PETROGRAPHIC DISTINCTION OF XENOTIME AND BASTNÄSITE*

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Abstract

The optical properties of xenotime (YPO_4) and bastnäsite ((Ce, La, Di) FCO_3) are so nearly identical that it is impossible to distinguish between them with certainty on that basis alone. Brief ignition, however, renders them easily distinguishable under the microscope. Such treatment is recommended in order to eliminate the danger of confusing the two minerals in heavy-mineral concentrates or other types of sample.

Introduction

Several years ago a granular sample labelled "Andalusite from South Africa" was submitted to the writer for evaluation. The optical properties were found to differ decidedly from those of andalusite, and suggested rather that the material might be xenotime. The apparent detrital nature of the grains seemed consistent with such an identity, and the writer and the late Dr. Albert B. Peck concurred in calling the mineral xenotime. A qualitative chemical analysis by Mr. Arthur Rautenberg failed to confirm this identification. The mineral proved to be essentially a carbonate of cerium and lanthanum, and not the phosphate of yttrium. When apprised of these findings the suppliers of the material reported that they had inadvertently submitted a sample of bastnäsite sand from the Belgian Congo.

Hutton (5) recently dispelled the erroneous impression given by several authorities (6) (7) that it is practically impossible to distinguish xenotime from zircon by microscopic means alone. He presented reliable criteria for optically distinguishing xenotime from zircon and monazite. However, he appeared to imply that positive identification of xenotime under the microscope is not too difficult, and that only zircon and monazite need cause concern. Yet if Hutton's procedure were carefully followed the determination of xenotime would still be inconclusive because of the marked optical similarity between xenotime and bastnäsite. In the absence of a confirmatory test there is no guarantee that bastnäsite would not be wrongly identified as xenotime, as in the instance cited above.

Occurrence of Xenotime and Bastnäsite

Xenotime and bastnäsite have considerable in common as regards mode of occurrence. Xenotime occurs in granites, pegmatites, and

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nepheline syenites (6). Bastnäsite occurs typically in contact zones between schists and granitic or pegmatitic intrusions, but it is also found within pegmatites (3). In at least one instance the two minerals occur in the same locality, perhaps even in close association, for both have been reported with tysonite near Pike's Peak, Colorado (1). Both minerals, too, have been noted in sands or gravels (3) (5). Either mineral, therefore, might be encountered in heavy-mineral separates from sediments, and possibly also from granitic rocks. In some cases both might even occur in the same sample. Thus there is real need for caution lest the two minerals be mistaken for each other. Association with such other cerium-bearing minerals as cerite, allanite, tysonite, törnebohmite and monazite cannot be considered as too indicative of bastnäsite. Xenotime also may be accompanied by cerium minerals: tysonite, monazite, and perhaps others.

Comparison of Optical Properties

The experience of the writer in confusing xenotime and bastnäsite could easily be repeated by others. So nearly identical are these two minerals in their optical properties that even the careful measurement of refractive indices would fail to distinguish conclusively between them. Examination of the data in Table 1 reveals how they could easily be mistaken for each other. Their refractive indices and birefringence are sensibly the same, and both are uniaxial positive. Both may show weak pleochroism and may vary in color from colorless in transmitted light, to yellow, red, or brown in reflected light. Bastnäsite is said to have a perfect basal cleavage (3), whereas that of xenotime is prismatic. Herein might conceivably lie a means of distinguishing the two minerals

Table 1. Refractive Indices of Xenotime and Bastnäsite

Mineral	Source	Omega	Epsilon	Reference
Xenotime	—	1.721	1.816	Hutton (5)
Xenotine	—	1.7207	1.8155	Hutton
Xenotime	New Zealand	1.720	1.827	Hutton
Bastnäsite	Sweden	1.7220	1.8235	Glass and Smalley (3)
Bastnäsite	Colorado	1.717	1.818	Glass and Smalley
Bastnäsite	Madagascar	1.717	1.818	Glass and Smalley
Bastnäsite	New Mexico	1.718	1.819	Glass and Smalley
Bastnäsite	Belgian Congo	1.722	1.823	Glass and Smalley
Bastnäsite	Colorado	1.716	1.816	Goddard and Glass (4)
Bastnäsite	New Mexico	slightly below 1.72	very close to 1.82	Dean and Dressel (8)

in powder-mounts, since basal non-birefringent grains might be expected to be very common for bastnäsite and rare or absent for xenotime. Apparently, however, there is little tendency for such preferred orientations. Powder-mounts of bastnäsite and xenotime are very similar in appearance, and the grains of both minerals almost without exception display high birefringence.

