Gümbel has figured a somewhat similar variety from the nummulitic series of Kressenberg, Bavaria, which he has referred to d'Archiac's *Operculina canalifera.*[1]

The specimens from Sinai measure $\frac{7}{25}$ inch (7 mm.) in the diameter of the shell, and its thickness is $\frac{1}{50}$ inch (·5 mm.).

Schwager's specimens were obtained from the white clay of Aradj (Mokattam Series), Egypt.

Coll. Geol. Surv. Egypt, No. 4,112, Box No. 2*l.* ? Bartonian Series (Upper Eocene) or ? top of Mokattam Series (Middle Eocene): beach deposit, Jebel Abyad, Sinai. Common.

Heterostegina, d'Orbigny [1826].

Heterostegina depressa, d'Orbigny. (Pl. XIII, Fig. 7*a*.)

Heterostegina depressa, d'Orb., 1826: Ann. Sci. Nat., vol. vii, p. 305, No. 2, pl. xvii, figs. 5–7; Modèles, No. 99.

The specimens now under description are very distinctly coiled at the commencement, and in general aspect resemble those specimens which belong to the microspheric form; and which are rare in our modern marine dredgings. This species is more commonly found in the later Tertiaries, but it is not entirely absent from the base of the Eocene.

Coll. Geol. Surv. Egypt, No. 3,902, Box No. 15*l.* Libyan Series (Lower Eocene): Jebel Krer, Sinai. Rare.

(*To be continued in our next Number.*)

VI.—The Development of Brown Mica from Augite by Reaction with Felspathic Material.

By James Parsons, B.Sc. (Lond.).

THE conversion of augite or hornblende into brown mica appears to take place from three causes:—

1. By crushing of pyroxenic minerals and felspar, as has been observed by Professor Bonney in sundry schists of the Alps.[2]

2. By the intrusion of felspathic material into a rock containing augite or hornblende, as in the Harz, where granite invades diabase, converting the augite into biotite.[3] A similar change has been observed in the gabbro of the Barnavave Mountain, in the Carlingford district, the diallage being wholly or in part replaced by biotite owing to the invasion of granophyric magma.[4] In Sark the intrusion of an aplitic magma into almost pure hornblende has resulted in the formation of biotite.[5]

3. By the corrosive action of a residual felspathic magma on previously consolidated augitic constituents. This method of formation has been noted by Mr. T. H. Holland in the augite-diorites

[1] Abhandl. bayer. Akad. Wiss., vol. x (1868), 1870, p. 664, pl. ii, figs. 112*a*, *b*.
[2] Q.J.G.S., vol. xlix, p. 104.
[3] K. A. Lossen: Congrès Internat. Géol. Comptes Rendues de la 4me session, 1888, p. 184.
[4] Sollas: Trans. Roy. Irish Acad., vol. xxx (1894), p. 477.
[5] Bonney: Q.J.G.S., vol. xlviii, p. 122 et seq.

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of Southern India. In this instance, after augite and plagioclase had consolidated a hydrous magma was left, which ultimately solidified as micropegmatite; this magma acted readily on the augite, converting it into biotite.[1] Under this head the following observations on some Norwegian rocks should probably be classed.[2]

(1) A granite from Almäs shows a similar process of change to that observed in the above-mentioned augite-diorites. The principal constituents of the rock are, oligoclase, orthoclase, augite of the pale-green non-aluminous type (sahlite), which commonly occurs in granite, biotite, and sphene. The biotite is developed round the augite, which is much corroded, passing into it along its cleavage cracks, in such a way that, in many cases, the line of division is fixed with difficulty. The two minerals are curiously intergrown, but not in such a way as to suggest simultaneous crystallization, for while the biotite invades the augite from the outside it does not form isolated inclusions in the latter. The quartz and orthoclase occur as a mosaic of varying coarseness and of later date than the oligoclase, and locally form patches of micropegmatite. The mosaic extends in narrow seams between the oligoclase crystals, broadening out at their angles to fill the intercrystalline spaces. It is largely developed round the augite-biotite aggregate, the grains separating the flakes of biotite at the margins of the main masses. Appearances suggest that the magma, from which the quartz and orthoclase formed, effected the corrosion of the augite and subsequent development of the biotite in the manner suggested by Mr. Holland. The sphenes occur as idiomorphic crystals, and are the earliest constituents of the rock, for they are included in the augite, which is itself earlier than the oligoclase. Where present in the biotite or in its immediate neighbourhood they are much corroded and cracked. The iron of the augite appears to be completely used up in forming the biotite, for though a few grains of magnetite occur, these are due to the subsequent hydration of the mica accompanied by the formation of a chloritic mineral. A little hornblende is present, apparently secondary, after augite.

(2) An augite-syenite from Svenöre well shows the conversion of augite into dark mica. This rock is closely allied to the well-known Lauvigite. The felspars are orthoclase, apparently of two varieties, with a little plagioclase. They exhibit microperthitic intergrowth, and this in many places at their margins passes into micropegmatite. The augite is of two types: (i) Pale brown, slightly pleochroic, showing, in the central portions of the crystals, good cleavage marked by the deposition of iron oxide in the cracks, which occasionally assumes the form of negative crystals. Incipient diallagic cleavage may be observed, traversing the earlier prismatic one. This augite is much corroded by the felspars, its margin being in some places curiously broken up and intergrown with the

[1] Q.J.G.S., vol. liii, p. 405.

