Kaims.—The old British word *Caim* (a heap) is locally applied to several of the strange ridges of gravel and sand to which the names Eskers, Åsar, and Kames have been applied by geologists. Beautiful examples of such ridges are to be seen at Chat Hill, and between the Hoppen and Spindleston, near Belford. I have read a considerable number of theories accounting for these Kaims in text-books and elsewhere, but am still quite unable to explain them.

Recent Deposits.—Under this head must be grouped the great deposits of the Moorland districts in which remains of extinct animals, such as the Red Deer, *Bos longifrons*, etc., are found, but the accumulation of which is still going on; the gravels and loams of our rivers; the sands of our beaches; but these need little notice here.

For lists of fossils and minerals, and for fuller details on the geological structure of the district, I beg to refer to my 'Handbook to the Geology of Northumberland and Durham,' about to be published by Messrs Lambert and Co., of Newcastle-upon-Tyne.

PETROGRAPHICAL NOTES ON SOME OF THE IGNEOUS ROCKS OF NORTHUMBERLAND.

By J. J. H. TEALL, M.A., F.G.S.

(Read July 2nd, 1886.)

In various papers published in the 'Quarterly Journal of the Geological Society'* and the 'Geological Magazine'† I have given details as to the mineralogical and chemical characters of some of the igneous rocks of Northumberland. To the facts published in those papers I have little to add, but as the President has requested me to offer some general remarks on the subject with a view to the Long Excursion, I gladly comply with his request. Since the papers were written I have gained a more extensive experience of the igneous rocks of similar

* "Petrological Notes on some North-of-England Dykes," 'Quart. Journ. Geol. Soc.,' Vol. xl, 1884, p. 209. "On the Chemical and Microscopical Characters of the Whin Sill," 'Quart. Journ. Geol. Soc.,' Vol. xl, 1884, p. 640.

† "Notes on the Cheviot Andesites and Porphyrites," 'Geol. Mag.,' Decade II, Vol. x, 1883, pp. 100, 145 and 252. "On some Quartz-Felsites and Augite-Granites from the Cheviot District," *Ibid.*, Dec. III, Vol. ii, 1885, p. 106.

composition from other districts; and I may, therefore, be able to supplement those portions of my original papers which deal with the subject of correlation.

For our present purpose, the igneous rocks of Northumberland, so far as I have examined them, may be grouped as follows :—

- (1.) The dykes of plagioclase-augite rock.
- (2.) The intrusive sheets of plagioclase-augite rock associated with the Carboniferous strata :—the Whin Sill.
- (3.) The volcanic rocks of the Cheviot district.
- (4.) The augite-granites and dykes of quartz-felsite in the Cheviot district.

(1.) The dykes of the first group are essentially composed of plagioclase, augite, and titaniferous iron. A considerable amount of interstitial matter, often rendered almost opaque by minute rods and granules of magnetite, is present in some; as, for instance, the Tynemouth Dyke. One interesting and somewhat important feature of these dykes is the comparative rarity of olivine. In many of them this mineral is entirely absent, and in one only (*viz.*, that of Morpeth) does it occur with sufficient constancy to be regarded as an essential constituent of the rock.

The feldspars in some cases belong to two distinct generations. The earlier and porphyritic feldspars, so far as they have been determined, belong to a species closely allied to anorthite; nevertheless, they are not typical anorthite, but intermediate, both in chemical and optical characters, between that mineral and labradorite. Dr. Schuster and Prof. Tschermack apply the term “bytownite” to such feldspars. These feldspars occur as crystals, and also as crystalline-granular aggregates, on the external surfaces of which crystal faces have been developed by the addition of substance differing somewhat in composition from the main mass of the feldspar. The mutual relations of the individual grains of bytownite are exactly similar to those of the grains in basic plutonic rocks, such as gabbro and troctolite; so that one is naturally disposed to regard these aggregates as having been developed under plutonic conditions, and then carried upward by a subsequent movement of the mass. During this upward movement additional feldspar substance was added to the external surfaces of the grains, and

crystalline faces were thus produced. These features are all admirably shown in the porphyritic portions of the dyke exposed by the Tynemouth breakwater.

The porphyritic feldspars sometimes show a good zonal structure. With regard to the distribution of these porphyritic feldspars in the different dykes, it may be remarked that, so far as is known, they occur in greater abundance, and attain a larger size, in portions of the Tynemouth Dyke than in any of the other dykes. They may, however, be detected in many of the other dykes when a considerable number of microscopic slides are subjected to examination.

