9. *On ANTIGORITE and the VAL ANTIGORIO, with NOTES on OTHER SERPENTINES CONTAINING THAT MINERAL.* By Prof. T. G. BONNEY, Sc.D., LL.D., F.R.S., F.G.S. (Read February 5th, 1908.)

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I. THE ORIGINAL SPECIMEN AND THE VAL ANTIGORIO.

THE exact locality of the type-specimen of antigorite is apparently unknown, as I found when preparing my portion of the paper by Miss Raisin and myself on the minerals forming serpentine.¹ E. Schweizer, who first described it,² states that the specimen (5 inches long, 2 inches wide, and 2 inches thick) was in the collection of D. F. Wiser of Zurich, who had bought it the year before

‘von einem mit Mineralien handelnden Bauer aus Oberwallis, nach dessen Aussage diese Substanz in kleineren und grösseren, bisweilen einen Fuss langen, dünn-schiefrigen Platten im Antigoriothale bei Domo d’Ossola gefunden werden soll’;

and was unable to obtain any more precise information from the man. It has been subsequently noticed,³ among others, by Des Cloizeaux,

¹ Quart. Journ. Geol. Soc. vol. lxi (1905) p. 690.

² Pogg. Ann. vol. xlix (1840) p. 595. He says that it is ‘wenig glänzend,’ semi-transparent in thin plates to transparent in the thinnest, with $H=2.5$ and $S.G.=2.622$, and gives two analyses which he afterwards withdrew as incorrect, the amount of water having been much underestimated.

³ In the following works:—(1) Kenngott, ‘Mitth. an Kenngott Uebers. Min. Forsch.’ 1856–57, p. 72, asserts that antigorite can be traced into ordinary serpentine. (2) G. J. Brush, Amer. Journ. Sci. ser. 2, vol. xxiv (1857) p. 128, gives a correct analysis, saying that it proves antigorite to be one of the slaty varieties of serpentine. (3) A. Des Cloizeaux, ‘Man. Min.’ vol. i (1862) p. 110. (4) Naumann, ‘Elemente der Min.’ 1877, p. 579, says that many include it with serpentine. (5) Dr. E. Hussak, Tschermak’s Min. & Petr. Mitth. n. s. vol. v (1883) p. 65, refers antigorite to a pre-existing pyroxene, describing and analysing specimens from Sprechenstein, etc. (6) Prof. A. Cathrein, Neues Jahrb. vol. i (1887) p. 151, adds interesting particulars of Tyrol serpentines, saying that those from augitic rock do not contain chromite or picotite, and quotes Kíspatich as saying (Mitth. aus d. K. Ungar. Geol. Anst. vol. viii, 1886–90, p. 198) that antigorite had come from a hornblende. (7) M. A. Michel-Lévy & A. Lacroix, ‘Les Min. des Roches’ (1888) p. 278, quote Prof. Rosenbusch as attributing ordinary serpentine to the transformation of peridot and amphibole, the leafy forms (bastite and antigorite) to the same pyroxenes, especially the enstatite-family. (8) Prof. F. Zirkel, ‘Lehrbuch der Petrogr.’ 2nd ed. vol. iii (1894) p. 384. (9) Prof. G. Tschermak, ‘Lehrbuch der Min.’ 5th ed. (1897) p. 514. (10) Prof. H. Rosenbusch, ‘Elem. der Gesteinlehre’ (1898) p. 524. (11) Prof. Carl Hintze, ‘Min.’ vol. ii (1897) p. 765, clearly connects antigorite with pressure. (12) M. A. Michel-Lévy, Comptes Rendus, vol. cvi (1888) p. 779, gives, with other minerals, antigorite du Valais, orthorhombic, lengthening or flattening parallel to g^1 , extinction with it 0° , optical sign – ve. (13) The optical properties of antigorite from the ‘Val d’Antigorio’ are mentioned also by Klein, Neues Jahrb. vol. ii (1895) p. 127.

Naumann, Hintze, Lévy & Lacroix, Tschermak, Brush, Rosenbusch, and Zirkel; the last adding to a full and precise description an extensive bibliography. But none of these authorities define the locality more exactly: each, as is not unnatural, being content with stating that the mineral came from the Val Antigorio, though Dr. Hussak and one or two of the later writers have noted its occurrence in other places. I failed, though some time was spent on the search, to obtain any better information from books on Italian geology,¹ or the maps in our Society's Library; moreover, no serpentine is recorded in the Val Antigorio on sheet xviii of the Swiss Geological Survey-map. That, however, hardly amounted to proof of its non-occurrence, because, as this district is in Italy, the map of it would probably be more or less of a compilation.

The completion of the Simplon tunnel has rendered the Val Antigorio so much more accessible than formerly from the valley of the Rhone, that I determined to end my stay in Switzerland last summer by paying it a short visit. I had once walked up it from Domo d'Ossola on my way to the Val Bedretto by the San Giacomo Pass, and had no recollection of serpentine,² but that was so long ago as 1860, and before I paid any particular attention to rocks; though, as it happened, I had shortly before obtained my first specimen of antigorite-serpentine in the neighbourhood of the Viso, taking it then as a singular instance of 'a serpentine-schist.' Again, in 1883, I had crossed from the Rhone Valley to the Tosa Falls by the Gries Pass, returning by the Hohsand Pass and the Binnenthal, without noting serpentine; but this brought me only into the Val Formazza, as the upper part of the Tosa Valley is called, the name being changed without any geographical reason into Val Antigorio at a little village called Passo.³ The latter title is dropped and that of the Val d'Ossola assumed at the junction of the Val di Vedro (down which runs the Simplon road and railway).⁴ On the same side, about 10 miles higher up, the Val Devero comes down from the Geisspfad Pass (leading to Binn), and about 2 miles below the Val di Vedro, that is, a little above Domo d'Ossola, the Val Bognanco descends, not from the watershed of the

¹ Dr. S. Traverso, 'Geologia dell' Ossola' Genoa, 1895, does not mention antigorite or the occurrence of serpentine in the Val Antigorio, though giving several localities in tributary valleys (including the Val Vigezzo) where that rock and even peridotites occur. Owing to a singular oversight, I did not make acquaintance with this very full account of the geology of the area drained by the Tosa and its tributaries till after my return, which I regret, though it would not have much aided me in my special investigations.

² Serpentine is not mentioned by H. B. de Saussure ('Voyages dans les Alpes' ch. ix), whose description of the scenery and rocks of the Val Antigorio is a model of careful observation.

³ The sketch-map (p. 154) may make the geographical details more intelligible.

