

NOTES AND NEWS

NEW DATA ON THE HAFNIUM, ZIRCONIUM AND YTTRIUM
CONTENT OF THORTVEITITE

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In another paper (this issue, page 562) we have described a high hafnium zircon from Norway associated with the rare scandium mineral thortveitite. Also, we have confirmed qualitatively that hafnium and zirconium are present within the thortveitite structure. Since submitting the results of our study on the unusual zircon we have had the opportunity to quantitatively analyze three thortveitite specimens for their hafnium, zirconium and yttrium contents. Two specimens were from Norway and one was from Madagascar. The specimen from Madagascar was kindly loaned to us by the U. S. National Museum.

The Hf/Zr ratios of thortveitite are particularly interesting inasmuch as thortveitite is the only mineral reported which may contain more hafnium than zirconium. The data compiled from the literature by Fleischer (1955, Table 8) show a considerable variation in the Hf/Zr ratios of thortveitite ranging from 0.29 to 1.9 in three Norwegian specimens and from 0.88 to 1.8 in three Madagascan specimens. These ratios are the only ones for thortveitite reported in the literature and all were obtained from the data in the early papers of Hevesy and/or associates in the period 1924-1928. From a historical point of view, we should note that Schetelig (1911, 1922) reported that zirconium was not detected in Norwegian thortveitite whereas Boulanger and Urbain (1922) reported 7.4, 7.8 and 9.9 per cent ZrO_2 in Madagascan thortveitite; these papers predated the discovery of hafnium. After the work of Hevesy and associates, Bjørlykke (1934) verified the presence of both Hf and Zr in Norwegian thortveitite but the estimated intensities of his x-ray fluorescence lines cannot be converted to weight per cent or weight ratio on the basis of the information supplied. The more recent analysis of thortveitite from Norway by Marble and Glass (1942) failed to uncover any zirconium although it was looked for specifically.

The results of our analyses are presented in Table I. The Norwegian specimens are the same ones described in the paper on the high hafnium zircon (Levinson and Borup, 1960). Of special significance (see below) is the fact that the reddish-brown thortveitite is the host crystal of the high hafnium zircons. The Madagascan specimen (U.S.N.M. number 94629) was found to give an x-ray diffraction pattern identical to that of the Norwegian material and, as in the case of Norwegian, the strongest line of zircon as well as the two strongest lines of baddeleyite, could not

be detected on an exceptionally long exposure. As a check on our *x*-ray data, an emission spectrographic analysis revealed a Hf/Zr ratio of 1.1 for the reddish-brown Norwegian crystal and 1.2 for the Madagascan specimen. These values are practically identical to those obtained by *x*-ray fluorescence.

Our data confirm the results of Hevesy and/or associates (tabulated by Fleischer, 1955) in that hafnium may exceed zirconium in thortveitite. We also confirm that the ratio of Hf/Zr, as well as the weight per cent of hafnium and zirconium, are variable in thortveitite from Norway at least. In addition, an interesting geochemical-paragenetic relationship is revealed when we consider the ratio of Hf/Zr of the high hafnium zircon from Norway reported by Levinson and Borup (1960) with that of the reddish-brown host thortveitite crystal. These are

high hafnium zircon: Hf/Zr=0.6 (average of the two analyses)
 host thortveitite: Hf/Zr=1.0

Paragenetically the zircon appears to have formed before the host thortveitite and it has a significantly lower Hf/Zr ratio. A similar paragenetic sequence was noted by Schetelig (1922) and Bjørlykke (1934) who report zircon (alvite) is paragenetically older than thortveitite in the Norwegian pegmatites. Although it has been well established that the Hf/Zr ratio is high in minerals of the pegmatite stage, the above tabulation reveals a clear-cut illustration of the increase in the Hf/Zr ratio with the younger paragenetic position within a pegmatite.

