THE NUCLEI OF PLEOCHROIC HALOES.

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ABSTRACT. A recent study of the mineralogy of the minor accessory constituents of some granitic rocks has shown that monazite, xenotime, and occasionally apatite form the nuclei of pleochroic haloes in biotite, but never zircon, although this mineral may be present in the mica. Some optical data for these phosphates are given and it is suggested that the relative sizes of the ions concerned may account for the preferential distribution of uranium and thorium.

IN a recent note Laemmlein[1] described the occurrence of pleochroic haloes surrounding grains of monazite in quartz crystals, and as a result of work in this country some additional information concerning haloes may be of interest. During a recent mineralogical study of the minor accessory constituents of some New Zealand granitic rocks, the writer was impressed by the rarity of pleochroic haloes in the biotites or chlorites derived therefrom, as compared with the prevalence of such features in a number of British and Continental granites. At first this fact seemed surprising since there was no lack of zircon in the concentrates from most of these rocks, and further the rocks are old enough (approximately mid- to late Paleozoic) for such phenomena to have had time to develop. Qualitative chemical tests failed to reveal the presence of either uranium or thorium in the zircons, and measurements of α-radiation in an ionization chamber indicated an an exceedingly low activity.

Now one point is quite clear; except in rare cases [2, 3, 4,] it has generally been assumed that nuclei of pleochroic haloes are zircons, but since the zircons in the New Zealand granitic rocks are almost completely devoid of uranium or thorium, or both, it is quite clear that radiation from some other mineral or minerals must be producing the rare but intense haloes that are seen in some rocks.

Therefore a careful search of many thin slices of New Zealand granites and related rocks was made in order to determine what minerals form these nuclei; however these mineral grains are far too small for a reliable diagnosis to be made. Hence it was decided to attempt to separate the nuclear mineral grains from the mica plates and to carry out accurate refractive index measurements by the immersion method. A migmatite was found containing numerous well developed haloes in red-brown biotite, and this rock was crushed and the powder passed through a 100-mesh Tyler screen; this material was then carefully elutriated to remove dust and was separated in bromoform (S.G. = 2·78) to remove quartz and feldspars. From the heavy residue so obtained the biotite was concentrated from the more strongly paramagnetic minerals by electromagnetic means. The biotite flakes were then hand-picked beneath a binocular microscope and a selection made of those flakes with haloes; finally the mineral grains forming the nuclei of the haloes were separated from these by careful rubbing in a mortar with a rubber pestle. The grains obtained therefrom proved to be monazite, xenotime, or very rarely apatite, but in no case was zircon found to be present. Tiny zircon crystals have been recognized in biotites of some specimens, but they were not surrounded by haloes in the examples determined.

The optical properties for monazite and xenotime were found to be as follows:

	α[5]	β	γ	$\gamma-\alpha$	2V
Monazite	1·787	1·789	1·839	0·052	12–14°
Xenotime	1·720	—	1·825–1·827	0·105–0·107	0°

Both minerals are almost completely colorless and when immersed in Canada balsam they are practically indistinguishable from zircon. For apatite the following data were obtained:

$$\alpha = 1{\cdot}634, \gamma = 1{\cdot}638, \gamma - \alpha = 0{\cdot}004.$$

The γ value of the refractive index ellipsoid in xenotime is rather higher than previously recorded for that mineral, whereas the data for monazite are comparable with those determined for a monazite containing 1·23% U_3O_8 and 5·32% ThO_2[6], and found in sands and gravels nearby. The recognition of apatite as the nucleus of a biotite halo is of considerable interest, but whether the radioactivity contained therein is due to uranium or thorium, or both, replacing the calcium in the apatite lattice, or due to radioactive mineral inclusions is not certain; sporadic very minute, colorless, transparent inclusions were observed in the apatite grains, but it is difficult to believe that the radioactivity is entirely due to these inclusions. Radioactivity in apatite, however, is not unknown, and instances of this have been recorded for apatite in granites from Tanganyika, Massachusetts, and Quebec[7], from California intrusives,[8] and from the Upsala granite[9]; in the latter instance the haloes have been developed in brown-green to blue-green hornblendes as well as in the biotite.

The fact that the zircon in these rocks is not radioactive whereas monazite and xenotime are both strongly so, is interesting, since all three minerals have undoubtedly crystallized at about the same time, although in view of the well-known insolubility of zirconia in a granitic liquid, zircon may well have commenced to crystallize before either of the two rare earth phosphates. The distribution of the available uranium and thorium appears to have been on a preferential basis, monazite and xenotime both having a share whereas zircon has been completely excluded. That uranium and thorium, or both, should enter the lattice of xenotime (but not isotypic zircon) and monazite appears to result solely from the similarity in size of the ions of yttrium, thorium, and uranium; the smaller size of the zirconium ion will apparently allow only a very limited degree of ionic substitution. Radioactive zircon is known however, and it is occasionally found in a metamict condition (e.g., malacon) but analyses of zircon[10] containing considerable percentages of radioactive elements are very difficult to understand; certainly some analyses suggest the possibility of impure material.

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