 1 (Oscillation *b*-axis).

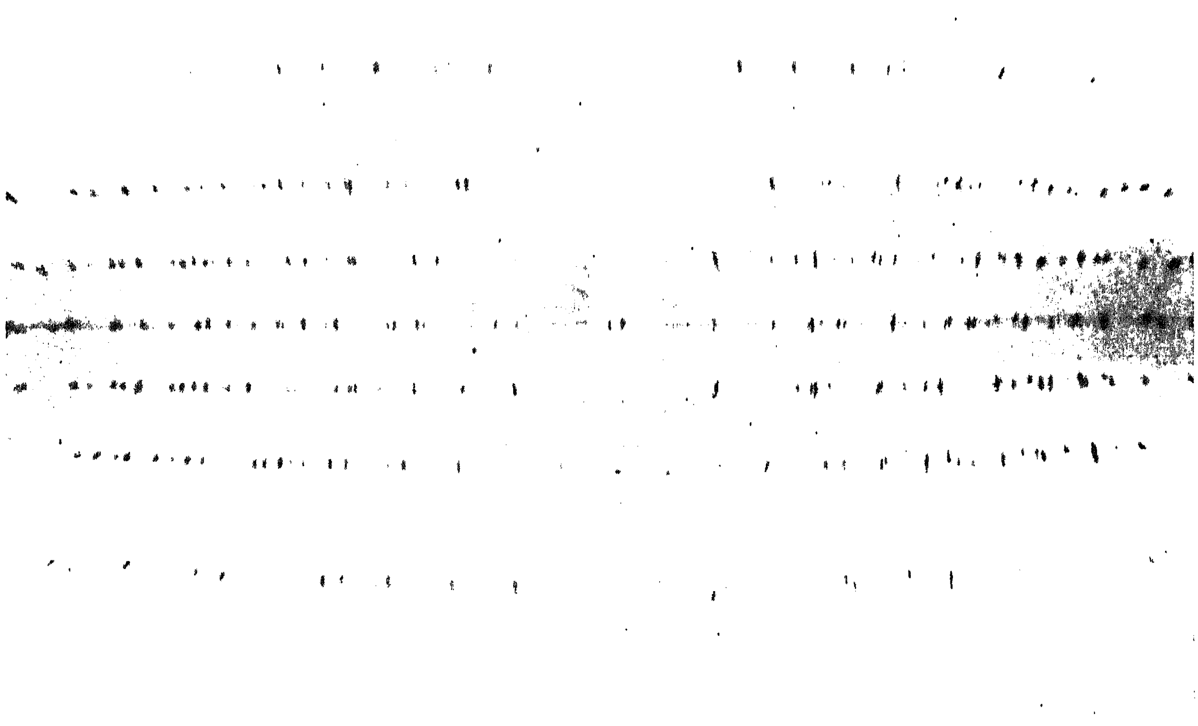

FIG. 2 (Rotation *a*-axis).

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FIG. 3 (Weissenberg *b*-axis zero layer).

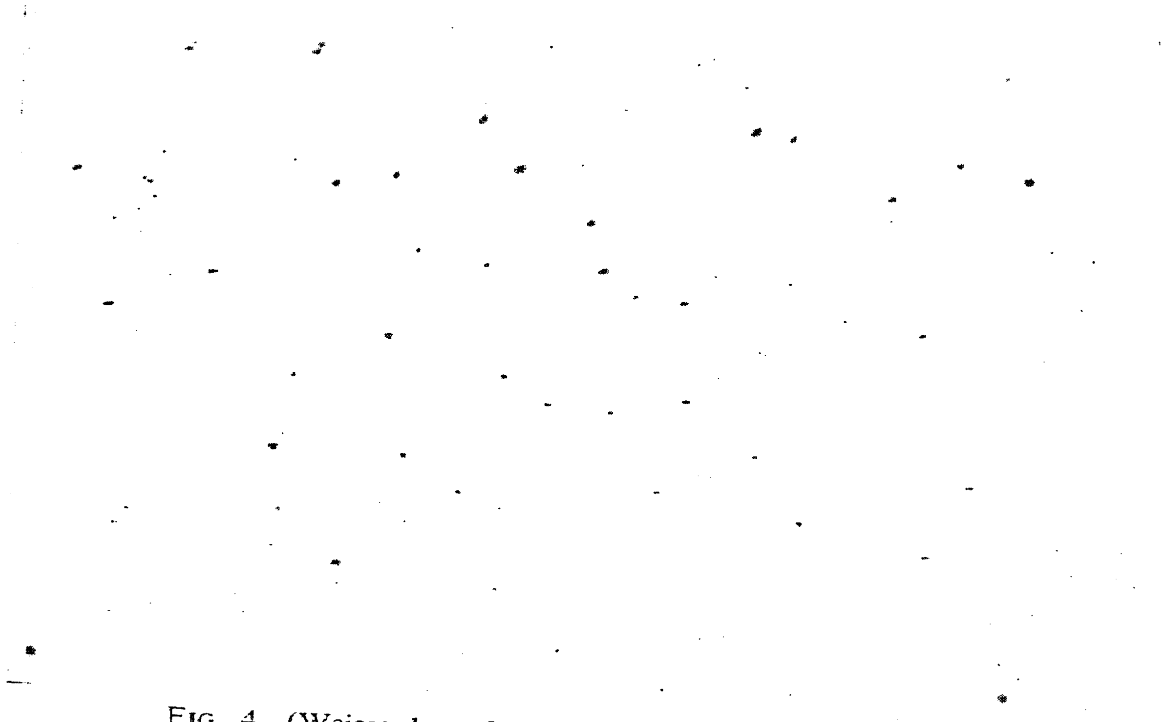

FIG. 4 (Weissenberg *b*-axis first layer equi-inclination).

The rotation photographs show the layer lines quite clearly indicating that the piece used was a single crystal and that the setting was accurate. This is further supported by the perfect Weissenberg pictures from which the *c*-axis and angle β were calculated. In fact these represent the first published single crystal photographs of thorium-bearing monazite.

It would be seen that $(h\ o\ l)$ planes are halved when $(h + l)$ is odd and $(o\ k\ o)$ planes are halved when k is odd. The space group is thus $P2_{1/n}\ (C^5_{2h})$.

Summary

Rotation and Weissenberg pictures have been taken of thorium-bearing monazite single crystal. The cell parameters are $a_0 = 6 \cdot 66$ Å, $b_0 = 6 \cdot 98$ Å, $c_0 = 6 \cdot 32$ Å and $\beta = 76° \ 38'$. The space group determined is $P2_{1/n}\ (C^5_{2h})$.

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