The feldspars of second consolidation, or, in other words, the feldspars of the ground-mass in the porphyritic rocks, and those which make up the main mass of the non-porphyritic rocks, are the small columnar crystals which give the well-known lath-shaped sections.

The augite of the dykes is almost colourless in thin sections, and occurs in the form of grains and granular aggregates; occasionally it shows traces of external form. The lath-shaped feldspar-sections are sometimes seen to penetrate the augite, thus giving evidence of having been formed before that mineral; but in no case is a marked ophitic structure present, except, perhaps, in one of the High-Green Dykes.

The titaniferous iron occurs in crystals, grains, and skeleton forms. The interstitial matter, which is sometimes a true glass, has already been referred to. Olivine and its serpentinous pseudomorphs are very rare.

The silica-percentages and specific gravities of some of the rocks are as follows :—

				Silica. p.c.	Sp. gr.
Tynemouth Dyke	...	...	...	58·30	2·84
Morpeth Dyke	...	...	...	51·20	2·88
Acklington Dyke	...	...	...	57·80	2·81
High-Green Dyke	...	...	...	53·70	2·9

It will be observed that the silica-percentages, if we except the olivine-bearing Morpeth Dyke, are somewhat high for basic rocks. The rocks, in fact, occupy a position intermediate between the normal basic and the normal intermediate types; between rocks of the basalt and rocks of the andesite class.

(2.) The rocks of the intrusive sheets (Whin Sill) are similar in mineralogical composition to those of the dykes, but they are holocrystalline, and the feldspars, as a rule, belong only to one period of consolidation. No olivine, so far as I know, occurs in the Whin Sill; but I have occasionally detected a mineral of the enstatite group. Coarse-grained varieties, with long-bladed augite crystals, are occasionally found in the Whin Sill; and in these the augite frequently possesses a diallagic striation parallel to the basal plane (001). The silica-percentage of the Whin Sill is about 51, and the specific gravity about 2.9.

It is an unfortunate circumstance that we are unable to speak with certainty as to the relative ages of the various dykes and intrusive sheets. Some of the dykes, as, for example, that of Acklington, may with a considerable amount of confidence be referred to the Tertiary period, whereas the Whin Sill is probably post-Carboniferous and pre-Tertiary. It is probable, also, that some of the dykes are of the same age as the Whin Sill. Thus one of the High-Green Dykes resembles the Whin Sill very closely in its petrographical characters.

Dr. Geikie mentions the occurrence of igneous rocks in the Permians of Ayrshire, and it is possible, if not probable, that the Whin Sill may be of the same age as these. Plagioclase-augite rocks, with a rhombic pyroxene (enstatite-, or hypersthene-dolerite), occur at Ratho, Kilsyth, and in Arran, with many points of resemblance to the Whin Sill; but I am unable to say whether the field relations of these rocks lend support to the view that they are of post-Carboniferous and pre-Tertiary age.

If we compare the plagioclase-augite rocks of Northumberland with the rocks of the Midland Counties, so well described by Mr. Allport, we are at once struck with some important differences. The latter abound in olivine, and a rich brown or brownish-violet augite. Deeply-coloured augites are, so far as I know, entirely absent from the Northumberland rocks, and olivine is very rare.

It is interesting to note that the Whin Sill presents many points of resemblance to the plagioclase-augite rocks which

occur so largely in the Triassic strata of the New England States, near the eastern coast of North America.

(3.) The lavas and tuffs of the Cheviot district belong to the Old Red Sandstone period. They are, so far as I know, of intermediate composition, but it is by no means improbable that acid lavas occur, for dykes of quartz-felsite are found in the district. The lavas are partly fresh and partly altered; and the former may be termed andesites, the latter porphyrites, but, of course, no hard and fast line can be drawn between the two. The least altered variety is that formerly known as pitchstone-porphyrity, now termed hypersthene-andesite, or more properly hypersthene-augite-andesite. This is a markedly porphyritic rock with resinous lustre. The porphyritic elements are labradorite, hypersthene and augite. The ground-mass is composed of minute feldspars, magnetite, hæmatite, and a glassy base. The rock as a whole contains about 60 p.c. of silica, and possesses a specific gravity of about 2·5 or 2·6. The glassy base has been isolated and analysed by Dr. Petersen,* and the result of the analysis shows that the base is richer in silica, poorer in lime, iron, and magnesia, and richer in alkalis than the main mass of the rock. Moreover the base is richer in potash than in soda, whereas the rock, taken as a whole, is richer in soda than in potash. It follows, therefore, as a natural consequence from these facts, that, in a magma having the composition of the Cheviot andesite, the progressive separation of crystals leaves the magma richer in silica and the alkalis, richer in potash than in soda, and poorer in lime, iron and magnesia. In other words, after a certain amount of crystal-development has taken place the fluid portion of the magma of an andesite possesses the composition of a trachyte or liparite.

