Irregularly developed crystals of Zircon (sp. gr. 4·0) from Ceylon.

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SOME small isolated crystals from the gem-washings in Ceylon, recently sent by Mr. A. K. Coomáraswámy to the British Museum for determination and study, were at first thought to be rutile, but on detailed examination proved to be zircon of a rather unusual type. This has a specific gravity of 4·0, which is not increased when the crystals are heated.

The majority of the crystals are from the Balangoda district in the Sabaragamuwa province, and, according to Mr. Coomáraswámy[1], have been derived from a group of zircon-granites which occur in this district; a few others are from Walaweduwa in the Bamberabotuwa district, and from the Hatton district. Associated with them are zircons of more usual types (see p. 48); the present description is, however, confined to the crystals of lower specific gravity.

On placing the samples as received in molten silver-thallium nitrate with indicators of corundum (sp. gr. 4·0), almandine (4·1), willemite (4·15), rutile (4·2), and barytes (4·5), it was found that the specific gravity of the different crystals varied from 4·0 to over 4·5, the darker coloured crystals being less heavy and the lighter coloured more heavy. Only a few of the crystals have a specific gravity of exactly 4·0, these being of a dark brown colour and almost opaque. The majority are slightly heavier and show a transparent patch of a yellowish-brown colour on one side. As this lighter coloured portion increases in amount in the different crystals so does the specific gravity; and between 4·0 and about 4·2 there is an unbroken series.

The largest crystal (measuring $10 \times 5 \times 3$ mm. and weighing 0·592 gram) was found by hydrostatic weighing to have a specific gravity of 4·00; this crystal is in all portions of a dark brownish-black colour, and, except on thin edges, is opaque. Other, rather smaller, crystals were also separately weighed in water and found to have specific

[1] Geol. Mag., 1904, new ser., dec. 5, vol. i, p. 418.

gravities of 4·02, 4·03, and 4·09 respectively; these all showed a lighter coloured and more transparent portion.

The crystals have an average size of half a centimetre across. Their hardness is 7. They are developed on all sides and only very rarely show any broken surfaces. Owing to the very irregular development of the crystals it was not at first easy to determine their symmetry, especially as the faces are somewhat rough and give only blurred images of the goniometer-signal. Further, zircon having in four zones [$ax = 31° 43'$, $xp = 29° 57'$, $pe = 28° 20'$] angles of nearly 30° and in three zones [$am = 45°$] [$mp = 47° 50'$] angles of 45° or nearly 45°, it was not

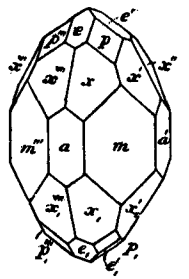

Fig. 1.
Ideal development.

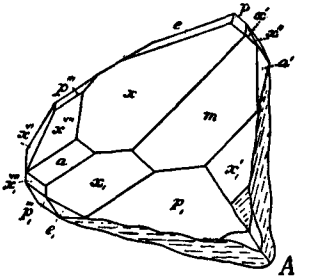

Fig. 2.
Actual crystal.

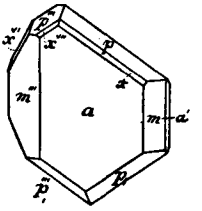

Fig. 3.
Actual crystal.

Zircon from Ceylon (Clinographic drawings and plans) [1].

always possible to distinguish the approximate measurements obtained from the angles of a cubic crystal, or to correctly orientate the crystals, until several zones on each had been measured.

The accompanying figures (figs. 2 and 3) are intended to give an idea of the shape of two of the crystals, while fig. 1 represents an ideally developed crystal with the same forms. The forms present are: a {100}, m {110}, e {101}, p {111}, and x {311}.

A peculiar feature presented by almost all the crystals of low specific

[1] The method of giving a plan of the crystal together with the clinographic drawing is borrowed from H. H. Robinson (Amer. Journ. Sci., 1901, ser. 4, vol. xii, p. 180).

gravity is that on one side they show an area of deeply striated and stepped surfaces. These surfaces usually lie in the principal zones of the crystal, and meet in a central point (*A* in figs. 2 and 3) to form a pyramid, which in most crystals is quite flat and has its base parallel to *a* (100) or *m* (110). The zones in which they are most prominently developed are [100, 010], [100, 111], and [100, 1$\bar{1}$1], the low striated pyramid being then six-sided, as in fig. 3. (In the crystal here represented, however, one set of the striated surfaces is not quite in the zone [100, 111].)

