Occurrences of zircon in the Dartmoor granite.

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THIN sections afford a very inadequate basis for the determination of the accessory minerals present in the Dartmoor granite, and they are of little or no value for assessing the relative proportions of these minerals. A recognizable crystal of zircon, for example, is rarely seen in thin sections of this granite, and until zircons were isolated in quantity from the crushed rock, stream-sands, &c., one type of zircon was not detected.

Types of Zircon crystals.

Loose crystals mounted in Canada balsam and examined under the microscope present two strongly contrasted types:

(1) Viewed by reflected light: dun-coloured to pale mauve, yellowish, or greenish-brown; lustre adamantine. Viewed by transmitted light the colour is unexpectedly deeper: yellowish to smoke-brown or tawny. The majority of these crystals are strongly zoned. The zones are numerous, thin, and close-packed; they are conformable with the surface of the zoned crystal, and they are alternately clear and turbid.

Form and habit:

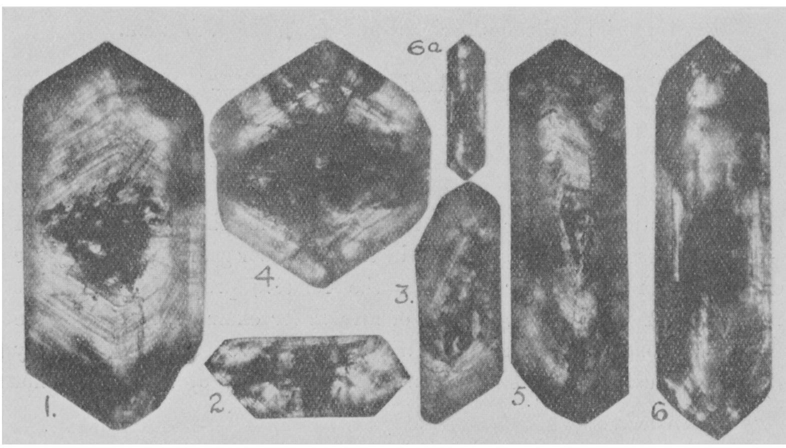
(*a*) The most common habit shows a combination of *m*(110) with terminal planes *u*(331) and *p*(111) about equally developed; occasionally *u* is dominant over *p*.

(*b*) A combination of the simple forms *m*(110) and *p*(111) is also common; *a*(100) is frequently present, and may be dominant over *m*.

The faces of the ditetragonal-bipyramid have been occasionally observed, but they are subordinate. Crystals from two to four times longer than broad are the rule; acicular crystals are distinctly rare. Maximum observed length of crystals 2·7 mm.

(2) Viewed by reflected light: very pale yellowish, mauve, or greenish; by transmitted light they are clear and colourless and are not zoned.

Form and habit: Combinations of the simple forms *m*(110) and *p*(111) are the most common; *a*(100) is not uncommon, but it is subordinate. This type has yielded crystals with terminal planes which are solely those of the ditetragonal-bipyramid. Short stumpy crystals are the rule, but



Photomicrographs of typical zoned zircons from the Dartmoor granite; illustrating the abundance and distribution of opaque and other inclusions.

FIG. 1. × 75. Stream-sand, Dartmeet Bridge.
,, 2. × 76. Princetown granite.
,, 3. × 76. Saddle Tor granite.
,, 4. × 110. Princetown granite.
,, 5. × 56. Sand pit, road side, near Northway, east of Widecombe.
,, 6. × 30. Stream-sand, Dartmeet Bridge. Dust-like inclusions pattern a dark cross, analogous to that commonly observed in chiastolite.
,, 6a. × 11. The same as fig. 6. Black cross more distinct.

elongated or acicular crystals are fairly common. Maximum length of crystals 0·7 mm.

In a sample of mixed zircons isolated from the typical granite, crystals belonging to the zoned type are much longer than those of the clear type, and the former greatly outnumber the latter, the relative proportions being of the order 50 : 1; frequently the ratio is still more in favour of the zoned type. The crystals of both types are strongly birefringent. Their densities and behaviour when heated have not yet been determined.[1]

Inclusions.