⁴ As might be expected, writers differ in the limits assigned to the Val Antigorio. H. B. de Saussure ('Voyages dans les Alpes' 1796) places the upper one at St. Michel, just below the entrance of the Val Devero; W. S. King ('Italian Valleys of the Pennine Alps' 1858, p. 545) carries it a little higher, to about Premia; John Ball ('Central Alps' 1873 edition, p. 250) puts it at Foppiano, 2 miles above Passo. I have followed Bædeker ('Guide to Switzerland') as a trustworthy authority.

Pennine chain, but from a short spur which runs out eastward from the Portjen Grat. On the eastern side, the Val Vigezzo and perhaps the Isorno Valley are the only tributaries of any importance—the mouth of the former being almost opposite to that of the Val Bognanco.

Under the circumstances, I thought that my best chance of running the antigorite to ground was to go up the Val Antigorio from Domo d'Ossola, keeping a sharp look-out for serpentine either as an erratic or *in situ*; and, if no sign of it appeared, to examine the pebbles in the bed, both of the Tosa and of its tributaries, since these

Sketch-map of the Val-Antigorio district.

would show whether any important mass of that rock occurred in the Val Formazza or in the other valleys. The test, though obviously imperfect, is a fairly safe one, unless the outcrop be quite small.

In applying it, I had the kind assistance of my friend, the Rev. Edwin Hill, who about a fortnight before had joined me at Saas Grund, and thus had become as familiar with antigorite-serpentine as with those of the Lizard. A walk about Domo d'Ossola on the evening of our arrival gave some hope of success, for among the pebbles paving its streets serpentine of the Saasthal type is not rare. Next morning we drove up the Tosa Valley to San Rocco,

distant between 17 and 18 miles from Domo d'Ossola. The road, on leaving this town, runs over a stony plain, where also the pebbles gave promise of serpentine, but these were left unexamined for the present; and, after passing the junction with the Simplon road at Crevola, we entered the beautiful Val Antigorio. Here and there the road skirts knolls of a variety of gneiss, now commonly called after the valley: its chief constituents are quartz, white felspar, and rather abundant biotite; its cliffs and its mode of weathering suggest a granite, with a rather irregular jointing on a large scale, but the rock generally exhibits a fairly-definite cleavage-foliation, and is thus extensively quarried, as in De Saussure's time, to make posts, steps, or flags for roofing, fencing, and paving.¹ Gradually the sides of the valley become more craggy, and the alluvial plain by the Tosa narrows away on approaching the mouth of the Val Devero, the torrent from which rushes through a fine, though not very deep, gorge below Baceno, a townlet picturesquely perched on a headland between the two valleys. Beyond this, after passing through Premia, we enter the grander part of the Val Antigorio, with its magnificent crags, frequent waterfalls, and rich vegetation.²

At San Rocco,³ about half a league below Passo, the bed of the valley (perhaps a quarter of a mile wide from cliff to cliff) is fairly level, and thus boulders and pebble-beds are not unfrequent by the riverside. Here we began our examination, walking up the road for about 3 miles, nearly to Rivasco, examining the outcrops of rock and the huge fallen masses, now abundant by its side, and making our way at intervals (six or seven times in all, including once just below San Rocco) to promising places by the river. We saw nothing from the road but Antigorio gneiss, and it formed the great majority of the pebbles and boulders, a few being pressure-modified diorites, and a still smaller number a greenish granitoid rock. Not one was serpentine, from which I infer this rock to be either absent from, or very rare in, the Tosa Valley above Premia.

We had now to ascertain the quarter from which the lower part of that valley had received pebbles of serpentine. Early next morning we left San Rocco, and after crossing the Devero torrent came to a spot at the foot of a slope by the roadside, where, on the previous day, I had noticed a few blocks of serpentine (the last

¹ That is to say, it is petrographically a gneiss, but is no doubt a pressure-modified granite. It is very fully described by Dr. S. Traverso in his 'Geologia dell' Ossola' 1895, pp. 59-69; also by Prof. H. Schardt, Archives des Sciences Physiques & Naturelles, ser. 3, vol. xxx (1893) p. 484.

² The band of white marble shown in the Swiss map near Premia was not visible by the roadside; but I found the rock next day both on heaps of road-metal and among the river-pebbles near Domo d'Ossola, nor was the Oberer gneiss with the micaceous variety containing unusually large garnets, of which I got specimens in 1860, at all well exposed (for a description see S. Traverso, *op. cit.* pp. 49-57). This gneiss differs considerably in aspect from the Antigorio gneiss, and reminded me of one variety common in the Saasthal.

³ Here, it may be mentioned, the Albergo Vescei affords very fair accommodation.

visible).¹ As at least a dozen were scattered over the few yards from which the surface-soil had been partly removed, and two or three of them were almost in contact, I infer that a fair number must be concealed by the vegetation. The blocks were angular or subangular in form, varying in diameter up to about half-a-yard, and the rock very closely resembled much of that in the Saasthal, being of a fairly dark-green colour, slightly mottled with blacker spots, so tough and hard that satisfactory specimens were difficult to obtain. It was but slightly schistose, developing under the hammer an irregular jointing. Under the microscope the rock is found to consist of antigorite, a residual augite, and an iron-oxide. The first needs little more than mention, as it resembles much of that described in our paper of 1905: it is practically colourless and non-pleochroic in a thin slice; it occurs in flakes, with hardly an approach to orientation and rather variable in size, the largest being about .025 inch in length, but most of them not exceeding the half of this. The augite, forming about one-eighth of the rock, occurs in irregular grains or granules, often with a slightly 'dusty' aspect, the former sometimes giving, for a space of about a fiftieth of an inch, fairly uniform polarization-tints, sometimes broken up, perhaps by pressure, into differently-coloured granules. The mineral is in process of conversion into antigorite, for it includes or is pierced by flakes of the latter, which bear no relation to the cleavage-planes in the few cases where these can be detected. The iron-oxide occurs in sporadic granules and irregularly-outlined grains, occasionally pierced by small flakes of antigorite. Examined by reflected light they have a general resemblance to magnetite, but the lustre seems to me not quite so bright as is usual; so possibly they are chromite or ilmenite.

