

DETERMINATION OF XENOTIME

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ABSTRACT

The rare yttrium phosphate, xenotime, has been recognised in river sands in North Westland, New Zealand. The optical properties of this mineral have been determined and they are compared with those of minerals with which xenotime might possibly be confused. It is shown that the positive diagnosis of xenotime is not as difficult a task as is suggested by a number of writers.

OCCURRENCE AND MORPHOLOGICAL FEATURES

During a recent mineralogical study of concentrates obtained from dredges working river alluvium in the Grey River—Mawheraiti River area, of North Westland, New Zealand—the rare phosphate, xenotime, was recognised; this mineral is an accessory or minor constituent of an assemblage that includes among other minerals, colorless zircon, hyacinth, ilmenite, spessartite-almandine, monazite, and tantalum-cassiterite.

The yttrium phosphate almost invariably occurs in short prisms showing a combination of m (110) with z (111). Rarely the form a (100) was noted in combination with m (110), but the latter form is always dominant. Infrequently a basal plane has been developed, and such crystals may orient themselves in the mounting medium so that they exhibit excellent centered uniaxial interference figures. However, this simple habit of the xenotime crystals contrasts sharply with the complex combination of forms so characteristic of the colorless zircons associated therewith. For most of the grains a slight degree of rounding was not sufficient to prevent identification of the forms developed.

Determination of the refractive indices in sodium light by the immersion method gave the following values:

$$\begin{aligned}\alpha &= 1.720 \pm 0.005. \\ \gamma &= 1.827 \\ \gamma - \alpha &= 0.107.\end{aligned}$$

The mineral is uniaxial and optically positive; in the larger grains an exceedingly faint dichroism was detectable according to the scheme:

$$\begin{aligned}X &= \text{very pale yellow.} \\ Z &= \text{very pale yellowish-green.}\end{aligned}$$

The colours were so weak that it was not possible to determine the intensity of absorption along X or Z with any degree of accuracy. Grains of xenotime did not fluoresce when exposed to ultra-violet radiation.

Grains that pass a 230-mesh U.S.S. screen (aperture=62 microns),

appear to be quite colourless when immersed in refractive index liquids, but in oblique illumination under a binocular microscope, a very delicate yellowish-green colour is discernible for xenotime, a tint that contrasts quite distinctly with the more yellow colour of the associated monazite. Although in all examples examined, xenotime appears to be devoid of the dusty alteration products that appear to be so frequently developed on the surface of this mineral (Weinschenk-Clark, 1912, p. 232; Milner, 1940, p. 353), dust-like opaque inclusions were noted in a number of grains. These could not be diagnosed with certainty but they are suspected to be magnetite, for they were readily soluble when finely crushed xenotime was treated with warm 5 N.HCl, and the solution gave a strong reaction for iron. The identity of some deep brown, semi-opaque inclusions could not be determined.

Xenotime, even when free from inclusions, is moderately paramagnetic and in an electro-magnetic grading it was concentrated entirely with the monazite fraction. Qualitative chemical tests verified the presence of abundant yttrium* and phosphorus.

A comparison of the optical properties, determined by the writer, with those that have been recorded for xenotime by Winchell (1933, p. 138), Milner (1940, p. 353), and Larsen and Berman (1934, p. 73), leaves no doubt as to the identification, although the value for γ in the New Zealand mineral is slightly greater than that previously recorded.

It was found that the diagnosis of xenotime by optical methods alone was, therefore, not necessarily such a difficult problem as has been indicated by Milner (1940, p. 354), Whitworth (1932, pp. 67-68), and many others, who have particularly stressed the invariable morphological and optical resemblance to zircon. Whereas there is little difference morphologically between crystals of xenotime and zircon of simple habit, some of the optical properties are quite distinct, and there should not be any necessity to have to resort to spectrographic methods for confirmation. Admittedly some difficulty might arise in the diagnosis of minute grains in a rock slice, but in heavy mineral residue investigations where free grains are available, immersion in methylene iodide ($n=1.738$), or methylene iodide-sulphur ($n=1.788$ approx.), should assist in leaving the determination in little doubt. On the other hand, the birefringence of xenotime is so much greater than that of zircon, that differentiation of the two minerals is possible after a little experience, even when they are immersed in Canada balsam, or clove oil ($n=1.54$ approx.). Furthermore, confusion with titanite should not result owing to the very marked dispersion and the greater refractive index of the latter mineral.

* For method used here see: *The Analysis of Minerals and Ores of the Rarer Elements*. W. R. Schoeller and A. R. Powell, 2nd Ed., p. 83 (1940).