At the centres, *A*, of these striated areas the crystals are pale yellow in colour, transparent, and possessed of a brilliant adamantine lustre. Away from this point the colour gradually shades off into brown, and the transparency and lustre diminish. The striated surfaces reflect long bands of images, but sometimes there are bright and smooth faces from which fairly good measurements, agreeing with the angles of zircon, could be obtained. On one crystal the centre of the area is occupied by a small projection having the form of a square pyramid bounded by (111), (11$\bar{1}$), (100), and (010).

The appearance presented by these striated areas is very similar to that shown by the individual crystals broken from a divergent group of crystals which have interfered with each other's growth. It would seem that several crystals had originally grown around a common centre, in which the points, *A*, of all the crystals coincided; the lighter and brighter striated surfaces would then have been the surfaces of contact between adjacent crystals; and the dull brown, freely-developed faces would represent the external boundaries of the whole group. The fact that the striated surfaces fall in the principal zones would further suggest that the crystals had some definite arrangement with respect to each other, and that the composite crystal was probably of the nature of a pseudo-symmetric or mimetic group. It is quite possible, however, that the crystals grew separately, and that their growth on one side was simply retarded by contact with some other body. The striated pyramidal portions of some of the crystals bear a striking resemblance to the so-called 'babel-quartz' from Beeralston in Devonshire, but they differ from this in having freely-developed faces on the opposite side.

When viewed through the prism-faces in parallel polarized light, the crystals extinguish uniformly parallel to the principal axis. Sections cut perpendicular to this axis are quite transparent and exhibit, in convergent polarized light, interesting variations in the optical characters.

Two sections (sp. gr. 4·1) taken through both the dark and light coloured portions of one crystal (sp. gr. 4·02) showed a gradual transition from colourless through pale yellow to rich brown, the last predominating in amount. In the small colourless portion (which is at the tip *A* of the striated area of the crystal) the section is biaxial with a small axial angle ($2E = 8°$ about), the axial plane being perpendicular to the prism-face *a* (100) on the opposite side of the crystal; the birefringence is very strong and positive. On moving the plate so that the coloured portion gradually comes into the field, the axial angle gradually diminishes in size until the figure becomes strictly uniaxial (+); at the same time the numerous coloured rings gradually expand outwards and become further apart. On moving the plate still further in the same direction, the rings continue to expand and at last disappear; finally the black cross also disappears, and, in the darkest brown portion, the section is perfectly isotropic. The greater portion of the section is optically uniaxial with weak positive birefringence.

The section, although showing such wide differences in the strength of its double refraction, has about the same mean refractive index in all parts. This was determined, by focusing on the scratches on the two sides of the section, to be about 2·0[1]: the scratches on the under side remained in focus as the section was moved about on the stage of the microscope.

Three other sections cut from two small brown crystals (sp. gr. 4·0) on which there was none of the lighter coloured portion, showed by transmitted light a brown colour of varying depth in different parts. These sections were also, for the most part, optically uniaxial with weak positive birefringence; the strength of the double refraction, however, varied slightly in different parts and was sometimes almost zero; in one or two places in one section the figure was biaxial with a slight separation of the optic axes.

When heated to redness in the flame of a Bunsen burner, the crystals change in colour from dark brown to bright green, and become much more transparent and lustrous. No phosphorescence was observed; and there was practically no loss in weight. By immersion in silver-thallium nitrate, it was determined that the crystals of specific gravity 4·0 had the same specific gravity after ignition as before, but that crystals with a slightly greater specific gravity (up to 4·1) showed a slight increase (up to 4·2).

[1] The mean of ten approximate readings, varying between 1·9 and 2·1, was 1·97. The section has a thickness of about 1 mm.

The sections after being heated to redness showed changes in their optical characters. The portions which were before brown are now green, and between crossed nicols, in parallel light, are doubly refracting with undulose extinction. In convergent polarized light the optic figures are confused and distorted, but positive biaxial figures with axial angles up to 20° and with axial planes of variable orientation can sometimes be distinguished. The birefringence is still low, though rather stronger than before. The small colourless portion in the sections of the first crystal remained, as before, biaxial with strong birefringence. The mean refractive index of the whole plate was also unchanged. When the crystals and sections were still more strongly heated over the bellows-blowpipe, no further change took place.