Evidently these blocks are relics of the glacier which formerly descended the Val Devero—part of a scattered lateral moraine on its right bank. At the head of this valley the map records an outcrop of serpentine, measuring about 2500 yards from east to west, and 1500 yards from north to south, the apparent thickness of which is said to be 'several hundred feet'.² This is crossed by the Geisspfad Pass (8365 feet) from Binn to Baceno. Some years ago my friend Mr. J. Eccles, F.G.S., kindly gave me two specimens of this rock. These consist mainly of an acicular green hornblende embedded in talc. But as the former mineral indicates pressure-metamorphism,³ and a schistose serpentine may be altered into a talc-schist,⁴ and as they were obtained near the junction with gneiss on the Swiss side, they are probably abnormal; for according to Dr. Preiswerk's account of the mass, to which I shall again refer, the bulk of it, which on the Italian side breaks up into separate sill-like intrusions, must often resemble the above-described

¹ The place was nearly opposite the actual junction of the Devero torrent with the Tosa and at least 100 feet (I forgot to take a note) above it.

² John Ball, 'Central Alps' p. 254 (ed. 1866).

³ Quart. Journ. Geol. Soc. vol. xlix (1895) p. 94.

⁴ Geol. Mag. dec. iii, vol. vii (1890) p. 540.

rock. But the number of the boulders shows that there must be other outcrops in the Val Devero; and Dr. S. Traverso¹ states that serpentine occurs, among other localities, on the Pizzo del Cervandone, where it is said to contain both unaltered olivine and asbestos.

We had next to determine whether any quantity of serpentine was received from the Val Bognanco and the Val di Vedro, the streams from which, at their junction with the Tosa, are only about three-quarters of a mile apart, and thus, as their fans are practically continuous, a boulder brought down even by the former might very well be reckoned as occurring in the Val Antigorio. After returning to Domo d'Ossola, we examined the stony plain deposited by the torrent from the Val Bognanco, the main channel of which must, I think, have formerly flowed to the south of its present position. Here water-worn fragments of serpentine were abundant: the larger (some 15 or 18 inches in diameter) more angular than the smaller, which were often flattened ellipsoids in shape; and the rock varying in structure from fairly massive to rather schistose. It was in fact indistinguishable from that so common in the upper part of the Saas Valley. Besides these, we found a few pebbles of a rock consisting of a fibrous green hornblende and rather saussuritic felspar, bearing some resemblance to one variety of the noted euphotide from the Allalin Glacier, and many of gneiss, which, however, generally was not of the 'Antigorio' type.

From this we went on to an extensive pebble-bed on the right bank of the Doveria torrent, and thus part of the fan from the Val di Vedro. Here serpentine was almost rare, and I saw only one pebble of the euphotide just mentioned, but the Antigorio gneiss was much more abundant, other varieties also occurring. The Swiss map shows two rather small outcrops of serpentine in the Val Bognanco,² and none in the Val di Vedro; but I think that the facts stated above justify the conclusion that this rock must occupy a considerable area in the former, and may even have a few small outcrops in the latter valley; though we must not forget that the Tosa, when in flood, might contribute some pebbles to the stony plain which is usually the 'dumping-ground' of the Doveria.

After this we crossed the Tosa above Domo d'Ossola, where it is divided into three or four channels, and examined the pebbles on an island very near its grass-grown eastern bank. This, under ordinary circumstances, must be out of range of the two above-named streams, but some stones might have come from the Val Devero, or have been brought by the tributary from the Val Vigezzo (which we were unable to visit). Here pebbles of serpentine were not very common, but of the usual types; we also found some of a white or greyish marble, occasionally micaceous, representing that already mentioned; a few of the hornblendic euphotide; a fair amount of the Antigorio gneiss with some other varieties, and sundry

¹ 'Geologia dell' Ossola' 1895, pp. 169-71.

² Scale $\frac{1}{100,000}$. In Dr. Traverso's map (scale $\frac{1}{250,000}$) there are at least four, one being crossed by the torrent not far from the mouth of the valley.

crystalline rocks, including that called *grüner schiefer* by the Swiss geologists. I have examined under the microscope a specimen of serpentine from the Val Bognanco, and another from the shoal near the left bank of the Tosa, which might possibly have come from the Val Devero, but more probably from the Val Vigizzo, selecting the one to represent a moderately schistose variety, and the other one of the most schistose. The former rock is of a rather light greenish-grey colour, with small dark mottling. Under the microscope it is seen to consist of matted antigorite, the flakes seldom, if ever, exceeding $\cdot 007$ inch, and showing sometimes 'thorn-structure,' sometimes a slight parallelism. The only trace of augite consists of 'cloudlets' of minute granules, seeming, with ordinary light, like a dust, only a very few of which show a fairly bright-yellow tint with crossing nicols. The iron-oxide is much as is described above. The other specimen, rather conspicuously schistose, is of a greyish-green colour, slightly mottled with dark; under the microscope it is seen to consist of antigorite, with a little residual augite in aggregated granules, which often have a more flaky aspect and lower polarization-tints than is usual (perhaps from incipient decomposition), and with magnetite, both obviously crushed. The antigorite is small, seldom, if ever, exceeding $\cdot 004$ inch, and shows a foliated structure, though not quite so conspicuously as I had expected. Enough to say that these serpentines of the Tosa valley, in both megascopic and microscopic aspect, so closely resemble those with which I was already familiar in the Vispthal, that I could not distinguish them, if without labels.

We see then that antigorite-serpentine, probably derived from an augite-olivine rock, is abundant in the region west of the Tosa from Foppiano to Domo d'Ossola, and is found in the Val Vigizzo,¹ but its occurrence *in situ* in the Val Antigorio itself is very doubtful. Thus the original specimen may have been obtained, either from an erratic in the lower part of that valley, or from an actual outcrop in a tributary one (such as the Val Devero or the Val Bognanco), to which the name of the main valley has been rather inaccurately attached. The proof of its absence from the Val Antigorio is obviously not complete, but could only be made so by long and laborious work, for which I have now neither the strength nor the inclination, and I am content to leave the task to members of the Italian Geological Survey.

II. OTHER ANTIGORITE-SERPENTINES.

Since the publication in November 1905 of the paper by Miss Raisin and myself, I have obtained some more information on antigorite. About a year ago, Dr. J. M. Bell, Director of the New Zealand

¹ Here, according to Dr. Traverso ('*Geologia dell' Ossola*' 1895, pp. 166-169), peridotites also occur.

Geological Survey, kindly sent me a copy of its 'Bulletin,' which contained a description of some serpentines and other rocks (designated the Pounamu Formation), illustrated by unusually good and large figures of microscopic sections.¹ Two of these, entitled 'an altered olivine-rock' and 'a serpentine-schist,' obviously consist of antigorite, although that name is not used; indeed it would be impossible to have a finer or more characteristic representation of the mineral than the former one affords. Dr. Bell states that these rocks must originally have been peridotites and 'are generally massive, though sometimes fairly schistose,' the latter figure representing a variety from a region which has obviously undergone great pressure-metamorphism. Our hopes of meeting during his recent visit to England were unfortunately frustrated, but I received just before completing this paper a box containing about a dozen fine specimens of dunite, serpentines, and allied rocks, which in accordance with his instructions had been sent to me from New Zealand. Four of these, the most important for my present purpose, I had immediately sliced; but I trust before long to examine the remainder,² and tender my most hearty thanks to Dr. Bell and other members of the Survey for so valuable a gift.