[2] I am indebted to Professor Bonney for the opportunity of studying these slices, which belong to his collection.

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surrounding felspar in a manner approaching micropegmatite. (ii) A pale-green augite, irregularly cracked, probably sahlite. It occurs in rounded fragments, which in places have been broken up and separated. Biotite is chiefly developed round the first-named augite, and it occurs only when that mineral is in contact with the felspar, and has been manifestly corroded by it. With ordinary light it is often impossible to say where the passage of augite into mica commences, for its first manifestation is a very faint brown tinting. With crossed nicols the first indication of its development is a marked increase of intensity in the polarization tints, along a narrow zone at the junction; this presently shows the characteristic mica cleavage, and varies in colour from a very light brown to a dark bright brown. Beyond the latter magnetite is developed. On the other side of the mass of magnetite the augite shows irregular cracks in which the magnetite is deposited, and beyond this the regular cleavage sets by marked iron oxide, as mentioned above. It should be understood that though this *order of sequence* is apparently constant, yet any stage owing to the irregularities of the decomposition may be locally very poorly shown or even absent. In some cases the augite is completely decomposed, and there remains only a core of magnetite with a corona of mica, darker in colour near it and lighter in contact with the felspar. The pale-green augite does not so readily develop mica as the other variety, though its smaller fragments show in places an abundant marginal growth.

Much serpentinization occurs along its cracks, accompanied by the formation of a little mica. Both these facts confirm the idea that this is a non-aluminous augite. It is, however, rich in iron oxide, which is largely excreted in the formation of mica and the serpentinization. Apatite is an abundant constituent of the rock, the larger crystals acting as the nuclei round which the augite consolidated.

(3) A similar formation of dark mica from augite may be observed in Lauvigite, which closely resembles the Svenöre syenite described above. The rock is too well known to require detailed description, but in the present connection the following points may be noted. The augite is of two types: (i) pale-brown, slightly pleochroic, with incipient diallagic cleavage; (ii) pale-green sahlite, irregularly cracked, some serpentine and a little biotite forming along the cracks. This is earlier than the first-named augite and in many places is enclosed by it. The felspathic mixture (anorthite, microperthite) has much corroded the augite, with which at its margins it is in places intimately intergrown. Round the augite mica is developed, the one passing almost insensibly into the other as already described, and the same darkening of the mica and final formation of magnetite occurs as the distance from the felspar increases. The felspathic magma has in places invaded the augite, producing in its centre patches of dark mica which appear at first sight to be isolated inclusions. Here also the mica is only formed with difficulty in the sahlite.

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(4) A gabbro from Humlebäk affords an interesting example of the corrosion of a felspar by augitic magma, resulting in the formation of brown mica. In this case the felspar is labradorite, occurring in idiomorphic crystals, round which the augite, a colourless variety, extends in ophitic fashion. The felspars are much corroded and in part melted down, thus enclosing small portions of the augite. Round the edges of the felspar, mica is developed, appearing at the outset as a faint brown tinting of the augite. At first the cleavage of this mineral is alone apparent as a rule, though occasionally traces of the mica cleavage may be discovered parallel to one of the cleavage planes of the augite. There are indications that at this earliest stage a mixture of augite and mica is present, or rather, a *solution* of mica in the augite is suggested. In one instance where a felspar lath is surrounded by biotite, obviously derived from augite, it has lost almost half its bulk by corrosion, and the remainder appears to be permeated by augitic material, converting it into a colourless mica whose cleavage planes are continuous with those of the biotite on each side. The mica when traced inwards from the margin of the augite loses its scaly appearance, due to the cleavage of that mineral, becomes more compact, and develops its own cleavage. At first it is a straw colour, then it becomes a dark bright brown, and finally magnetite is formed; and in the larger augite grains this is followed by an irregularly cracked zone which passes into a central portion showing fine cleavage striation. With this, as a rule, the outer portion is in optical continuity. When the augite is more remote from and unaltered by the felspar, it is twinned sometimes more than once parallel to the orthopinacoid; this, combined with basal cleavage striation, giving the well-known herring-bone structure. In the smaller augite grains the conversion into mica and magnetite is sometimes complete, a corona of light mica surrounding the bright brown mica, and in most cases a core of magnetite occupying the centre of the grain. The following explanation may be offered of the transition shown in this rock and the syenites:—where the felspar is in contact with the augite a mica is formed, poor in iron and rich in alumina, probably phlogopite, while, as the distance from the felspar increases, ferric oxide takes the place of alumina, resulting in lepidomelane, biotite being formed as an intermediate stage, and finally, beyond the limit to which the felspathic magma permeated, magnetite is excreted.

Thus the normal order of change seems to be as follows (commencing from the side of the felspar): (1) fusion of felspar and augite with faint brown tinting of the augite, due to incipient development of mica; (2) pale-brown mica (phlogopite); (3) biotite; (4) dark red-brown mica (lepidomelane); (5) intimate mixture of dark mica and magnetite; (6) mass of magnetite; (7) augite with irregular cracks in which magnetite is excreted, which is followed by augite with fine cleavage striation.

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