On a peculiar chlorite-rock at Ible, Derbyshire.

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In this paper is described an apparently hitherto scientifically unnoticed mode of alteration of olivine-dolerite in the intrusive sill at Ible near Matlock.

The igneous rocks of Derbyshire, locally called 'toadstones', constitute a well-known basic series of both contemporaneous and intrusive rocks. They comprise lava-flows, sills, a few thin dikes, agglomerates, and tuffs. All occur in beds of Lower Carboniferous age, and are confined to the upper half of the known thickness of the Carboniferous Limestone, with, in the south of the county, the overlying Limestone Shales. They have been described, in recent years, by Sir A. Geikie ('Ancient Volcanoes of Great Britain', 1897, vol. 2); H. H. Arnold-Bemrose (Quart. Journ. Geol. Soc., 1894, vol. 50, pp. 603–644; 1907, vol. 63, p. 241, et seq.); and H. C. Sargent (ibid., 1918, vol. 73, pp. 11–25).

The Ible Sill.

Situated immediately to the east of the village of Ible, is the intrusive sheet which is known as the Ible Sill; it was described by Bemrose (loc. cit., 1907, p. 275). He says that the sill measures about half a mile from east to west, and a third of a mile from north to south; and that on the north-east the toadstone passes under the limestone with a north-north-easterly dip of 20°. He also says that about 200 feet of the igneous rock are seen on the same horizon as the adjacent limestones: it evidently traverses the beds of limestone, and there is some marmorization of the limestones immediately to the south of the sill. He describes the rock as 'an ophitic olivine-dolerite, rich in olivine-phenocrysts. The olivine occurs in large idiomorphic crystals measuring up to 5·5 millimetres in length, and in groups or nests of crystals. It is embedded among the felspars, and is present in the ophitic plates of augite.'

The Metamorphosed Rock.

The rock of the sill was, some years ago, quarried somewhat extensively for use as road metal, and the quarry, so formed near the present southern limit of the sill, cuts through a stratum (within the dolerite) of highly altered rock. This stratum occurs, for the most part, deep within the normal rock of the sill (and much of the latter has been already removed by denudation), traversing it with an easterly dip—not at a regular angle, but forming a portion of a somewhat anticlinal-like curve with a dip approaching 40° at the lower exposed end just above the quarry floor, which is probably several feet above the base of the sill.

The stratum is, in parts, moderately well defined, but for the most part it has indistinct margins—the two types of rock (i.e. normal and metamorphosed) merging gradually, though somewhat rapidly, the one into the other. In thickness it varies considerably; near its lower exposed end it is about 4 feet; a little higher it is rather thicker (at the same time, with less distinct margins), but still higher it thins out very much and becomes, on one side of the cutting, almost lost by branching or forking.

Within the stratum may be found small masses of rock with almost normal unaltered portions near their centres, and from the margins of these masses specimens of the rock in varying stages of the alteration may be obtained.

About the middle of the stratum of altered rock, and in the plane of that stratum, in places, may be seen what appears to have been a narrow fissure, but no effects of movement can be detected—unless traces of a slightly schistose kind of 'bedding', which is suggested here and there, be due to slight movement.

Also within the bed or stratum, and in the same plane, small lenticular or sheet-like masses of quartz occur.

Petrology.—The rock of the stratum is of quite a different appearance from that of the original dolerite. As seen in the mass it is of a somewhat uniformly dull, dark-green colour, and is quite soft and friable.

When more closely examined, the rock appears to consist mainly and essentially of a dark olive-green mineral, having a greasy feel and lustre, and existing as a confused mass of intergrown lamellar or foliated aggregates.

As seen microscopically in thin sections, the green mineral is of a much more golden-green colour, and purer portions of the rock contain little else than this substance, but the majority of specimens also contain variable quantities of minerals of the primary rock scattered throughout the mass. Such vestiges of the original dolerite usually consist of fragments and small groups of felspars in varying degrees of freshness; but in all specimens of the altered rock, small, dense, knot-like masses of the foliated mineral occur which sometimes contain incompletely altered augite. Quartz, obviously secondary, and usually containing, in variable quantity, intergrown fibres of the green mineral, occurs infilling minute fissures and spaces in the secondary mass.

Throughout the rock mass there occurs, in very small quantity, a mineral which appears, under the usual powers of the microscope, as minute, opaque, white specks. Under a $\frac{1}{12}$-inch oil-immersion objective, however, these specks are seen to be minute crystals having a very high refractive index and an adamantine lustre. This mineral is probably anatase.

Examination of mineral fragments separated by heavy liquids from samples of the crushed rock revealed ilmenite, magnetite (in small quantity), traces of calcite and the felspars, and small amount of augite as already noted.