Of those four, the dunite (from the Dun Mountains, Nelson) is a block, measuring nearly $7 \times 5 \times 3$ inches, of greenish-yellow colour, showing occasional blackish and dull-green specks, with a slight cleavage, rudely parallel with the broader surfaces. Under the microscope it is seen to consist chiefly of grains of olivine, very clearly exhibiting interrupted lines of crush, in which serpentinization is incipient; a few of the larger grains show a rather vaguely-defined oscillatory twinning, probably also a result of pressure. A little diopside is present in the slice, as also some rather rounded subtranslucent and deep-brown grains of chromite, or perhaps in some cases picotite. A handsome specimen of an 'actinolite-and-tale rock from a boulder, Clear Creek, Mikonui (Toaroha District),' has a general resemblance to the rock described above (p. 156) from the northern margin of the Geisspfad mass of serpentine; but the actinolites, many of which are rudely parallel, are more numerous

¹ New Zealand Geol. Surv. n. s. Bull. No. 1, 'Geology of the Hokitika Sheet, North Westland Quadrangle' by J. M. Bell & Colin Fraser, 1906. See Ch. viii (the plates are not numbered). The figures appear, with brief descriptions of the slices (without, however, using the name antigorite), in Prof. Sollas's Memoir on the Rocks of Cape Colville Peninsula, New Zealand, vol. ii (1906) pp. 186-202.

² [Slices from these reached me immediately after this paper was read. The following are most nearly connected with it:—(1) 'Ultrabasic rock, Dun Saddle': a dark compact rock, with some rather small bastite, consisting of olivine, more or less serpentinized, bastite, sometimes much altered, (?) diallage (one grain), and picotite. (2) 'Serpentine, Dun Saddle': a dark, rather uniform serpentine, which shows under the microscope a pale yellowish-green tint and the usual 'meshwork' serpentine, marked out by strings of magnetite-granules, with a slight parallelism. There are some small grains of chromite and a few (rather larger) of a more steatitic aspect, possibly indicating the former presence of a pyroxene in very small quantities. Two other interesting specimens are described below.]

and much larger, some being at least an inch long; while the talc, as becomes very plain on microscopic examination, is less abundant.¹

That the other two specimens were antigorite-serpentines was obvious at a glance. One (boulder in Cross River, Mikonui, Whitcome Pass District), a somewhat flat flake, measuring fully 6×5 inches, and about an inch and a half thick, with a slight and rough cleavage oblique to the broader face, is a mottled rock—dark purplish-green, and lighter green, here and there irregularly streaked with a still paler green. Microscopic examination shows it to be composed of antigorite, with a fair amount of residual augite, perhaps a few flakelets of talc, and iron-oxide, with a little sulphide. The antigorite-flakes have a slightly tufted and occasionally somewhat acicular habit, attaining not seldom a length of about $\cdot 03$ inch. There is a fair amount of residual augite, often ‘stabbed’ by the other mineral, which, so far as I can ascertain, is not related to the cleavage-planes of the augite, except that in a few cases, where the remnant is a very narrow wedge, this extinguishes at a rather small angle with its sides. The granules of iron-oxide are irregularly distributed and in one or two places, which are free from residual augite, they suggest the former presence of a ‘mesh-work.’ Of the occasional larger grains, one is distinctly translucent, and of a rich brown colour; others slightly so: thus chromite, or possibly picotite, must be present. The light-coloured streaks mentioned above, when examined with a lens, included a mineral with some resemblance to olivine; but, as a little of the powder showed under the microscope distinct, rather elongated, prisms with a low extinction-angle, it must be a variety of actinolite. The second specimen, from Griffin Range, Hokitika (Turiwate District), is a still larger slab, rather darker in colour, which retains on one side a portion of an external surface with a bright brown tint and a slightly ‘corded’ structure. A slice, cut perpendicular to, and in the direction of, the slight cleavage, proves to be wholly composed of antigorite and iron-oxide; the latter being apparently not very abundant or large in grain, but now and then pierced by the former, to which it locally imparts a rich sienna-brown stain. The antigorite-flakes are smaller, not more than one-third of the length of those in the other specimens, and generally narrower in proportion to their length. Some parts of the slice, where the smallness is rather marked, show an approach to ‘thorn-structure’; others a distinctly tufted grouping, which occasionally is slightly cruciform

¹ A specimen labelled ‘coarse peridotite (Dun Saddle, Nelson), probably with bronzite,’ is crowded with close-cleaved specimens of the latter mineral, sometimes about an inch long or wide. Examination of it, when powdered, leads me to refer the bulk of it at any rate to diallage. [A slice, received since this paper was read, shows that a diallage is the dominant mineral, but there is some enstatite (probably bastite); and, I think, a few grains (sometimes pœcilitic) of a brownish-yellow, slightly-fibrous, obviously much-altered mineral, probably representing a ferriferous member of this group (bronzite or perhaps hypersthene). A grain or two of olivine may be present, with some granules of iron-oxide. I should think it likely that the rock formed dykes or veins cutting the dunite.]

or almost spherulitic: the axes of the former showing some inclination (though it is not very marked) to parallelism with, and perpendicularity to, the direction of the slight cleavage. I have noticed this tendency to an acicular or dagger-like form occasionally in my Alpine specimens; and if either of these two had been given to me as coming from one of the regions mentioned above, I should not have had any suspicions. I may add that among the other interesting specimens is a much slickensided piece of a dark-green serpentine, closely resembling some of those from the Engadine, described below. It comes from Asbestos Creek, Mikonui (Toaroha District). [Microscopic examination shows the resemblance to be as close as possible. The rock consists of serpentized olivine with some grains of chromite and a much altered, close-cleaved mineral, probably once enstatite. In parts it shows signs of fracture under pressure, which has given rise to curving lines of more or less fibrous serpentine, the fibres lying either along or oblique to their direction. Here and there an approach to a rather minute 'thorn-structure' may be detected, but nowhere any thoroughly typical antigorite.]

