On the occurrence of chondrodite in the Glenelg limestone of Inverness-shire.

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INTRODUCTION.—There are many old records of the occurrence of chondrodite in the British Isles. Greg and Lettsom [1] mentioned Co. Donegal in Ireland and near Loch Ness in Scotland. J. H. Collins [2] gave Wheal Druid, Redruth, and also Scotland and Ireland. The mineral is included in a list of those associated with the kyanite of Glen Urquhart, Loch Ness, Inverness-shire, given by T. Wallace.[3] Though reference to the Loch Ness locality is made by Dana in the 6th edition of the 'System' (1892, p. 540), the existence of chondrodite at Glen Urquhart, the only likely locality near Loch Ness, had been queried by M. F. Heddle so early as 1879. Heddle [4] failed to find chondrodite at this locality; he gave the name xantholite to a yellowish serpentinous substance that he suggested had been hitherto mistaken for chondrodite. In the Supplement to the 'Mineralogy of Scotland' Heddle and J. G. Goodchild [5] dismiss other Scottish localities; the supposed Glenelg chondrodite had been shown by Teall [6] to be forsterite, whilst that recorded from Rum was olivine.

It is seen, therefore, that no certain occurrence of chondrodite in Scotland, or indeed in Britain, is on record. The present note is concerned with the discovery of undoubted chondrodite in the Glenelg limestone of Inverness-shire.

The geological setting of the occurrence.—Chondrodite has been found by us in the Glenelg limestone exposed on the west side of the Allt

[1] R. P. Greg and W. G. Lettsom, Mineralogy of Great Britain and Ireland. London, 1858, p. 223.

[2] J. H. Collins, Mineralogy of Cornwall and Devon. Truro, 1871, part 2, p. 33.

[3] T. Wallace, Min. Mag., 1884, vol. 6, p. 107.

[4] M. F. Heddle, Min. Mag., 1879, vol. 3, p. 59.

[5] M. F. Heddle, Mineralogy of Scotland. Edinburgh, 1901, vol. 2, pp. 208–209.

[6] Cf. C. T. Clough and W. Pollard, Quart. Journ. Geol. Soc. London, 1899, vol. 55, p. 372.

Eas Mòr Chùil an Dùin, a tributary joining the Amhainn a' Ghlinne Bhig from the south. The locality is 2 miles 16° E. of S. from the church at Kirkton of Glenelg, or ¾-mile NW. of the summit of Beinn a' Chapuill, the prominent hill, 2421 feet in height, on the south side of Gleann Beag. The exact spot can be readily located by ascending the Allt Eas Mòr Chùil an Dùin from Gleann Beag for slightly more than half a mile till the stream follows a conspicuous NW.–SE. fault-line. The Glenelg limestone is encountered at the south-eastern end of the fault-gorge, and by following its outcrop south-south-westwards for 300 yards the chondrodite locality is reached on the peaty ridge west of the stream. The limestone outcrop and the fault just mentioned are shown on the One-inch Geological Survey map of the area, Sheet 71.

The geology of the Glenelg district has been described by C. T. Clough.[1] A series of bands of rocks considered to be Lewisian run north-north-east and south-south-west and are separated from one another by bands of siliceous granulites referred to the Moine Series. The Lewisian rocks include many sedimentary types, such as limestones, garnet-biotite-kyanite-gneisses, biotite-schists, graphite-schists, &c. With these are associated rocks of igneous or mixed parentage—eclogites, garnet-amphibolites, hornblende-schists, various ultrabasic types, felspathic gneisses, and thinly banded, hornblendic gneisses.

The traverse up the Allt Eas Mòr Chùil an Dùin from Gleann Beag to the chondrodite locality shows thinly alternating quartzo-felspathic and hornblendic granulitic gneisses with lenses or intercalations of eclogite and hornblende-garnet-rocks. The limestone of the chondrodite locality is structurally underlain by striped hornblendic granulites and is structurally succeeded by similar rocks with thin limestone bands and eclogitic pods, as seen in the burn east of the locality.

