47. *On the* Diorites *of the* Warwickshire Coal-field.

By S. Allport, Esq., F.G.S. (Read June 25, 1879.)

In a paper communicated to the Geological Society, and published in the 30th volume of the 'Quarterly Journal,' I briefly described the microscopical structure and composition of the various masses of igneous rocks which occur in the Carboniferous strata of the Midland Counties, with the exception of those found in the Warwickshire Coal-field. I now propose to complete the series with a short account of the only hornblendic rocks to be found among them.

Although they form but a small group they are of considerable interest, as some of them present remarkable varieties of structure, and others a mineral constitution which distinguishes them from any British rocks hitherto examined.

The geology of the Warwickshire Coal-field has been described in the Memoir of the Survey published in explanation of sheet lxiii. S.W.; and a reference to that map will show that the rocks now to be described are restricted to the district between Atherstone and the village of Marston Jabet, about two miles south of Nuneaton, and also that the several bands and larger masses occur only in the lower unproductive beds of the Coal-measures and in the underlying Millstone Grit. Although the sheets usually run very regularly between the beds of shale they are clearly intrusive, as they sometimes pass from lower to higher beds, and have invariably altered the shales in contact with their upper and under surfaces. The junction of the eruptive and sedimentary rocks may be seen in several clear sections. In a quarry in Purley Park, about a mile south of Atherstone, there is a good exposure of both rocks; at first sight they appear to be interbedded, but in one place there is a wedge-shaped band of shale enclosed in one of the sheets of trap. A still more interesting example may be seen in the railway-cutting near Chilvers Coton, where there are no less than ten alternations of the two rocks (see fig.). Although the geological period of the

Diorite intrusive in Carboniferous Shales in Railway-cutting near Chilvers Coton.

intrusion cannot be precisely determined, it is at least certain that it was previous to the deposition of the Triassic rocks, for in an old quarry near Marston Jabet the Lower Keuper sandstone lies horizontally on the upturned edges of the Carboniferous shales and included trap.

The Microscopic Structure of the Warwickshire Diorites.

An examination of numerous specimens from the different masses shows clearly that, as a group, these rocks must be regarded as diorites, the characteristic constituents being a triclinic felspar and hornblende; these two minerals together with magnetite and apatite are invariably present, and in addition a little orthoclase is seldom absent. Although many of the specimens examined are ordinary diorites, there are occasionally such wide departures from the normal type, that, from a mineralogical point of view, some of them must clearly be classed with rocks not hitherto observed among the older eruptive series. On the whole, it would perhaps be difficult to point to a group of rocks presenting more interesting varieties of composition and texture, or which afford more instructive examples of extensive alteration.

Quarry near Marston Jabet.—A finely crystalline specimen, very like a basalt in external appearance, contains an immense number of small hornblende crystals in a felspathic base, both minerals being nearly or quite unaltered. The clear brown crystals of hornblende are unusually well developed, and as they lie in all directions a single thin slice affords many excellent transverse and longitudinal sections of the prism. One rarely meets with an augitic or hornblendic rock containing such an assemblage of well-formed crystals. They are thickly set in a clear matrix of triclinic felspar, and interspersed among them are rather numerous grains of magnetite, with here and there a few needles of apatite. The only indication of alteration is a little calcite in the matrix; no other minerals are present.

The three following specimens, selected from a number collected in the same quarry as the last, may be taken to represent the more general character of the rocks of the district; and they possess a special interest, as they afford excellent examples of successive stages of alteration. The first example is rather coarsely crystalline in texture, and the original constituents are very well preserved; the plagioclase is generally clear, and exhibits well its characteristic twin striation. The hornblende is of a clear brown colour, for the most part quite unaltered, and presents its ordinary optical and physical characters; it is much fissured, and occasionally contains so many cavities that the crystals are little more than skeletons; it also encloses many grains of magnetite, and the latter are also rather thickly disseminated through the mass. Long hexagonal needles of apatite are rather abundant; and, lastly, there was a glassy or felsitic ground-mass in which the crystallized constituents were set. This

ground-mass has been much altered, and now consists of a fine granular substance, partly serpentinous in character, with here and there a little calcite.

The second example is quite similar in texture to the first; the felspar, still easily recognizable as triclinic, is far from clear, having been partially converted into a grey pulverulent substance. The hornblende occurs in various stages of alteration; some crystals are but slightly attacked, while others are to a considerable extent converted into a pale green serpentinous substance. The alteration has followed the cleavage-lines and fractures, and has also invaded the substance of the crystals on each side; while the numerous cavities just mentioned are also filled by the same substance. In a single slice there may be seen almost every degree of change from a slight marginal erosion to a mere skeleton of the original. Of the latter, however, some little is always left; and whether the alteration be little or great the original crystalline forms are perfectly preserved. In the third specimen the alteration has proceeded still further, the whole of the hornblende crystals having been completely converted into pale green pseudomorphs; they were originally rather large and well developed, and their forms are still perfectly sharp and distinct. The felspar is here quite turbid and opaque, and the interstitial ground-mass is represented by calcite.

It may here be well to observe that the importance of a series of specimens like those just described can hardly be overestimated; in fact a collection of specimens in various stages of alteration is absolutely essential for any one who wishes to acquire an accurate knowledge of the older rocks; and it fortunately happens that a diligent search will very frequently supply the requisite materials for study. Among the older rocks, which have been quarried to some extent, it is generally possible to obtain specimens in every stage of alteration; and a careful study of such examples frequently renders it easy to determine the former presence (in other rocks) of minerals whose original composition and appearance may have been entirely changed. In other words, it will be found that many pseudomorphs possess characteristic microscopic features which render their recognition easy to an experienced and cautious observer. I venture to urge this point, as there is no more promising field for microscopic research; it is one which has, however, been treated with comparative neglect, and even the very existence of extensive pseudomorphic changes has not long since been denied by at least one writer of eminence.

