

tain no extinct shells ; but some are locally extinct and some differ markedly from their present day representatives. If this bed were worked as thoroughly as the Glacial beds these distinctions might be greatly emphasised. Two skulls and a number of bones of the whale were got at the base of the forty foot raised beach at Irvine. The remains of other mammals have also been found, but it is difficult to say whether or not they were contemporary with the raised beaches. These include *Bos primigenius*, *B. longifrons*, *Megaceros hibernicus* and *Equus caballus*, while man himself is supposed to have made his appearance here in the Raised Beach Period.

III.—THE PETROLOGY OF THE DISTRICT.

By G. W. TYRRELL, A.R.C.Sc., F.G.S., Lecturer in Mineralogy and Petrology, Glasgow University.

The Glasgow district, including within this designation the coasts and islands of the Clyde Estuary, as well as the area of which the city is the centre, is one of extraordinary petrological interest, owing to the profusion of igneous rocks of varied ages and affinities, and to the number of new and rare types it has yielded in recent years. Indeed there are several outcrops of the rare analcitic igneous rock known as *teschenite* within the boundaries of the city itself.

The igneous rocks of the district may be grouped according to their ages into four main groups, those belonging to the Old Red Sandstone, Early Carboniferous, Late Carboniferous, and Kainozoic respectively.

Old Red Sandstone.—The most prominent intrusive mass of this period is that of Garabal Hill, near the head of Loch Lomond, which was first described by Dakyns and Teall (1892). It consists mainly of porphyritic granite, with tonalite and diorite passing to hornblendite. There are also small areas of peridotite and pyroxenite. A recent re-examination of the intrusion by B. K. N. Wyllie and A. Scott has resulted in destructive criticism of the hypothesis that the Garabal series has arisen by "the differentiation of an originally homogeneous magma," and in the discovery of a new rock-type called *davainite*. This consists almost entirely of brown hornblende, with cores of diallage, and is believed to have arisen from the annealing of a diallage rock by the heat of a later diorite intrusion (Wyllie and Scott, 1913). Volcanic rocks of Lower Old Red Sandstone age occur in the Carrick Hills, south of Ayr, where an area of twelve square miles is occupied by pyroxene-andesite, associated with intrusive rocks described as plagiophyre and dolerite (Tyrrell, 1914). Similar

rocks occur near Galston, North Ayrshire, where they are associated with intrusions of quartz-gabbro (Tincorn Hill), but this area is very imperfectly known. A thin strip of Old Red Sandstone lavas (pyroxene-andesites with olivine) also occurs near the Highland Boundary Fault in the Aberfoyle district (Kelty Burn). Pebbles of augite- and hornblende-andesites, with occasional rhyolites, form beds of conglomerate in the Lower Old Red Sandstone of the Killearn district (*Glasg. Mem.*, p. 6). In Arran, both the Upper and Lower Old Red Sandstone contain a series of lavas. In the former the described specimens are olivine-basalts; in the latter they are basalts and andesites (*N. Arran Mem.* pp. 26-7, 34, 171-3).

Early Carboniferous.—Great scarps of volcanic rocks of this age, belonging to Sir A. Geikie's aptly-named Clyde Plateau, overlook the Glasgow basin on the north, west, and south. These are conveniently divided by faults and valleys into several ranges, which, on the north, are named the Kilsyth, Campsie, and Strathblane Hills; and on the north-west, the Kilpatrick Hills. To the south the enormous block of volcanic rocks covering most of Renfrewshire and North Ayrshire has not yet received a distinctive name.

For the most part these plateau lavas consist of basalts of various types, but rocks of sub-acid and acid composition, whilst subordinate, have recently been found to have a much wider distribution than hitherto supposed. The basalts have a slight alkaline cast, shown by their greater richness in alkalis as compared with the average basalt, by the occurrence of mugearites and analcite basalts (East Lothian), and by their association with trachytes and phonolites. They form a continuous series, the members of which are conveniently grouped around certain arbitrary types for field and petrographic classification (Tyrrell, 1912, No. 2).