Absorption bands in the spectrum of light which had passed through the crystals were sometimes observed, but only after ignition.

The crystals described therefore consist mainly of a dark brown zircon of specific gravity 4·0, which is optically uniaxial with weak positive birefringence; when heated, this material changes to green in colour and becomes optically biaxial, but undergoes no change in specific gravity. Intergrown with this variety, in most crystals, there is a lighter coloured variety of zircon of higher specific gravity, which is biaxial with strong positive birefringence; this variety when heated increases in density, but shows no change in its optical characters. The two varieties are identical in crystalline form.

A chemical examination of one crystal of low specific gravity showed the presence of much silica and zirconia, and the absence of titanium. From a neutral solution containing the zirconium, oxalic acid threw down a bulky white precipitate which was very readily soluble in excess of oxalic acid; potassium zirconium sulphate was precipitated from a neutral sulphate solution; and a satisfactory colour was obtained with the turmeric-paper test for zirconium. Comparative tests were made with a red zircon from Expailly (sp. gr. 4·7), and the reactions were apparently the same for this as for the Ceylonese crystal. It is, however, quite possible, as suggested by Stevanović[1], that in one of these zircons there may be instead of zirconium another closely allied element.

From his own observations and from those of Professor A. H. Church[2], it has recently been pointed out by Dr. S. Stevanović[3] that zircons may

[1] Zeits. Kryst. Min., 1903, vol. xxxvii, p. 252.

[2] Journ. Chem. Soc. London, 1864, new ser., vol. ii, pp. 389, 415; Geol. Mag., 1875, new ser., dec. 2, vol. ii, p. 322; Chem. News, 1902, vol. lxxxv, p. 270.

[3] Zeits. Kryst. Min., 1903, vol. xxxvii, p. 247.

be divided into three classes according to their different specific gravities and behaviour when heated, viz.:—

(i) Sp. gr. 4·0, both before and after ignition. (α-zircon.)

(ii) Sp. gr. 4·7, also unchanged by heating. (β-zircon.)

(iii) Sp. gr. between 4·0 and 4·7; when strongly heated the zircons of this class increase in density, reaching sometimes the higher limit.

The stable modifications of lower and higher specific gravity may be distinguished as α-zircon and β-zircon respectively. The former kind, to which the dark brown crystals described above belong, appears to have been noticed previously only twice. Church (1875) mentions a dark green stone of sp. gr. 4·02, which experienced no change in density when heated. Stevanović (1903) has described brown pebbles from Ceylon of sp. gr. 4·06, which showed a slight change from 4·02 to 3·965 when strongly heated; the colour at the same time passing to siskin-green and the transparency increasing: both before and after ignition the material was optically uniaxial with very feeble positive birefringence. The material described in the present note is thus very similar to that examined by Stevanović, though it shows some differences in the optical characters.

A zircon of low specific gravity is not necessarily α-zircon, for Damour[1] records a green stone from Ceylon which increased in density from 4·043 to 4·318 when heated; and Church (1902) mentions a green Ceylonese zircon which changed from 4·0 to 4·31. These belong to the third class, and may be inferred to consist of an intergrowth of α-zircon with an unstable modification (γ-zircon), which increases in specific gravity to 4·7 when heated. Specimens (all[2] of sp. gr. greater than 4·33) which increase in specific gravity to the higher limit (4·7) can contain no α-zircon, though they may consist of an intergrowth of β-zircon and γ-zircon. The fact that zircons of the third class frequently exhibit zonal structures amply supports the supposition of these intergrowths.

These variations in the specific gravity and optical characters of zircon give rise to many suggestions, but as Professor Church and others are still engaged on this work I merely offer the results of my determinative examination of the crystals described above as a contribution to this most interesting problem.

[1] Compt. Rend. Acad. Sci. Paris, 1864, vol. lviii, p. 158.

[2] The lowest recorded is by Stevanović (loc. cit., p. 250), who describes greenish crystal-fragments, from Ceylon, which increase in sp. gr. from 4·33 to 4·66, at the same time losing their colour and changing from optically biaxial to uniaxial.