Petrography of the chondrodite-bearing rocks.—A synopsis of the twenty or so slices containing chondrodite cut from rocks of this locality shows that the constituent minerals are calcite, forsterite and forsterite-serpentine, phlogopite, chlorite, diopside, iron-ore, and chondrodite. Ferromagnesian minerals other than forsterite are not abundant, and the chondrodite-bearing rocks are essentially forsterite-marbles. They are coarse rocks formed mainly of calcite grains and rounded masses of partly serpentinized forsterite. In slices calcite

[1] C. T. Clough, The geology of Glenelg, &c., Mem. Geol. Surv. Scotland, Explan. Sheet 71, 1910, pp. 18–44.

is seen to be the dominant component in large grains; in it are set ovoid grains of colourless forsterite usually more or less converted into mesh-serpentine. The ferromagnesian mineral next in abundance to the forsterite, and one seen in every slice, is colourless phlogopite as lath-shaped sections. Often chlorite, colourless and lamellar-

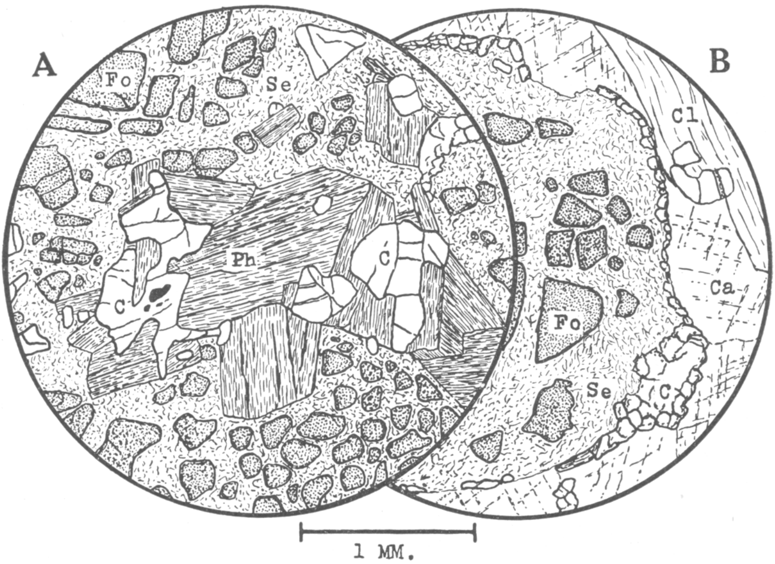

FIG. 1. Chondrodite in the Glenelg limestone. C = chondrodite, Fo = forsterite, Ph = phlogopite, Se = serpentine, Cl = chlorite, Ca = calcite, solid black = iron-ore.

twinned, accompanies the mica. Diopside is present in a few slices; it is colourless and shows excellent cleavages. The chondrodite is never abundant. In many slices it is limited to one or two minute grains, but in a few it is more abundant and the grain-size reaches 0·6 mm. In the slice richest in chondrodite some fields viewed with the 1-inch objective show over 10 % of the mineral.

The chondrodite.—The typical mode of occurrence of the mineral is as a rim of small granules around large forsterite or forsterite-serpentine masses (fig. 1 B). Rarely the rim of chondrodite extinguishes simultaneously with the forsterite. In a few cases plates of phlogopite, and still more rarely laths of chlorite or grains of diopside, are bordered by a similar rim. In addition to this usual mode of occurrence the chondrodite forms rather large spongy masses, the interspaces of which are of calcite or chlorite, or it builds small irregular grains in phlogopite, forsterite, or chlorite (fig. 1 A). Often it makes irregular granular masses in calcite and then may be accompanied by phlogopite.

The grains are usually shapeless, but occasionally elongated forms are seen which have negative elongation and rarely a twin-plane parallel to their length. Suggestions of a cleavage are rarely found; in the best example the mineral extinguishes at nearly 30° to this cleavage. Usually a few irregular cracks traverse the larger grains.

