

*Note on cordierite in a cordierite-gneiss from
Madura district, Madras, India.*

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[Read November 4, 1924 ; communicated by the Foreign Secretary.]

THE specimen of cordierite-gneiss under notice was collected by Mr. T. N. Muthuswami (Assistant Professor of Geology, Presidency College, Madras) in a quarry at Ganguvarpatti in the Madura district. On examining thin sections of the rock, he found that many of the cordierite crystals were optically positive, and, thinking that the mineral might be worth further investigation, he sent a specimen of the rock to me. The investigation was carried out in the Geological Department of the Imperial College of Science and Technology, and my thanks are due to Professor W. W. Watts and Dr. J. W. Evans for their kindness in affording me facilities for this work, and also to Dr. H. H. Thomas, of H.M. Geological Survey, for his kindness in placing Fedorov's universal stage at my disposal for the measurement of the optic axial angle.

According to Mr. Muthuswami, the cordierite-gneiss occurs as the result of the contact-metamorphism of an Archaean biotite-gneiss by an intrusive tongue of charnockite from the main mass of the Palni Hills. The rocks observed in and around the quarry include cordierite-garnet-gneiss, sillimanite-gneiss, crystalline limestone (with scapolite, forsterite, diopside, garnet, sphene, and apatite), biotite- and hornblende-gneisses, charnockite, and very locally hypersthenite.

The cordierite occurs in the garnet-sillimanite-cordierite-gneisses in various proportions, sometimes forming 25-30 % of the rock. Its mineral associates are orthoclase, oligoclase, pinkish garnet, sillimanite, magnetite or titanoferrite, (and kyanite?). In hand-specimens, the cordierite is dark-violet in colour, and has a vitreous to resinous lustre. The crystals never show any definite crystallographic faces.

In order to determine the specific gravity by means of the pyknometer, a small piece of the specimen was crushed to coarse powder, from which the cordierite was separated grain by grain under a magnifying lens. The average of two closely concordant determinations was 2.598, at 9° C.

A quantitative analysis of the mineral, separated carefully from a

crushed specimen of the rock, gave the percentages of oxides shown in column I. Mr. I. C. Chacko's analysis (1916) of cordierite from Travancore is quoted under II for comparison.

	I.	II.
SiO ₂	48.37 ...	49.74
Al ₂ O ₃	29.22 ...	35.21
Fe ₂ O ₃	2.20 ...	5.65
FeO	7.07 ...	3.00
MgO	9.54 ...	4.30
CaO	1.92 ...	1.05
MnO	0.42 ...	—
H ₂ O	1.84 ...	1.74
Total	100.58 ...	100.69

Optical characters.—As seen in thin sections, the cordierite occurs as allotriomorphic individuals, associated with the minerals mentioned above. Thick sections are strongly pleochroic, the colours being: α yellowish, β violet, and γ colourless. But even in sections of ordinary thinness the pleochroism is quite distinct, the mineral changing from colourless to a delicate pale-blue when rotated above the polarizer.

Intense yellow pleochroic haloes are sometimes abundant, especially around minute inclusions of zircon. Some of the larger haloes are remarkably beautiful and strong.

Sometimes the cordierite displays simple twinning (fig. 1), the two individuals severally showing colour-contrast in polarized light. But lamellar twinning, recalling that of the plagioclases, is more common, the inter-digitation of the lamellae being a characteristic feature (fig. 2). Occasionally, the larger crystals may show two sets of lamellar twins inclined to each other.

Pinitization is quite characteristic, all stages being observed. The alteration generally starts at the periphery, along minute cracks extending inwards, and developing, as alteration proceeds, into ramifying veins traversing all parts of the mineral. This pinite resembles chlorite in appearance, yielding very low interference-colours (ultra-blue), and sometimes it is practically isotropic.

One thin section, specially mounted on a circular glass slip, was used on Fedorov's universal stage for the determination of the optic axial angle. Four different individuals gave values for $2V$ ranging between 81° and 84° on the positive bisectrix (γ), while one gave the value $2V = 85^\circ$ on the negative bisectrix (α). Hence the positive character of some of the individuals is certain, the optic axial angle being very wide.

It is interesting to note in this connexion that optically positive

cordierite has been described, from Travancore, by Mr. I. C. Chacko,¹ and from Vizagapatam (Madras) by Dr. G. de P. Cotter (quoted by I. C. Chacko). Thus, for cordierite from such widely separated areas as Vizagapatam, Madura, and Travancore, this peculiar optical character is consistent.