Diorite containing Augite and Olivine.

Purley Park, near Atherstone.—A portion of the mass in this ocality is in an excellent state of preservation; it is a greyish-black rock, distinctly crystalline in texture, and in external appearance closely resembles a fine-grained dolerite.

A thin slice exhibits under the microscope a mass of plagioclase

crystals with a few of orthoclase; among these are scattered numerous small crystals of brown hornblende, many crystals and grains of clear yellowish augite, many grains of magnetite, a few needles of apatite, and several pseudomorphs after olivine. There is also a matrix in which the original constituents are set, but whether glassy or felsitic in its original state, there is no evidence to show; it has undergone a considerable amount of alteration, and now consists generally of a pale green serpentinous substance frequently accompanied by calcite. In several instances the usual forms of the augite crystals are perfectly well seen, some of them being twins; they exhibit no trace of dichroism when examined without the analyzer in the same way as the hornblende; and as well-formed crystals of both minerals occur in a single slice, their crystallographic and optical characters may be observed side by side. The augite appears to be very irregularly distributed throughout the mass of the rock; for in some slices it is almost as abundant as the hornblende, while in others it is nearly or even quite absent. It is slightly altered here and there, but never resembles uralite, the altered parts having merely a turbid grey aspect, like that observed in many of the dolerites.

Having given special attention to the various kinds of pseudomorphs after olivine, I had no difficulty in detecting their presence in several of these rocks; the discovery was, however, so entirely unexpected that, after cutting many slices, it was no small satisfaction to meet with a thoroughly characteristic form of the crystal. Some of these pseudomorphs consist exclusively of calcite, while in others the central parts are filled with viridite; they thus correspond in every way with many observed in the more highly altered dolerites described on a former occasion*. In some slices the pseudomorphs are very numerous and are generally larger than the crystals of augite or hornblende; they nearly all contain a few grains of magnetite, but never any other of the original constituents. The fissured condition of the unaltered crystals is also clearly indicated by the veins so familiar to those who have studied this mineral in the older dolerites. These and other features described in the paper just referred to are so thoroughly characteristic, that there is no room for doubt as to the former presence of olivine in these rocks.

There is also present in some quantity another mineral of which it will be well to speak less positively. It is quite colourless and occasionally clear, though it generally contains more or less of a fine dust which gives it a cloudy appearance, especially round the margins. Some of the sections are hexagonal, others rectangular; the former are dark between crossed Nicols, while the latter are coloured, though the tints are not brilliant. The crystals certainly belong to the hexagonal system, and are larger and stouter than the ordinary needles of apatite, many of which also occur in these rocks; it is possible, I think, that they may be nepheline. Against this

* S. Allport, "On Carboniferous Dolerites," Quart. Journ. Geol. Soc. vol. xxx. p. 542.

view there is, of course, the difficulty of an easily decomposed mineral like nepheline having remained unaltered from Palæozoic times; but, on the other hand, it should be remembered that olivine presents a similar difficulty, yet has nevertheless been frequently preserved unchanged throughout the same enormous periods.

Two of the secondary constituents have already been mentioned, namely calcite and viridite, or a serpentinous substance; to these may be added an orthorhombic zeolite which fills small cavities with long radiated lamellar crystals; they are clear and colourless, but exhibit brilliant colours in polarized light.

Quarry close to Atherstone.—In this mass the hornblende is also accompanied by a considerable quantity of very pale brown augite; the crystals are well formed and among them are several twins. The felspar is highly altered, but a few crystals may be recognized as triclinic. In two slices examined there were no pseudomorphs after olivine.

Railway-cutting, Chilvers Coton.—This is an excellent locality for collecting well-marked varieties of the intrusive rocks. On the west side there is a light-coloured mass composed chiefly of pink felspar, with rather long prisms of altered hornblende scattered through it. Another variety is of a dark green colour, and consists almost entirely of hornblende in comparatively large crystals. Between these extremes there may be found several intermediate varieties. Microscopic examination of these rocks affords no additional fact of importance.

Conclusion.

It appears from the preceding investigation that the intrusive rocks of the Warwickshire coal-field are for the most part ordinary diorites, but that they also occasionally present remarkable variations from the normal type.

The varieties described appear, however, to be strictly local; and in all of them the predominant and characteristic constituents are a triclinic felspar and hornblende, together with a little magnetite and apatite; a glassy or felsitic matrix is also nearly always present.

Hornblendic rocks containing augite and olivine have not been previously found in these islands, nor, I believe, elsewhere, except among rocks of Tertiary or later age. They appear, moreover, to be rather rare everywhere, a few only having been observed among the hornblende and augite andesites* or the Bohemian basalts described by Boricky†.

It is now certain that rocks of precisely similar composition were erupted during the later Palæozoic period; how much earlier remains to be seen. The existence of these rocks may therefore be regarded as additional evidence against the singular notion, apparently held by many, that the products of volcanic action were in some unaccount-

* Zirkel, Lehrbuch der Petrographie, vol. ii. p. 222.

† Basaltgesteine Böhmens, pp. 137, 138.

able way suddenly changed about the commencement of the Tertiary period.

It may be observed in conclusion that these Warwickshire rocks differ greatly from the neighbouring syenites of Leicestershire, recently described by Professor Bonney*, with which I am also well acquainted. In the latter the prevailing felspar is orthoclase, and quartz is always present; epidote is also a very common secondary constituent. I have detected no trace of either quartz or epidote in the diorites, and orthoclase invariably occupies a very subordinate position.

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 225.