The Madagascan thortveitite received from the U. S. National Museum was labelled as the variety "befanamite." The varietal name be-

TABLE I. ANALYSIS OF THORTVEITITE

Locality	Description	HfO ₂	ZrO ₂	Hf/Zr	Y ₂ O ₃
Iveland, Norway	grayish-green	0.6	1.2	0.6	2.2
Iveland, Norway	reddish-brown	1.7	1.9	1.0	4.4
Befanamo, Madagascar	U.S.N.M. 94629	1.4	1.4	1.2	4.3

X-ray fluorescence analysis in weight per cent. All values quantitative ($\pm 10\%$ of the amount present).

fanamite was proposed by Lacroix (1923) for the thortveitite from a pegmatite at Befanamo. Based on the analyses of Boulanger and Urbain (1922), befanamite had a zirconia content of 8.4 per cent (average of 3 analyses) and only 0.3 to 1.0 per cent Y₂O₃. The low yttria and the high

zirconia content, in comparison with the type Norwegian thortveitite, justified the varietal name to Lacroix (1923). However, the work of Hevesy and/or associates (Fleischer, 1955, Table 8) plus the results reported in this paper show that hafnium and zirconium contents of thortveitite from both Madagascar and Norway are in the same order of magnitude even though quite variable. None are as high as those reported by Boulanger and Urbain (1922). Table I also gives our determination of Y_2O_3 of 4.3 per cent which is considerably higher than that reported for the type befanamite. The only conclusion to be drawn from these observations is that the thortveitite specimen from Befanamo, Madagascar we have studied does not have the characteristics for the varietal name befanamite. Perhaps a re-examination of the original type befanamite would be desirable.

The yttria contents of the Norwegian thortveitites are also given in Table I. Of the other rare-earth elements, our x -ray fluorescence study indicates the presence of Yb, Lu and probably Gd. No other rare-earths were detected, in part due to the complex spectra, but they may well be present in trace amounts. However, the total of the rare-earth oxides exclusive of Y_2O_3 is probably not more than 1 per cent. This estimate also holds for the Madagascan specimen. Our figures for the rare-earth oxides are considerably below those previously reported for Norwegian thortveitite. The literature indicated considerable variation in the early analyses (Schetelig, 1922) ranging from 8.89 to 17.7 per cent total yttria and rare-earth oxides. Marble and Glass (1942) report 11.0 per cent yttria and rare-earth oxides, whereas the most recent analysis by Vickery (1955) using ion exchange methods yielded 12.1 per cent. The information presented in Table I, plus that which is available in the literature, indicates considerable variation in the rare-earth (including yttrium) content of Norwegian thortveitite. It should be noted, however, that recent papers reported in the chemical literature show that some of the early gravimetric methods for the analysis of thortveitite are not entirely satisfactory (Vickery 1955, 1956), (Spedding, *et al.*, 1958).

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A CASSITERITE PSEUDOMORPH AFTER QUARTZ FROM
TORRINGTON, NEW SOUTH WALES

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This short paper serves to record the occurrence of cassiterite pseudomorphous after crystallized quartz from the Torrington tin mining district of north-eastern New South Wales.

In Dana's System of Mineralogy, Vol. 1, p. 579 (Palache *et al.*, 1944) it is stated "The reported pseudomorphs of cassiterite after tourmaline and quartz appear to be without foundation." This contention indeed expresses the general case, for, in order to have a quartz crystal pseudomorphed by cassiterite, it is necessary that the precipitation of cassiterite follows *after* the development of vug quartz implicitly of hydrothermal origin.

Such a succession of mineralogical events contravenes general experience regarding cassiterite mineralization which is usually considered to be typically pneumatolytic.

These contrary circumstances, however, prevailed in most of the hydrothermal cassiterite veins of the Torrington district of New South Wales where epi-Permian granite has intruded a series of Permian sediments and volcanics, and in a late, relatively low temperature, hydrothermal stage of mineralization (Lawrence, 1957) has given rise to a series of shear fissure veins.

One of these fissure veins known as the Dutchman Lode consists of a wall zone of quartz, containing in places, small vugs of crystals, followed by an inner zone of sericite-chlorite-quartz-cassiterite and lastly a central filling of crustified quartz.

Pre-existing vein quartz was penetrated by a later generation of cassiterite bearing fluids. Deposition of cassiterite and the associated chlo-