In the discussion of a paper by Dr. C. E. Tilley, at a meeting of the Geological Society of London, Dr. L. L. Fermor² remarked that he found cordierite forming an important constituent in a hornfels formed as a result of thermal metamorphism of a shale by the burning of a coal-seam, and that the rock as a whole was found, on analysis, to be rich in iron and poor in magnesium. The cordierite here is highly pleochroic, and the deep-violet colour is regarded by Dr. Fermor to be due to the high iron content. The cordierite does not seem to have been analysed separately.

Violet colour in minerals is often attributed to the presence of a small amount of manganese oxide, but it is doubtful whether richness in iron may be responsible for the same effect, as Dr. Fermor thinks. What seems to be highly probable is that the isomorphous replacement of MgO by FeO may produce a change in the value of the optic axial angle, imparting the positive optical character to the cordierite. The parallel cases of the series enstatite-hypersthene and forsterite-fayalite suggest that the ratio of MgO to FeO determines the sign and the value of the optic axial angle.

With regard to the origin, Mr. Muthuswami states that the cordierite has resulted from the metamorphism of biotite-gneiss, the iron and magnesium being probably derived from the biotite. I have not at my disposal any facts concerning the ultimate origin of the parent biotite-gneiss—whether igneous or sedimentary.

In his Presidential Address to the Geologists' Association, Sir J. J. H. Teall remarked:³

'Cordierite . . . is found under two conditions. In the gneisses and contact-rocks it occurs, as a rule, in irregular colourless grains which are not pleochroic in thin sections, except around minute inclusions of zircon. In this form it is often crowded with needles of sillimanite, and not infrequently contains . . . rounded scales of biotite.

In volcanic rocks it often occurs as six-sided prisms, cross sections of which break up into sectors in polarised light. . . . The cordierite of the volcanic rocks is, moreover, often pleochroic.'

¹ I. C. Chacko, *Optically positive cordierite*. *Geol. Mag. London*, 1916, dec. 6, vol. 3, pp. 462-464 [*Min. Abstr.*, vol. 1, p. 66]; also *Records Dept. Geology of Travancore, Trivandrum*, 1922, vol. 1 (for 1921), p. 14.

² *Quart. Journ. Geol. Soc. London*, 1924, vol. 80, p. 70.

³ J. J. H. Teall, *Proc. Geol. Assoc. London*, 1899, vol. 16, p. 62.

In the case under consideration, and indeed in all the Indian cordierites, pleochroism is distinctly visible in thin sections, and hence Sir Jethro Teall's generalization cannot hold. It seems therefore that pleochroism and colour must be assigned, not to the mode of origin, but to the chemical composition of the cordierite.

So far as I am aware, optically positive cordierite has been observed only from the ancient crystalline complex of Peninsular India, but whether it is peculiar to that region, or attributable to the high iron content which such cordierite shows, is at present difficult to say. More

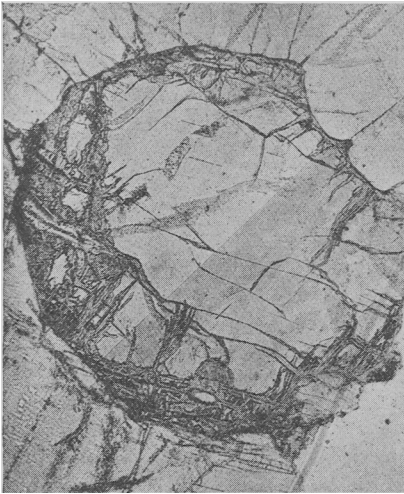


FIG. 1.

Cordierite from Madura district, Madras, India.

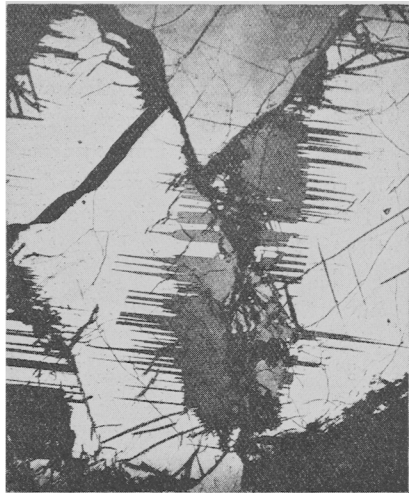
(Photomicrographs $\times 22$.)

FIG. 2.

FIG. 1. Crystal showing simple twinning and pinitization.

FIG. 2. Crystal showing lamellar twinning.

data on the characteristics and composition are required for cordierite, not only from Peninsular India, but also from other areas, such as Scandinavia, South Africa, Brazil, and Canada, where the ancient gneisses may include members containing cordierite. Perhaps future work will contribute towards a full explanation of the positive sign, since all the cordierite hitherto found in Europe and America has been known to be optically negative, though the optic axial angle ($2V$) varies between 40° and 85° .