The Cheviot porphyrites differ from Tertiary and Recent andesites merely in containing numerous secondary products due to decomposition. The feldspars are more or less kaolinised, the ferro-magnesian minerals are represented by chlorite and the ill-defined, green, decomposition-products, generally known as viridite. The chlorite and viridite are often associated with black (opacite), or brown, specks (ferrite), and sometimes also with minute, vividly-polarising granules (epidote). The mag-

* 'Mikroskopische und Chemische Untersuchungen am Enstatit-porphyrity aus den Cheviot Hills,' Inaug. Diss. (Kiel, 1884).

netite is often changed to ferric oxide, and the glass has been devitrified and more or less altered by the agents of decomposition. Notwithstanding the alteration, it is, however, possible in many cases to make out the original character of the andesite from which the porphyrite has been derived. We thus recognize in the Cheviot area those varieties which are common in Tertiary volcanic districts. We have for instance, hypersthene-porphyrates, hypersthene-augite-porphyrates, augite-porphyrates and mica-porphyrates. The only common variety not known in the Cheviot district is hornblende-porphyrite.

The fragmental volcanic rocks associated with the lavas are, as we should naturally expect, similar to them in composition. These fragments are, however, in all cases much altered; a feature which is of course easy to understand when we remember the loose and porous nature of a tuff or agglomerate.

(4.) The district in which the andesites and porphyrites occur is traversed by dykes of quartz-felsite which probably belong to the same general period of volcanic activity as the andesites, but to a later phase of it. These usually consist of porphyritic crystals of orthoclase, plagioclase, quartz, and biotite embedded in a micro-crystalline ground-mass. It is worthy of note that the quartz-felsites have the same composition as the glassy base of the andesites; so that we can explain the succession of quartz-felsite to andesite if we suppose the former rock to represent the mother-liquor squeezed out of the plutonic representative of the andesite after crystallization had progressed to a certain extent.

Dykes of plagioclase-augite rock also traverse the district in which the andesites and porphyrites occur, but these evidently belong to a much later phase of igneous activity. The Acklington Dyke is very probably of Tertiary age.

In the central and somewhat inaccessible portions of the Cheviot district, about Hedgehope, holocrystalline rocks of granitic texture occur. These rocks vary in the relative proportions of their different constituents, and consequently in general aspect. Some are dark and syenitic-looking, others resemble a normal grey granite. The principal constituents are soda-orthoclase, oligoclase, black mica, colourless augite, quartz and a little magnetite. In the granite of Staindrop Rigg the two felspars may be easily distinguished; the

orthoclase being pink and the plagioclase light-coloured, or white. The augite is always colourless in thin sections. It occurs most abundantly in the dark syenitic-looking rocks, and is frequently associated with micropegmatite. The black mica is of the ordinary type.

The granites of the Cheviots may therefore be termed augite-biotite granites. The occurrence of quartz and orthoclase in association with augite is an interesting and somewhat important fact. The only other British localities in which I have observed a similar association are Carrock Fell, in Cumberland, Groby and some other places in Charnwood Forest, and the Isle of Mull. In all these cases the augite is associated with micropegmatite. The Charnwood Forest hornblende granites present many points of resemblance with the more basic Cheviot granites, so that one is tempted to ask whether the hornblende of the former rocks may not be in part secondary after augite. No trace of hornblende occurs in any of the Cheviot granites which I have examined. Rocks closely allied to the Cheviot augite-granites occur at Laveline and Oberbrück in the Vosges.

An important question arises as to the relation of the granites to the volcanic rocks of the Cheviot district. We have no chemical analyses of the Cheviot granites, but it is quite clear that many of them must be of intermediate rather than of acid composition. There seems, therefore, some probability in favour of the view that they are merely the plutonic representatives of the lavas and tuffs; that they constitute, in fact, a portion of the core of the Old Red Sandstone volcano.