

# HUTTONITE, A NEW MONOCLINIC THORIUM SILICATE

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WITH AN ACCOUNT OF ITS OCCURRENCE, ANALYSIS,  
AND PROPERTIES

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## ABSTRACT

The name huttonite is given to a mineral of composition  $\text{ThSiO}_4$ , isostructural with monazite. It has been isolated in minute grains from beach sands of South Westland, New Zealand. It is monoclinic; sp. gr. 7.1;  $\alpha=1.898$ ,  $\beta=1.900$ ,  $\gamma=1.922$ ; dispersion  $r < v$ , moderate;  $2V=25^\circ$ ;  $Y \parallel b$ ,  $Z$  near  $c$ ; colorless to very pale cream. Space group  $C_{2h}^8-P2_1/n$ ;  $a_0=6.80\text{\AA}$ ,  $b_0=6.96$ ,  $c_0=6.54$ ,  $\beta=104^\circ 55'$ ; cell content  $4(\text{ThSiO}_4)$ .

## X-RAY EXAMINATION

Professor Hutton turned over to the writer a portion of a new mineral which he had concentrated from the sands of Gillespie's Beach, South Westland, New Zealand. The material received consisted of several hundred minute grains, none more than 0.2 mm. in maximum dimension, weighing a few hundredths of a gram altogether. The grains were all anhedral, mostly bounded by more or less conchoidal fractures and in part by smoother surfaces taken to be parting or rudimentary cleavage. These surfaces were invariably found to be parallel to the  $b$ -axis. Several somewhat platy fragments were found to be flattened nearly parallel to the (100) plane. The distinct cleavage nearly normal to the acute bisectrix, reported by Hutton, was only seen in a few grains.

From this material both powder and single crystal diffraction patterns were obtained. The single crystal patterns required very long exposures due to the minute size of the crystals. All crystals had to be mounted with the aid of the polarizing microscope. The first fragment was mounted with the rotation axis parallel to a prominent parting surface and at right angles to  $Y$ . When finally adjusted after several trial runs the rotation axis proved to be the  $c$  axis. Thereafter it was possible to set crystals for rotation on a desired axis fairly well if fragments could be found yielding a suitable interference figure. Eventually rotation and zero and first layer Weissenberg patterns were obtained on both the  $c$  and  $b$  axes.

The cell dimensions, obtained from the best lines of the indexed powder pattern and checking closely with values derived from single crystal patterns, calibrated by quartz, are:

$$\begin{array}{lll} a_0=6.80 \pm 0.03 \text{ \AA} & & \\ b_0=6.96 \pm 0.03 \text{ \AA} & \beta=104^\circ 55' \pm 10' & Y \parallel b \\ c_0=6.54 \pm 0.03 \text{ \AA} & & Z \text{ near } c. \end{array}$$

All patterns were made with copper radiation. The wave length of the unresolved Cu- $K_{\alpha}$  radiation was taken to be 1.542 Å.

Assuming a cell content of 4( $\text{ThSiO}_4$ ) the calculated density becomes 7.18, to be compared with the value 7.1, found by Hutton.

Systematic extinctions unambiguously indicate the space group to be  $C2_h^5 - P2_1/n$ .

These findings show the thorium silicate found and described by Hutton to be a new mineral, distinct from the tetragonal form of this compound long familiar as the mineral thorite. It is proposed to call this new mineral *huttonite*.

#### SYSTEMATIC RELATIONS

The cell dimensions of huttonite are very close to those of monazite, the cell content is analogous and the space group is the same. The optical character and orientation are also similar. As may be seen from Tables 1 and 2 and from Fig. 1 there is close correspondence of both rotation and powder patterns of the two minerals.

Reports on the cleavage of monazite are conflicting, but  $\{100\}$  and  $\{001\}$  are sometimes recognized as cleavage or parting directions. Rather obscure or imperfect cleavage or parting close to these directions is also noted in huttonite.

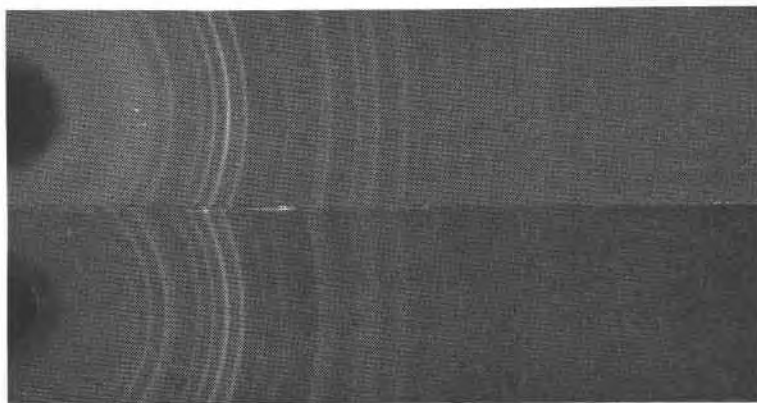


FIG. 1. Powder patterns CuK rays, Ni filter. Camera diameter 114.6 mm.  
Top—monazite; bottom—huttonite.