The Mineralogical Museum at Cambridge contains three specimens of antigorite-serpentine, about which Prof. Lewis and Dr. A. Hutchinson have kindly supplied me with information. Two are in the Wiltshire Collection (presented in 1897), one purchased from Foote, the other from Baldon; both being labelled 'Zermatt, Switzerland.' I have little doubt that they were obtained near the well-known tarn (about 9000 feet) at the base of the peak of the Riffelhorn.¹ The third specimen has been for many years in the Museum, and its locality is not known; but it is so like the others that it might well be from the same place.

The result of my journey led me to re-examine the specimens in the Mineral Collection at the British Museum (Natural History), and to enquire more particularly into their history, and I gladly take this opportunity of thanking Mr. L. J. Spencer for his kind assistance. They are as follows:—(1) A pale-green slab measuring about 6 by $4\frac{1}{2}$ inches, rather thin, but opaque, purchased from F. H. Hoseus, mineral-dealer at Basel, in 1871: his label gives Maderanerthal (Switzerland), which is corrected in Mr. Fletcher's handwriting to Zermatt. It might very well have come from the base of the Riffelhorn or the neighbouring part of the Gorner Grat. (2) A flake, $2\frac{1}{2}$ by 2 inches, transparent green, without any black mottling; one of the Allan-Greg specimens received in 1860 without number, and entered in an appendix by the late T. Davies to the catalogue of that collection as: 'Antigorite, Antigorio Valley: this also much resembles Riffelberg specimens. (3) A thin oval slab, $5\frac{1}{2}$ by nearly $3\frac{3}{4}$ inches, polished on both sides, translucent in parts, rich green mottled with dark: entered under date 1829 (Allan-Greg Collection) as 'noble serpentine' without locality, to which T. Davies has

¹ See my paper, *Geol. Mag.* dec. iii, vol. vii (1890) p. 533.

added 'Antigorite, Antigorio Valley.' (4) A thin polished slice, resembling the last in translucency and colour ($2\frac{1}{2}$ by $2\frac{1}{4}$ inches), probably acquired before 1837: registered by T. Davies as 'Antigorite, Antigorio Valley.' (5) A box, with a lid, made of thin polished slabs cemented together, $3\frac{3}{4} \times 1\frac{3}{4} \times 1\frac{1}{2}$ inches; material similar to the last two: this specimen has the same history as No. 4. (6 & 7) Two paper-knives, mounted in wooden handles, material similar to that of other polished specimens; entered, under date 1831, as 'noble serpentine,' with the remark 'This substance occurs in boulders on the shore of the Island of Ischia near Naples.' As I have never landed on Ischia, I cannot say more than that it is one of the last places in which I should have expected to find serpentine of this type.

I regret to say that, when writing my note on the microscopic section made in 1905,¹ I supposed it to have been cut from No. 2, to which the megascopic description applies. But I now find that it represents No. 4, a small portion of which was ground down to the requisite thinness. A second study of this slice has made me less confident about the very few and very ill-preserved pyroxenes being enstatite. I was led to this conclusion by observing traces of a parallel cleavage (with straight extinction) in one or two grains, but have found in specimens from the Saasthal (sliced since those words were written) that occasionally the larger flakes of antigorite (formed from grains of diallagitic augite somewhat bigger than the rest) locally arrange themselves, side by side, so as to present, with their straight extinction, a rather close resemblance to a serpentinized enstatite.² In any case, whether these mottled rocks were originally saxonites, lherzolites, or augite-olivine peridotites, it is evidently uncertain from what localities they were obtained.

During our stay at Saas Grund last summer, we examined (as I had done on previous occasions) the boulders of serpentine which abound in the moraines of the Fee Glacier and on the bed of the main valley between that village and the Mattmark Inn.³ Near the latter they are exceptionally numerous in two places: one, just at the lower end of the Mattmark See, where the path crosses a slope of broken rock, mostly a fissile antigorite-serpentine, which very probably formed part of the right moraine of the Allalin Glacier, when the ice extended across the river⁴; the other, a short distance above the inn, where the gigantic 'Blauenstein,'⁵ with its two associates, one of

¹ Quart. Journ. Geol. Soc. vol. lxi, p. 700.

² The structure of one grain, I may add, rather resembles that of olivine, though the strings are not marked out by iron-oxide.

³ See the paper by Miss Raisin and myself in this Journal, vol. lxi (1905) pp. 707-709.

⁴ As it did in 1860.

⁵ For a figure, see E. Whymper, 'A Guide to Zermatt & the Matterhorn' 7th ed. (1903) p. 189; J. de Charpentier ('Essai sur les Glaciers' 1841, p. 252) states that in 1821 old men were still alive, who had heard their fathers say that they had seen it 'sur le dos du glacier.' As the size has been variously stated, I may say that I measured it roughly in 1891, and found the length to be 58 feet, the breadth 50 feet, and estimated the height as about equal to the length.

which would elsewhere be considered very large, and a host of smaller blocks, represent a scattered moraine of the Schwarzenberg Glacier. In 1905, I described a slice from the least of the trio and this year managed to detach from the Blauenstein itself a loose fragment just big enough to furnish a slice. The rock consists of antigorite, with a fair amount of residual augite in granules suggestive of crushed grains, and some iron-oxide and sulphide. One portion of the slice shows rather distinctly a 'puckered' foliation. Thus the rock has undergone pressure, though it is not now at all fissile. I had neglected to carry away specimens of the Allalin moraine, but that defect was kindly remedied by my friends, Messrs. J. J. Lister, F.R.S., and R. H. Rastall, F.G.S., who brought me three good cabinet-specimens: one barely, another moderately, and a third very fissile, and slightly puckered. A slice from the second shows, as I was certain would be the case, that it is rich in antigorite, much of it small and with a foliated aspect. It also contains a little residual augite and some iron-oxide suggestive of crushing.

I again visited the great dyke of fissile serpentine¹ which cuts calc-mica-schist on the western flank of a mound on the Fee Alp, to which the figures 2136 metres (7081 feet) are attached. It is marked on sheet xxiii of the Swiss Geological-Survey map, but I think that the breadth is rather exaggerated.² Its junction with the calc-mica-schist was not well exposed on the more northern side, but on the southern it was clearer; and, notwithstanding much crushing and an oblique fault, it still remained unbroken for 2 or 3 feet, showing a good weld with a slightly wavy surface. The serpentine also completely overarched a mass of much contorted calc-mica-schist about a couple of yards wide and a little more in height,³ the more northern side of which apparently exhibited a slight interlamination of serpentine and the schist, as if the former had thrust a tongue or two into the latter and both had been crushed out together. On the other side a little wedge of the schist was isolated in crushed serpentine; also a small patch of serpentine, measuring about 2 by 3 inches, still adhered to the face of the included mass of calc-mica-schist. I have no recollection of having seen the latter, either in 1891 or in 1901, and the notes then made differ in some details from what we saw last summer, so I think that the face of the cliff must have been changed in the interval by falls of rock. The serpentine again crops out, after being concealed beneath turf, scree, and moraine, on the steep rocky slope descending to the northernmost arm of the Fee Glacier. Here it is, if possible, yet more crushed, and the junctions are masked.