In the initial stages of the writer's work, however, some difficulty in the diagnosis of xenotime arose owing to the presence of grains of monazite that are nearly colourless when less than 62 microns in diameter, and are characteristically tabular parallel to the orthopinacoid. These monazite particles have been slightly rounded by abrasion and as a result the superficial appearance is similar to that of xenotime, or for

TABLE 1. OPTICAL DATA OF ZIRCON, XENOTIME, AND MONAZITE

Mineral or mounting medium	α	β	γ	n_D (approx.)	$\gamma - \alpha$	References
Zircon	1.936	—	1.991	—	0.055	Milner (1940, p. 354); Winchell (1933, p. 184); Larsen & Berman (1934, p. 75).
Zircon	1.926	—	1.985	—	0.059	Larsen & Berman (1934, p. 75).
Zircon	1.924	—	1.968	—	0.044	Ford (1921, p. 521); Iddings (1906, p. 416).
Zircon	1.923-1.960	—	1.968-2.015	—	0.045-0.055	Ford (1932, p. 611).
Zircon	1.925-1.931	—	1.985-1.993	—	0.060-0.062	Rogers & Kerr (1942, p. 306).
Zircon	1.960	—	2.015	—	0.055	Iddings (1906, p. 416).
Zircon	1.9313	—	1.9931	—	0.0618	Weinschenk-Clark (1912, pp. 350-351).
Xenotime	1.721	—	1.816	—	0.095	Milner (1940, p. 354); Ford (1932, p. 700); Larsen & Berman (1934, p. 73).
Xenotime	not stated	—	not stated	—	high as in zircon	Iddings (1906, p. 482).
Xenotime	1.7207	—	1.8155	—	0.0948	Winchell (1933, p. 138).
Xenotime	1.720	—	1.827	—	0.107	Westland, Hutton (this work)
Monazite	1.787-1.800	1.788-1.801	1.837-1.849	—	0.045-0.055	Winchell (1933, p. 139); Larsen & Berman (1934, p. 138); Rogers & Kerr (1942, p. 223); Krumbain & Pettijohn (1938, p. 437).
Monazite	1.786	1.788	1.837	—	0.051	Ford (1932, p. 701)
Monazite	1.7957	1.7965	1.8411	—	0.0454	Iddings (1906, p. 482).
	1.7863	1.7879	1.8373	—	0.0510	
Monazite	1.800	1.801	1.849	—	0.049	Milner (1940, p. 314).
Monazite	1.785	1.787	1.840	—	0.055	Gordon (1939, p. 7).
Monazite	1.787	1.789	1.839	—	0.052	Westland, Hutton (this work).
Clove oil	—	—	—	1.54	—	—
Methylene iodide	—	—	—	1.738	—	—
Methylene iodide-sulphur	—	—	—	1.788	—	—
Tetra-iodo-acetylene	—	—	—	1.81	—	—
Phenyl-di-iodoarsine	—	—	—	1.843	—	—

that matter, of slightly abraded zircons. Owing to the crystallographic development most of the grains of monazite tend to lie on the orthopinacoid and since the optic axial plane is almost parallel to (100), such crystals normally exhibit very nearly the maximum birefringence for that mineral. The refractive indices of Westland monazite, containing 5.32% ThO₂, are rather lower than those often recorded for monazites ($\alpha=1.787$, $\beta=1.789$, $\gamma=1.839$; $\gamma-\alpha=0.052$), but are similar to those determined by Gordon (1939, p. 7) for a thorium-free specimen from Bolivia. Thus in clove oil or in Canada balsam differentiation of almost colorless monazite from zircon or xenotime might be uncertain, but inspection of assemblages containing these minerals in methylene iodide or methylene iodide-sulphur mixtures enables accurate diagnoses to be made.

A summary of the distinctive properties of xenotime, monazite, and colourless, or pale yellow zircon, is set out in Table 1, and the refractive indices of a number of standard immersion media employed in heavy mineral identifications have been added.

Careful searching of a number of concentrates from New Zealand and foreign sources has shown xenotime to be present, and it is believed that this mineral is by no means the rarity that it has generally been considered. Therefore the writer would like to stress the very real necessity for the use of high refractive liquids and mounting resins, when heavy mineral assemblages are being studied, otherwise recognition of a number of minerals may be difficult if not impossible.

For a preliminary investigation of heavy mineral assemblages the following procedure has been found to be most useful and is appended herewith in the hope that it may assist other investigators on such problems:

1. Screen the heavy mineral fraction; the screens most used are U.S.S. Nos. 60, 120, and 230, with mesh diameters of 250, 125, and 62 microns, respectively.
2. Mount a portion of each fraction after careful splitting in Canada balsam ($n=1.54$) and in hyrax ($n=1.70$) for permanent reference and study.
3. A complete and thorough investigation of the mineral assemblages requires that portions of each screening should be examined in α -monobromnaphthalene ($n=1.65$), methylene iodide ($n=1.738$), methylene iodide-sulphur ($n=1.788$), tetra-iodo-acetylene ($n=1.81$), and possibly phenyl-di-iodoarsine ($n=1.84-1.85$).

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