The finding of a close relation of huttonite to monazite has been foreshadowed to some extent by the finding of a substantial  $\text{ThO}_2$  and  $\text{SiO}_2$  content in many monazites. In a number of cases these "impurities" are present in the proportion of  $\text{ThSiO}_4$ . This led some mineralogists to the supposition that these monazites were contaminated by mechanical

TABLE 1. COMPARISON OF ZERO LAYER LINES OF *c*-AXIS ROTATION PATTERNS OF HUTTONITE AND MONAZITE

<i>Huttonite</i>			<i>Monazite</i> ‡		
Gillespie's Beach, South Westland, New Zealand			"Turnerit," Perdatsch, Switzerland, as reported by S. von Gliszczynski in Table 1, <i>Zeit. Kr.</i> , <b>101</b> , 4 (1939).		
<i>hkl</i>	<i>Intensity</i>	<i>Spacing</i>	<i>hkl</i>	<i>Intensity</i>	<i>Spacing</i>
020	1+	3.49	020	w	3.45
200	10	3.29	200	st	3.32
120	8	3.10	120	m	3.11
210	3	2.98			
220	1	2.400	220	w	2.405
310	2	2.095	310	w	2.115
320	5	1.859	320	st	1.862
040	3	1.749	040	m	1.742
140	4	1.692	140	m	1.686
400	5	1.647	400	st	1.657
410*	6	1.600	410, 330?	st	1.614
240	2	1.546	240	w	1.545
340, 150†	1	1.370	340, 150	mst	1.369
510*	4	1.293	510	st	1.301
			250?	w	1.285
520	2	1.233	520	st	1.237
440	1-	1.199	440	m	1.203
			350	vw	1.180
060	2	1.169	060	m	1.164
530*	5	1.148	530, 160	st	1.151
260*	3	1.102	260, 600	m	1.099
610	5	1.085	610	st	1.089
450	2	1.068	450	m	1.068

\* Indexing assured by comparison with Weissenberg pattern.

† Not observed on Weissenberg pattern.

‡ Gliszczynski lists angles, from which spacings have been derived for this table. The question marks with certain indices have been copied from Gliszczynski. The beta spots in his table are here omitted.

admixture of thorite. Brögger (1906), however, considered the  $\text{ThSiO}_4$  as being a part of the monazite itself and spoke of the "homoiomorpher Verbindung  $(\text{ThO})\text{SiO}_3$ ," which may be considered to have been found in the new mineral huttonite.

The structure of monazite has been investigated by Kokkoros (1942) and the structure of artificial  $\text{CePO}_4$  has been reported by Mooney (1948). These investigators agree as to cell dimensions, cell content and space group but arrive at different parameters. Since the original paper by Kokkoros has not been accessible to the writer and the findings of

TABLE 2. COMPARISON OF POWDER PATTERNS OF HUTTONITE AND MONAZITE

<i>Huttonite</i>			<i>Monazite</i>			
Gillespie's Beach S. Westland, N. Z.			near Chochi-wan, southern Korea*			
<i>Intensities estimated</i>	<i>Spacings</i>		<i>hkl</i> ‡	<i>Spacings</i>		<i>Intensities estimated</i>
	<i>obs.</i>	<i>calc.</i> †		<i>calc.</i> †	<i>obs.</i>	
3	5.29	5.28	101	5.13	5.23	4
—	—	4.80	110	4.78}	4.72	4
5	4.71	4.69	011	4.67}		
6	4.23	4.19	111	4.13	4.17	6
4	4.08	4.08	101	4.11	—	—
4	3.53	3.52	111	3.54	3.52	5
—	—	3.48	020	3.50	—	—
6	3.29	3.29	200	3.29	3.31	7
—	—	3.16	002	3.12	—	—
8	3.09	3.07	120	3.08	3.09	10
—	—	3.05	021	3.05	—	—
3	2.98	2.98	210	2.98	2.99	2
—	—	2.96	211	2.92	—	—
—	—	2.89	121	2.88	—	—
7	2.89	{ 2.89 2.88 }	{ 112 012 }	{ 2.83 2.86 }	2.88	7
—	—	2.65	121	2.66	—	—
3	2.65	2.64	202	2.57	2.61	2
—	—	2.48	211	2.45	—	—
3	2.48	2.47	212	2.41}	2.45	3 (b)
1	2.44	2.44	112	2.45}		
—	—	2.39	220	2.40	—	—
4	2.19	—	—	—	2.19	4
2	2.156	—	—	—	2.139	6
3	2.110	—	—	—	1.969	5
4	1.953	—	—	—	1.963	1
3	1.893}	(b)			1.899	2}
2	1.857}				1.875	6}
2	1.810	—	—	—	1.800	2
2	1.784	—	—	—	1.766	4
4	1.749 (b)	—	—	—	1.746	6
2	1.692	—	—	—	1.695	4
2	1.646	—	—	—	1.651	1—
—	—	—	—	—	1.630	1—
3	1.603	—	—	—	1.605	1
3	1.550	—	—	—	1.541	4

\* Kindly furnished by Mr. C. W. Chesterman.