Another and much greater mass of serpentine occurs on the same 'buttress of an alp' at a considerably higher level. This is the Langefluh, a broad promontory of rock, about two-thirds of a mile in length, running almost north and south between the arms of the Fee Glacier, and rising ultimately to a height of 2875 metres

¹ The microscopic structure is described at p. 709 of vol. lxi of this Journal.

² In the face of the cliff it was perhaps more than 20 yards broad, but the section may be oblique.

³ This statement is from memory; I forgot, at the time, to record the figures.

(9433 feet), with a precipitous eastern face, up which a narrow path leads obliquely from the Fee Alp. The whole, so far as I could see,¹ is serpentine, rather fissile where first traversed, but afterwards generally massive. This is of the usual rather dull-green colour, mottled with darker patches (the fissile specimens being of a paler tint, no doubt from incipient weathering), and the exposed surfaces are changed to a fawn-brown colour. In fact, the blocks so abundant in the moraines of the Fee Glacier, specimens of which were described in 1905, represent either this mass or some part of the Allalinhorn (13,235 feet) of which it may be a spur. The rock is considerably harder and tougher than the ordinary bastite-serpentine, and as the surface is everywhere rounded by ice-action, it is difficult to obtain well-shaped specimens. I took samples:— (1) at the spot where I turned back (probably about 200 feet below the highest point); (2) from about half-way between this and the place where the path reaches the top of the cliff; and (3) from the fissile part, near its base.

The first (1) consists of the following minerals:—antigorite in rather irregularly matted flakes, seldom exceeding .005 inch in diameter—those in one or two little patches being distinctly smaller than the rest. A few minute granules giving bright polarization-tints may be residual augite, but occasionally bear some resemblance to talc. One or two grains of fair size and irregular outline, of a very pale warm-brown tint, show a close parallel cleavage, extinguishing parallel to it with crossed nicols and giving in other positions a dull but rich blue colour; flakes of antigorite sometimes pierce these grains, sometimes lie between their cleavage-surfaces. A mineral presenting a resemblance to this occurs in one of the Anglesey serpentines,² where I think that it represents a member of the enstatite-group. The second (2) consists of a similar antigorite, but with some residual augite, pierced and often 'riddled' by flakes of the other mineral, which, to judge from the polarization-tints, may have formed grains about 0.1 inch in diameter. Granules of iron-oxide and sulphide are rather numerous, but irregularly distributed, being often apparently associated with the augite and probably showing signs of crushing. The third, not the most fissile variety of (3), consists of antigorite and iron-oxide (hardly any sulphide) as above: both exhibiting a more definite foliation, and the latter occurring in more distinct layers, which suggest here and there the crushing-out of grains, and sometimes impart a brown stain to the neighbouring serpentine. No residual augite is visible.

It is rather remarkable that none of the specimens prepared either for this or for our former paper contain any residual

¹ Want of time obliged me to turn back near the foot of the rocky mound at the upper end.

² That from near a quarry south of Cru-Glas, Quart. Journ. Geol. Soc. vol. xxxvii (1881) p. 45.

olivine.¹ In a few the matted antigorite is traversed by tiny strings of opacite resembling those in a serpentine formed from that mineral, or it occupies small spaces in one of the larger grains of pyroxene, suggestive of poecilitic olivine; but that antigorite can be produced from olivine seems to be certain. Dr. F. Becke, in his valuable paper on 'Olivinfels & Antigorite-Serpentine' from the Stubachthal,² distinctly states that the unaltered rock consists of olivine and picotite, sometimes with a diopside. It shows signs of a cataclastic structure, and flakes of antigorite can be seen in the cracks of the grains of olivine, separating them into granules, but not forming so characteristic a meshwork as in the ordinary process of serpentinization, while in other parts of the mass the change to an antigorite-serpentine is complete. Dr. H. Preiswerk³ also, in his concise and interesting account of the serpentine at the upper part of the Geisspfad Pass, says that the mass in its central portion is a dunite, though it contains diallage towards the periphery, where it occasionally becomes almost a diallagite. Antigorite is produced from both its minerals, but seems to come more directly from the pyroxenic constituent, and a little actinolite is a usual alteration-product.⁴ Again, Dr. J. M. Bell in his reply, dated December 7th, 1907, to an enquiry about the specimens of antigorite-rock, forwarded to me from New Zealand, says:

'I feel confident that the parent rock was mainly olivine, with perhaps a little pyroxene, either orthorhombic or monoclinic. One gets apparently the transition of this rock into dunite.'

In No. 3 of the Bulletin ('The Geology of the Parapura Subdivision, Karamea, Nelson'), for which I am also indebted to him, serpentines and talc-schists (sills and perhaps dykes) are described (Ch. ix), which break through highly metamorphic strata and may possibly be of Haupiri (? Devonian) age. The former consist chiefly of antigorite, with minor quantities of talc, chromite, etc.; the latter, no doubt a further stage of alteration, due partly to pressure, pass

¹ Last autumn, a friend suggested to me that some clear sienna-brown grains, in a slice from a specimen obtained on an old moraine near the Findelen Glacier, were titanolivine. As his experience is large and that mineral has been obtained in this district, I have again examined not only that slice, but also the others with residual pyroxene. The form of the grains, however, is more suggestive of augite than of olivine; a rudely shaped prism may be tinted at one end, clear at the other; the pleochroism seems hardly strong enough for titanolivine, and the extinction in both coloured and uncoloured grains is oblique and like that of augite. Hence I think the former only a result of staining (see our paper of 1905, p. 706).

² Tschermak's Min. Petr. Mitth. n. s. vol. xiv (1894-95) p. 271.

³ Eolog. Geol. Helvet. vol. vii (1901-1902) p. 123.

⁴ R. von Drasche, Tschermak's Mineral. Mitth. p. 1, in Jahrb. K. K. Geol. Reichsanst. vol. xxi (1871), describes the formation of antigorite (without, however, using the name) from an olivine-rock. The Cogne serpentines (see Quart. Journ. Geol. Soc. vol. lix, 1903, pp. 58-60) on the whole favour the formation of antigorite from olivine.

into the former, and evidently are generally similar to some that I have described from the Alps.¹ Both, it is said,

'have apparently resulted from the alteration of some olivine-rock, most probably dunite, as judged by the presence of chromite in greater or lesser quantity' (p. 66).