The body-colour and the pleochroism are well marked, α being bright yellow, β faint yellow or colourless, γ faint yellow or colourless, with absorption $\alpha > \beta = \gamma$. Twinning is fairly common; it appears to be dominantly on one law and may be either simple or lamellar. No morphological directions are observable in the grains, but if the common twin-plane is taken as (001) (that most seen in chondrodite), then α: (001) exceeds 20° in the sections available. One grain, in addition to this assumed (001) twinning, shows another which may be on (305); this suggestion is made from comparison of this twinned grain with one figured by H. von Eckermann[1] from Mansjö Mountain, Sweden.

The refractive indices were determined by the immersion method, with light from a Zeiss sodium lamp. The lowest and highest values found were α' 1·610 and γ' 1·639. The birefringence is strong.

Two thin sections showed grains suitable for the determination of the optic axial angle with the universal stage. Two grains in each slice were measured with the following results for 2V(+):

First slice	72·6° and 72·0°.
Second slice . . .	73·6° and 74·5°.

The determination of the optic axial angle in small grains by the universal stage, even with the use of the special Leitz objective U.M. 4, is not entirely satisfactory. The results given above, however, are based on repeated observations and are sufficiently accurate to show, in our opinion, that the Glenelg chondrodite has an optic axial angle between 72° and 74°.

The optical properties of the Glenelg chondrodite are similar to those of the yellow or G-chondrodite of Mansjö Mountain, Sweden,

[1] H. von Eckermann, Geol. Fören. Förh. Stockholm, 1922, vol. 44, fig. 99, plate 57.

described by von Eckermann (loc. cit., pp. 379–383). The Mansjö material has 2V 72° 14′, α 1·607, and γ 1·643. Von Eckermann remarks that the optic axial angle of the Mansjö G-chondrodite is the lowest on record.

In the Glenelg rocks the chondrodite is occasionally altered to a dense brownish, greyish, or black aggregate with the separation of iron-ore at the margins.

Other chondrodite localities in the Glenelg district.—By the kindness of Dr. H. H. Thomas, F.R.S., Petrographer to H.M. Geological Survey, we have been able to examine some of the rock-slices of the Glenelg limestone contained in the Geological Survey collection of sliced rocks. Three of these slices have been found to contain chondrodite in abundance.

The first slice, no. 12322, comes from the locality for chondrodite described in the previous pages—west side of the Allt Eas Mòr Chùil an Dùin. The slice shows many kernels of chondrodite in patches of probably micaceous material. In one patch many now-isolated fragments of an originally large crystal show excellent lamellar twinning.

The second slice, no. 12320, comes from the limestone outcrop 250 yards NNE. of Balvraid, Gleann Beag. This locality is 2 miles from that described by us, and is 2¾ miles SE. from the church at Kirkton of Glenelg. The chondrodite forms rims of markedly pleochroic granules around partly serpentinized forsterite, a mode of occurrence exactly similar to that already described by us.

The third slice, no. 7917, comes from Ross-shire, its locality being the limestone outcrop ¾-mile up from the foot of the Allt Easan Mhic Garraidh. This locality is some 4 miles NNE. from our original one, or 3 miles NE. from Glenelg church. This slice is mentioned by Clough and Pollard (loc. cit., p. 337) as showing diopside grains forming a rim around forsterite grains. This observation has been confirmed by us, but in addition we have noted that abundant yellow chondrodite occurs in the same fashion. It is interesting to recall that Pollard (loc. cit., p. 378) in the course of his separation of forsterite for analysis obtained a fraction in which a few yellow grains were observed, and that the analysis of the forsterite (loc. cit., p. 379) shows a 'trace of F'.

Conclusion.—Chondrodite thus occurs in forsterite-marbles from widely separated localities in the Glenelg district. A detailed investigation would most likely show that it is a ubiquitous component of this limestone. In characters the Glenelg chondrodite closely resembles the yellow chondrodite from Mansjö Mountain, Sweden. Its typical mode of occurrence at Glenelg is as small granules forming rims around forsterite crystals; this suggests that the chondrodite has been produced from forsterite by the accession of fluorine- and hydroxyl-bearing fluids.