† Spacings obtained by the graphical method of Peacock (*Zeit. Kr.*, **100**, 93–103, 1938) from cell dimensions given in Table 3.

‡ The sequence of indexed lines in the table is determined from huttonite.

Mooney have been reported only in a preliminary fashion it is not easy to arrive at an opinion on the merits of the conflicting results. Nevertheless it can be asserted with great confidence that huttonite is isostructural with monazite.

TABLE 3. CELL DIMENSIONS OF SOME MATERIALS ISOMORPHOUS WITH MONAZITE AND ZIRCON

<i>Material</i>	$a_0$	$b_0$	$c_0$	$\beta$	Cell volume	Reference
Huttonite, ThSiO <sub>4</sub>	6.80 Å	6.96 Å	6.54 Å	104°55'	299	Pabst, 1950
Monazite†						
(Ce, La)PO <sub>4</sub>	6.76	7.00	6.42	103 10	296	Parrish, 1939
LaPO <sub>4</sub>	6.89 Å	7.05 Å	6.48 Å	103 34	306	Mooney, 1948
CePO <sub>4</sub>	6.76 Å	7.00 Å	6.44 Å	103 38	296	Mooney, 1948
PrPO <sub>4</sub>	6.75 Å	6.94 Å	6.40 Å	103 21	292	Mooney, 1948
NdPO <sub>4</sub>	6.71 Å	6.92 Å	6.36 Å	103 28	287	Mooney, 1948
BiPO <sub>4</sub>	6.78	6.99	6.45	104	297	Zemann, 1949
Crocoite, PbCrO <sub>4</sub>	7.108	7.410	6.771	102 27	353	v. Gliszczynski, 1939
Zircon, ZrSiO <sub>4</sub>	6.60		5.88		256	Wyckoff & Hendricks, 1927
Thorite,* ThSiO <sub>4</sub>	6.315		5.667		226	Boldyrev et al., 1938
Xenotime, YPO <sub>4</sub>	6.88		6.013		285	Vegard, 1927
YVO <sub>4</sub>	7.126		6.197		314	Broch, 1933
CaCrO <sub>4</sub>	7.25		6.34		333	Clouse, 1932

Note:—Where units are not specified in this table they are in doubt though probably kX.

\* See text for comment on the cell dimensions of thorite.

† Slightly differing cell dimensions for monazite have been published by v. Gliszczynski (1939), Machatschki (1941), Kokkoros (1942) and others.

A number of substances isostructural with monazite are listed in Table 3. According to Mooney (1948) the phosphates of lanthanum, cerium and neodymium are "dimorphic," existing also in an hexagonal form. However, she states that "the presence of zeolitic water . . . is probably necessary to stabilize the structure." Under these circumstances this is not strictly a case of dimorphism. ThSiO<sub>4</sub>, on the other hand, is now known to be dimorphous, having representatives in both the monazite and zircon groups.

The more familiar tetragonal form of ThSiO<sub>4</sub>, thorite, is nearly always metamict. Vegard (1916) failed to observe any x-ray diffraction in it. An indexed powder pattern of thorite from the Langesundfjord, Norway, has, however, been published and cell dimensions given by Boldyrev, Mikheiev, Kovalev and Dubinina (1938) as well as by Mikheiev and

Dubinina (1939). In the first of these papers it is stated that "This pattern has only lines with rather weak intensity as consequence of transformation of nearly whole mass of mineral to metamict state, i.e., isotropic state of secondary origin." It will be seen from Table 3 that the cell volume of thorite given there is quite out of line with that of other members of the zircon and monazite groups. Also some of the indices assigned to powder lines by Boldyrev et al. are not in conformity with the space group  $I4/amd$  and the writer has found that the published pattern does not fit well an ideal set of spacings calculated from the given cell dimensions. Hence those dimensions are to be regarded with some reserve.

It is of interest to consider a possible explanation of the fact that the tetragonal form of thorium silicate is characteristically found in the metamict condition whereas the newly recognized monoclinic form occurs entirely in clear crystal fragments showing not the slightest trace of alteration. This may be correlated with observations on the better known relatives of these two minerals. Zircon has frequently been found in the metamict state whereas monazite is rarely, if ever, found in this condition. It has been suggested by Machatschki (1941) that the metamict condition of zircon arises due to an inherent instability of the structure of zircon. In this zirconium has an 8-fold coordination, whereas the radius of  $Zr^{+4}$  is near the boundary of 6 and 8-fold coordination and in many minerals  $Zr^{+4}$  goes into 6-coordinated positions. It may then be that the huttonite structure is more stable than the thorite structure though it is not possible at this time to state precisely what the differences in the two structures are.