Veins.—The dolerite of the Ible Sill, as seen in the quarry, is traversed by numerous small veins of a fibrous or columnar mineral which has been supposed to be chrysotile. It occurs as small veins occupying cracks and fissures in the rock and, in the best examples, the fibres are set at right angles to the walls of the fissures occupied by the mineral. The veins are most numerous, thickest, and purest in the vicinity of the higher parts of the metamorphosed stratum—into which they sometimes pass—and here they may attain a thickness of up to about 4 inches.

This mineral, which, as previously stated, has been regarded as chrysotile, is deep olive-green in colour, greasy in feel and lustre, and has a specific gravity of 2·37. Optically, it exhibits slight pleochroism in paler and darker golden-greens. Between crossed nicols it gives first-order colours and straight extinction. In refractive index it is sensibly above 1·53. It has a very good cleavage parallel to the longitudinal axes of the columns, which are brittle and not readily separable into fibres.

Calcite is a frequently associated mineral in the veins; but quartz, as more or less fibrous aggregates intergrown by the green fibres, is usually present in varying amount.

The following analyses were made on samples dried at 100° C.

	1.	2.	3.	4.	5.
SiO_2 ...	42·7 %	41·1 %	37·5 %	47·0 %	40·88 %
Al_2O_3 ...	8·2	8·9	10·4	13·8	10·96
Fe_2O_3 ...	13·6	13·6	8·8	7·1	8·72
FeO ...	2·8	2·8	10·8	7·5	8·96
MgO ...	20·7	17·2	20·8	13·3	20·00
CaO ...	nil	3·4	nil	0·8	0·68
H_2O ...	11·7	10·0	12·0	9·6	10·18
CO_2 ...	nil	2·6	nil	nil	—
	99·7	99·6	100·3	99·1	100·38

1. A pure sample of the fibrous vein mineral: Ible.
2. A sample of the fibrous vein mineral containing a little calcite: Ible.
3. A very pure specimen of the foliated green mineral from Ible. It was dark leek-green in colour; sp. gr. 2·52; hardness about 2.
4. A good sample of the rock of the described stratum at Ible. Microscopical examination of this sample revealed the presence of quartz, felspar and its hydration products, and a little augite; their presence is also evident in this chemical analysis.
5. Analysis of 'epichlorite' from Harzburg, Harz, by C. Rammelsberg, 1849.

By their analyses the identity of these minerals is established as chlorites; and furthermore, with the exception of specific gravity, there is a considerable similarity between those now under consideration and that described by C. Zincken and C. Rammelsberg in 1849 (Ann. Phys. Chem. (Poggendorff), vol. 77, p. 237) and called by them 'Epichlorite' in allusion to it being near chlorite in its characters. It is quoted as being fibrous or columnar, between bastite and chlorite in its characters, and occurring in the Harz Mountains as thin veins in a rock resembling serpentine. They give the following details: hardness, 2 to 2·5; sp. gr. 2·76; colour dark leek-green; and greasy in lustre. Analysis number 5 is the one given by them.

'*Epichlorite*'.—On account, therefore, of the considerable similarity between the mineral now described from Ible, occurring as fibrous veins and as a rock constituent in the form of intergrown aggregates, and that mentioned by Zincken and Rammelsberg, the present writer proposes the adoption of the name which they used for this mineral.

Similar Veins at other Localities.—Similar, but very much poorer, occurrences of these fibrous veins may be sometimes seen in the quarry (which is at present being worked) in the olivine-basalt and deep in the centre of the vent at Calton Hill near Taddington, Derbyshire.

The intrusive sill (olivine-dolerite) in Tideswell Dale, Derbyshire, was described by Dr. Bemrose in 1899 (Quart. Journ. Geol. Soc., 1899, vol. 55, pp. 239–250), but the quarry in which he investigated the rock is now so full of debris that it is impossible to examine the face. However (op. cit., p. 247), he says, 'The rock in the quarry is traversed by numerous small veins of a mineral which is probably chrysotile'. He continues briefly to describe the mineral, but he had no analyses to aid him in his identification. His account is in close agreement with that now given of the fibrous veins at Ible: and furthermore, in a private communication (June 1918), Dr. Bemrose remarked on the similarity of the occurrences.

Genesis.—From the mode of occurrence, already described, it will be seen that the veins, at least, must have formed in cracks or fissures in the rock after solidification of the magma, and the process must have been a hydrothermal one following that event. The veins were apparently formed a little later than the altered bed, into which some pass, but the two forms of the occurrence are undoubtedly genetically similar and connected.

A feature of the metamorphosed stratum is the scarcity of calcium carbonate—a compound which would be expected to have been simultaneously formed—it must therefore have been removed in solution. Zeolites, epidote, &c., are not present, although such minerals have been considered to be produced by the action of magmatic waters on aluminous basic rocks.

In conclusion, I wish to express grateful thanks to my wife for assistance continuously rendered in every stage of the work; to Prof. P. G. H. Boswell for facilities kindly afforded in the Geology Dept., Liverpool University, and for assistance and advice; and to Miss S. W. Harris for discussion of the work. The analyses are by the author.