Some, however, of my specimens, as described in 1905,² exhibit very clearly the direct production of antigorite from augite, and prove that the latter mineral must have been so abundant in the original rock as to make it an olivine-augite rock, like some of that in the Vosges, where the pyroxenic constituent occasionally dominates.³ It must also have been very closely related to the hornblende serpentines from the Lizard coast between Mullion and Lower Predanack,⁴ besides the well-known one from the Rauenthal⁵ (for hornblende and augite are practically isomorphous), and in all these the monoclinic constituent is occasionally more abundant than the olivine⁶; and that there was a like excess in some of these specimens of Alpine serpentines appears, from the abundance of the residual augite in the slices, to be very probable.

That this mineral is converted into antigorite more readily than olivine seems, however, fairly certain. When I saw, now several years ago, the bastite-serpentines in the Eastern Grisons and the Mont Genève district, I naturally took my specimens from the parts least affected by pressure, and thus had hardly any material for studying its effects. From this difficulty I was relieved by Miss Raisin, who very kindly halted on her way to Pontresina last September to examine the serpentines near the Julier road, and has provided me with an ample supply of specimens from the crushed parts of outcrops east of Tiefenkastell, the Val da Faller, and by the Silser See.⁷ These are seen at a glance to be very different from the antigorite-serpentines. Pressure makes the latter fissile, converting them, when it has been very severe, into slabs or even slates, as already described, but it breaks up these bastite-serpentines into lenticular masses, more or less irregular in form. Their exterior is covered by a lustrous dark-green film, showing slickensides, but when the rock is broken across its character is comparatively normal, and flakes of bastite can sometimes be detected.

I have examined slices from seven of the most promising specimens. They come from an outcrop near the Silser See at the head

¹ Geol. Mag. dec. iii, vol. vii (1890) p. 533, & dec. iv, vol. iv (1897) p. 110.

² Quart. Journ. Geol. Soc. vol. lxi (1905) pp. 706-12; also several specimens collected since the reading of that paper.

³ *Op. cit.* p. 697.

⁴ This variety occurs at other localities on the peninsula. See this Journal, vol. lii (1896) p. 46.

⁵ Geol. Mag. dec. iii, vol. iv (1887) pp. 67-69, & Miss C. A. Raisin, this Journal, vol. liii (1897) p. 246.

⁶ It is also noteworthy that the hornblende-serpentine at the Lizard is distinctly harder to break and rougher to the touch than the ordinary bastite-serpentine.

⁷ Described in my paper, Geol. Mag. dec. ii, vol. vii (1880) p. 538.

of the Inn Valley, and from three localities connected with the upper valley of the Oberhalbstein Rhine, namely, at Salux, in the Val da Faller, and from near the high-road south of Tiefenkastell.¹ Of two specimens from the first place, both exhibit serpentinized bastite and traces of olivine (in the characteristic meshwork); they contain here and there a rather fibrous variety of serpentine, often with a slightly tufted habit (? chrysotile or picrolite), which in one specimen assumes a more flaky character, and thus approaches antigorite. In the Val da Faller the serpentine occurs in four masses, three dyke-like and the fourth more irregular in outline, having probably one outlying patch. Of specimens from these, the first, in one case, shows the meshwork indicative of former olivine, altered bastite, and some augite, none of the serpentine having the antigoritic habit; another specimen affords little evidence of the original minerals, and is becoming talcose, but the serpentine, when not of the usual habit, is at most fibrous. The second mass shows serpentinized olivine and enstatite, the latter retaining traces of the usual cleavage, but almost inert to polarized light except at the edges, where it has some little resemblance to antigorite. There are also some irregular grains of augite. Fibrous serpentine is rather commoner than usual, but typical antigorite is not present. A specimen from the third mass retains traces of altered olivine, but though evidently much crushed, even to showing some 'crumpling,' it does not contain antigorite. A flaky specimen (9 feet from the junction) of a probable outlier of the fourth mass, exhibits under the microscope a felted, somewhat foliated aggregate of a serpentinous mineral (rather minute), in which are small acicular prisms of a mineral with much the same refractive index, but higher polarization-tints and a rather large extinction-angle. If the former represent antigorite, it is very abnormal. A flattish, rather fissile flake, about as hard as the finger-nail, 'from N. of Salux,'² consists mainly of a rather minute and fibrous mineral, with grey polarization-tints, and a felted-foliated structure, which is probably nearer to steatite than true serpentine; but an uncut specimen resembles a normal olivine-serpentine, and may retain traces of bastite. Of three specimens from the mass near the village of Rofna (south of Tiefenkastell³) on the Julier road, one, though crushed and veined, retains some indications of altered olivine, has recognizable bastite, and is unusually rich in an iron-oxide (probably chromite); another contains some altered bastite, locally darkened with granules of magnetite, and suggests the former presence of olivine, but is traversed by some rudely parallel veins, occupied by a fibrous serpentine (? picrolite) arranged at right angles to their general direction, which occasionally exhibit a slight approach to the mica-

¹ For further particulars, see Geol. Mag. *ut supra*. I restrict, for the sake of brevity, the present notice of microscopic structures to those germane to the purpose of this paper.

² On the western slope of the Oberhalbstein valley, between Molins and Tiefenkastell.

³ Geol. Mag. dec. ii, vol. vii (1880) p. 539.

like habit of antigorite. The third consists of a mass of acicular flakes with a general parallelism and slightly wavy structure, a few of which have a higher refractive index than the rest. This approaches nearer to the antigorite exhibited in very fissile specimens, but cannot be called a satisfactory example of that mineral.