The contrast presented by these two types of zircon in respect of relative abundance and size, crystal-form and habit, is emphasized by differences in respect of the nature and abundance of inclusions.

The zoned zircons usually contain abundant inclusions. Among these are minute euhedrons of monazite, and spherical or irregular bodies referred to that species; slender needles referred to apatite; stumpy rods, needles, and irregular granules which may be zircon ; opaque clots and dust-like particles referred to ores; and globular forms which may be cavities. But most of the inclusions are of indeterminate nature.

Clot-like masses of black or brown material frequently occur about the centre of a crystal; dark films and dust-like particles distinguish the dark zones, and such particles may be so abundant about the solid corners of a crystal and of its zones that they pattern a dark cross, which recalls that characteristic of chiastolite.

The clear type of zircon contains only very scanty inclusions, most of which appear to be cavities, or bodies too minute to be determinable. A few particles referred to biotite have been observed.

Possible Xenotime.

A suspicion that some of these zoned crystals might be xenotime was early put to the test. A spectroscopic analysis, for yttria specially, was carried out on two different concentrates by Professor A. Fowler, F.R.S. (Imperial College of Science), whose kindness in this matter the authors gratefully acknowledge. Professor Fowler definitely identified yttria in the spectra, and the suspicion that xenotime might be present thus received some support. A little later, however, a chemical analysis of the Dartmoor monazite showed that this mineral contained an appreciable amount of earths of the yttria group. Still later, the occurrence of monazite as inclusions in zircon was definitely established: one zircon observed contained nine minute monazites, including two euhedrons, in a single marginal zone. Xenotime thus became a very doubtful identification, and its absence was placed beyond all reasonable doubt by the results of an analysis of a zircon concentrate known to be free from loose monazite grains: the analysis showed that the crystals were

[1] Cf. L. J. Spencer, Min. Mag., 1904, vol. 14, p. 48.

essentially pure zircon; the only impurities identified were iron in appreciable amount, titania, and barium sulphate. The last was ultimately traced to loose particles of barytes, which occurs in minute quantity as a secondary accessory mineral in the Dartmoor granite and is probably attributable to reaction between decomposing pyrrhotite and the celsian-bearing felspar.

On the whole, therefore, the evidence is against the possibility that the zoned zircon-like crystals include xenotime individuals.

Discussion.

The two types of zircon, and their strongly contrasted features, presented a somewhat perplexing problem. It was difficult to understand why the great majority of the crystals, large and small, should have grown by increments of turbid and clear substance alternately; while the remainder, of consistently small size, should have grown by increments of clear substance only.

The possibility that these clear crystals represent early zircons born in a clear magma but quickly isolated from it by becoming inclusions in other minerals such as biotite, could not be entertained after it was found that clear crystals, together with zoned crystals, occur as inclusions in the groundmass felspar and quartz. Moreover, the 'zircons' isolated from biotite (by digesting the biotite with hydrofluoric acid and isolating the insoluble residue) yielded much dust (some of which may be zircon) but few recognizable zircon crystals, most of which were zoned.

Differences in form and habit for one and the same mineral-species must record in some obscure way differences between the growth conditions (environment) for the contrasted occurrences. This proposition, brought to bear on the contrasts presented by the two types of Dartmoor zircon, leads the authors to suggest the following as the probable explanation of the facts observed:

The main crop of zircon crystals separated out from the magma at a stage when separation of ores had either just begun or was imminent, and the growth period for this crop overlapped the periods for monazite, apatite, and possibly also biotite. After the main portion of the 'mafic' content of the magma had separated out, the residual liquor, of high 'felsic' content but containing some zirconia still, yielded clear zircons, few in number and of small size, then groundmass felspar and quartz. This mode of genesis is somewhat similar to that presumed for zircons occurring in acid pegmatites.

In this connexion it may be mentioned that comparatively large rounded blebs of quartz—essentially a 'late' mineral developed as a constituent of the groundmass—occur frequently as inclusions in felspar phenocrysts, and similar, though smaller, blebs have been observed in biotite. Moreover, monazite grains present two contrasted types: one is characterized by abundant inclusions; the other is remarkably free from inclusions.