Selection of Suitable Confirmatory Test

It is apparent that some test other than a strictly optical one is necessary to distinguish unfailingly between xenotime and bastnäsite. A simple and rapid test which dispenses with the need for spectrographic, *x*-ray diffraction or qualitative chemical analysis is desirable.* Ideally, the test should be applicable to isolated tiny grains as well as to large fragments and to intimate mixtures of the two minerals, either with each other or with any or all of their usual associates. In the search for such a test a number of different procedures were tried. One of these proved to be so superior to the remainder in the early trials that little time was devoted to the less promising procedures. However, it might be well to describe briefly the various techniques tested, with the reasons for rejection or acceptance.

Examination under ultraviolet light revealed no distinction between the two minerals, in the two samples of xenotime and four samples of bastnäsite at the writer's disposal. Fluorescence tests under both long (3650 A.U.) and short (2537 A.U.) radiation were in all cases negative. Hutton (5) reported that xenotime from New Zealand likewise failed to fluoresce. Such tests are useless, then, for present purposes. However, fluorescence inspection proves to be useful in distinguishing zircon from monazite and xenotime (2) and from bastnäsite.

Sandell (9) has referred to the blue fluorescence imparted to a borax bead by cerium. This should constitute a suitable procedure for distinguishing bastnäsite from xenotime. Only a few tests were made by the writer, and these were inconclusive, probably because optimum conditions were not achieved. Rejection of this method was dictated not by any doubt as to its validity, but by the realization that it would not have general applicability. Associated monazite or other cerium-bearing minerals would cause interference, and mixtures of bastnäsite and xenotime would behave in the same way as would bastnäsite alone.

Xenotime is insoluble in acids, whereas bastnäsite is very slowly at-

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* The specific gravity of bastnäsite (4.99) is sufficiently different from that of xenotime (4.59) to be useful in some cases. But samples of sufficient purity and weight are not always available for such a determination.

tacked with accompanying evolution of carbon dioxide. For concentrated samples of appreciable size this appears to be a satisfactory method of distinction, if the possible presence of other gas-evolving minerals can be excluded. Attempts to carry out such a test in powder-mounts, using sulfuric or hydrochloric acid as the immersion medium, were not too satisfactory. Although bubbles of gas slowly accumulated beneath the cover-slip there was no visible effervescence of any of the bastnäsite grains. The test would therefore be unsuitable for samples containing both bastnäsite and xenotime, or for sparsely distributed grains in a heavy-mineral separate.

A simple and effective test which appears to meet all the requirements consists merely of ignition at red heat in the flame of a laboratory burner for about one minute. Xenotime so treated is found, upon microscopic examination, to be unaffected, whereas bastnäsite suffers a notable reduction in birefringence and an increase in refractive indices such that both indices considerably exceed 1.80. The microscopic color is changed from colorless to yellow or yellow-brown. Every grain of bastnäsite from the smallest to the largest is similarly affected, so that even a few isolated grains of this mineral in a heavy mineral separate reveal their true identity by such treatment. Furthermore, the occurrence of both bastnäsite and xenotime in the same sample does not cause any difficulty.

DECOMPOSITION PRODUCT OF BASTNÄSITE

It might be expected that the product of the thermal decomposition of bastnäsite would be essentially a cerium oxide containing other rare earths in solid solution. To test this a sample of powdered New Mexico bastnäsite was calcined for several hours at 1450° C., and analyzed on a Norelco *x*-ray spectrometer. The diffraction pattern was strikingly similar to that of pure ceric oxide (CeO_2), although showing somewhat larger interplanar spacings. The length of the cubic unit cell is 5.57 kX, as compared to a length of 5.42 kX for the cell of ceric oxide. The enlarged cell of the decomposition product is probably to be attributed to lanthanum oxide and other rare earths present in solid solution. Microscopically the decomposed product is isotropic with index well above 1.80 and is deep yellow-brown in color. When xenotime is exposed to similar thermal treatment it yields an *x*-ray pattern identical with that given by the uncalcined mineral.

Bastnäsite heated momentarily in the burner-flame, as in the test previously outlined, is apparently not completely converted to the cubic oxide. This is suggested by its residual birefringence and by the character of its *x*-ray pattern. The latter is a poorly developed yet recognizable pattern of the ceric oxide type. Nevertheless, this rapid ignition is capable of rendering bastnäsite microscopically dissimilar to xenotime. For the purposes of our test, therefore, there is no advantage in heating to complete decomposition.

CONCLUSION

The criteria used by Hutton to distinguish xenotime from zircon and monazite do not suffice to distinguish it from bastnäsite. It is suggested that an additional confirmatory test is necessary in order to render the determination of xenotime conclusive. Such a test, which depends upon the difference in behavior of xenotime and bastnäsite upon heating is described. The decomposition product of bastnäsite is essentially a cubic ceric oxide. Hutton's recommendation of more careful immersion work in order to insure detection of certain easily overlooked minerals such as xenotime cannot be overemphasized.

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