Thus the evidence of these specimens of crushed bastite-serpentine from the Rhaetian Alps seems at first sight unfavourable to the very clear and precise statements of Becke and Preiswerk. We may perhaps offer the following explanation of the discrepancy. When a peridotite rich in olivine (for instance, dunite) is acted on by pressure,¹ it becomes slightly slabby, and microscopic examination shows that mineral to occur in grains, rather variable in size, with some little approach to a parallel ordering; in other words, the rock shows signs of a crush-structure. Turning to the antigorite-rocks of the Alps, we find that some of these exhibit, by means of the residual augite, clear indications of having been more or less crushed. The flakes of the antigorite in some cases are arranged at right angles to the pressure, but in others they lie at all angles, and are even 'matted' together. In the latter cases the development of antigorite seems to have made the rock as a whole more solid; while in the former, as the fissility increases, the size of the flakes diminishes.² I infer, then, from examination of the specimens in my collection, that, in the case of many, an augite-peridotite was first more or less crushed; next, the comminuted parts (most of the olivine and some of the augite) were converted (still under some pressure) into antigorite, which change often had the effect of making the rock less fissile than it had been. By the renewal of severe pressure, the layers of residual augite and of antigorite might be folded, or, if the former mineral had disappeared, the mass might be rendered very fissile, with diminution of the size of the constituents, as we find in the most 'slaty' antigorite-serpentine. In other words, owing to the comparative uniformity of the rock, pressure acts upon it as on any other nearly homogeneous mass, and produces a very conspicuous cleavage. In the latter case, then, the stages are: (1) augite-olivine rock, (2) the same somewhat cleaved, (3) antigorite-rock, comparatively massive, and (4) antigorite-'slate' (consequence of renewed pressure). Thus many of the antigorite-rocks, described in this paper, are, speaking in general terms, in the third stage, while others are intermediate between it and the fourth, which is completely reached by the most fissile specimens.

But a peridotite, whether with augite or enstatite, or with both these minerals, which has been converted into a serpentine like that in the Rhaetian Alps, has in consequence become brittle; hence, under pressure, it forms a 'crush-breccia' with fragments of various shapes, irregularly angular, as well as lenticular. These,* if the

¹ I have examined specimens from New Zealand and from Norway.

² Gornier Grat, Fee Alp, Col de Vallante, etc. The same thing occurs commonly in mica-schists, which may be so crushed as to be distinguished with difficulty from ordinary phyllites.

pressure be continued, slide one over the other¹ and thus often elude much further crushing.² In the last extreme an antigorite-serpentine may perhaps be produced, but then it will be of the most 'slaty' type.

Thus these later observations confirm the opinion founded on work done before the summer of 1905, namely, that while antigorite apparently forms with greater facility from augite than from olivine, pressure is a most important factor in its production,³ and this should come into play before the minerals have undergone much alteration. Enstatite, while forming a mineral rather of the antigorite-type, seems, if uncrushed, generally to retain some distinctive characteristic; so that I think we cannot, as has been suggested, place it nearly on the same level with augite as the parent of the mineral, named with dubious authority from the Val Antigorio.⁴

III. NOTE ON BOWENITE.

The above-described studies led me to re-examine some miscellaneous slices of serpentine in my cabinets, among which was one of bowenite given to me by the late General McMahon, soon after writing his paper on that mineral—or rather rock—from Afghanistan.⁵ The microscopic structure, as it differed much from that of the serpentines on which I was then occupied, had escaped my memory, but on looking at it recently, I was surprised at its resemblance to antigorite. Needless to say that my late friend's description is accurate, though perhaps in the specimen before me flakes are more numerous than fibres,⁶ which, however, may be due to my being practised in identifying the former: also, though I occasionally see three directions of orientation for the flakes, only one seems to me definite enough to be suggestive of a cleavage. In other words, I note here and there a group of flakes—running up to about .02 inch in length—lying parallel with and near one another—suggesting the former presence of a diallage or a bastite. At high (not always right) angles with these are occasional shorter flakes, or groups of such, parallel one with another, while some parts of the slice show 'thorn-structure' on a smaller scale, as described in our paper of 1905. Scattered about the field are a few needles or flakes with a higher refractive index than those forming the groundmass, though not yielding brighter polarization-tints.

¹ The surfaces are so completely slickensided that a new fracture must be made to show the rock.

² That is the reason why very fair specimens of the normal rock can often be obtained from the middle part of an Alpine mass, the outer crush-zones having acted like a 'packing' of shavings or sawdust to the rest.

³ Quart. Journ. Geol. Soc. vol. lxi (1905) p. 714.

⁴ Without marked pressure olivine changes into ordinary serpentine more readily than enstatite, and that than augite (perhaps also than hornblende). To produce antigorite pressure seems essential, and this apparently makes augite pass into that mineral more readily than into ordinary serpentine in the other case.

⁵ Min. Mag. vol. ix (1890) p. 187.

⁶ The flakes, however, not unfrequently are rather dagger-shaped.

Still, I think them indicative of actinolite or partly-altered residual pyroxene. As we find only very slight traces of any ferriferous constituent, I would suggest the possibility of the rock having originally consisted almost entirely of an augite akin to diopside (like some which occur in Canada) rather than, as my late friend suggested, an olivine-rock from which the iron has been leached out.

DISCUSSION.

Dr. J. S. FLETT congratulated the Author on having traced the antigorite-serpentine of Val Antigorio to its source. These rocks were full of interest, though rare. Very few examples occurred in the British Isles: the speaker had met with some in Perthshire accompanying the great epidiorites that go with the Loch-Tay Limestone; he had also seen specimens which were believed to come from Shetland, and were as perfect as any that the Author of the paper had exhibited on this occasion. In Unst and Fetlar, in the extreme north of Scotland, there were large masses of serpentine known to geologists through the descriptions of Hibbert, Heddle, Peach, and Horne. In Balta Sound and Haroldswick the Unst serpentine was intersected by many veins of pyroxenite. The whole complex had been sheared, and in these veins antigorite was developing from the pyroxene, which corroborated the Author's views as to the origin of this mineral.

Mr. J. ALLAN THOMSON instanced a case of pseudomorphism of olivine by an antigorite-like mineral in the hornblende-peridotite of Greystones. It differed from true antigorite in possessing a very faint pleochroism and higher birefringence. The Author had concluded in his former paper that these properties, which he had sometimes found in minerals accompanying antigorite, were accidental. They might, however, be explained on Prof. Tschermak's hypothesis of the composition of the orthochlorites as solid solutions of the antigorite- and amesite-molecules. Dr. Weinschenk considered iddingsite as a pleochroic antigorite.

The interesting point about the pseudomorph was that the antigorite-flakes lay parallel to the clinodomes of the olivine, which met at an angle of about 60° . The resulting 'gitter'-structure might easily be confused with the lattice-structure of serpentine derived from a non-aluminous amphibole. Dr. Weinschenk had described the same phenomena in the olivine of the Stubach serpentine, and considered the antigorite as an original mineral intergrown with olivine by 'piezocrystallization.'

The AUTHOR said that he was much interested to hear from Dr. Flett that antigorite-serpentines had been found in Shetland, and should look forward to reading the account of them. The replacement of olivine by antigorite, in the case described by Mr. Thomson, was remarkable; but he thought that any definite relation between the flakes of the latter and the crystal-figure of the former mineral was very rare. He thanked the Fellows present for having listened so patiently to a statement which had taken more time than he had anticipated.