In the Kilpatrick and Campsie Hills the basalts have been poured out from a series of small vents aligned around the northern and western margins of the plateau. A much larger and later type of vent is represented by the Meikle Bin of the Campsie Hills, and the Misty Law area of the Renfrewshire Hills. These vents are filled with tuff and agglomerate, pierced by swarms of dykes, in which sub-acid types are represented as well as basalts. Yellow and pink trachytes and felsites in great profusion, trachyandesites, and trachydolerites, are described from the Meikle Bin vent (*Glasg. Mem.*, pp. 109, 143-5). A fine nepheline-phonolite has been obtained near Fintry (*ibid.*, pp. 110, 144). A little farther east Mr. J. V. Harrison has obtained a series of trachytes in the March Burn. Although not yet fully explored, the Renfrewshire and North Ayrshire district is known to contain sanidine-trachyte (Neilston Pad), quartz-keratophyre, trachyte, and felsite

(Misty Law), and a beautifully fresh quartz-keratophyre in the great Craigmushat Quarry at Gourrock, noted for its druses studded with fluorite. Similar rocks are also found in the Fairlie and Ardrossan districts (*Summ. Prog. Geol. Surv.*, 1913, p. 58). So far as known these acidic rocks are all intrusive. The preponderant lavas of North Ayrshire and Renfrewshire are basic, and belong mostly to the Dunsapie and Craiglockhart types of basalt. Trachyte (or bostonite)* and felsite dykes are so abundant in the Great Cumbræ Island as to suggest that a Meikle Bin type of vent is probably buried beneath the waters of the Firth of Clyde in this vicinity. In South Bute, along with the basic lavas, W. R. Smellie (1915, p. 138), has found several lavas of trachytic (or bostonitic) affinities.

Late Carboniferous and Permian.—A feeble recrudescence of volcanic activity occurred in Millstone Grit times along a line from Ardrossan to north of Kilmarnock, giving rise to a few olivine-basalts and tuffs (*Summ. Prog. Geol. Surv.*, 1913, p. 60). A much greater revival of igneous activity occurred toward the end of Carboniferous time, or early in the succeeding period, in Ayrshire (Tyrrell, 1912, No. 1). This, however, was still of much less extent than that of the Early Carboniferous, although it gave rise to more specialised rock-types, and had a more prominent intrusive phase. The products of this eruptive period are distinguished generally by their alkaline and basic character, and by the presence of primary analcite. The surface outpourings are now restricted to a small saucer-shaped basin near Mauchline, lying between the Red Barren Coal Measures and the New Red Sandstone, but there is reason to believe that they once also covered the Patna and Dalmellington districts. These lavas were emitted from about sixty small vents, and consist mainly of olivine-basalts of Dalmeny and Hillhouse types, with analcite basalts, nepheline-basalts, and limburgites.

A large series of intrusive rocks are associated with this eruptive period. These are classified as follows:—

1. *Analcite-syenite* (Howford Bridge, Dippol Burn, Prestwick).—This is a thoroughly fresh rock consisting of alkali-felspar and analcite, with titanite, ægirine, and arvedsonite.
2. *Teschenite*.—These are by far the most abundant intrusive rocks in the province. They are divided on mineralogical and textural grounds into three types, named respectively the Glasgow, Galston and Cathcart types, after the typical locality.
3. *Picrite and Peridotite* (Lugar, Ardrossan, etc.).—These are gravitational differentiates of the teschenites.
4. *Lugarite* (Lugar, and Barshaw, near Paisley).—A leuco-

* These rocks differ considerably from true trachytes in the almost complete absence of ferromagnesian minerals. They are alkali-felspar rocks with a large content of iron-ore and good trachytic texture, and are allied to the bostonites.

cratic rock allied to ijolite, and containing 50 per cent. of analcite and nepheline, with titanaugite, barkevicite, and labradorite.

5. *Monchiquite*.—One occurrence, at the vent of Carskeoch, near Patna, carries huge phenocrysts of hornblende and biotite.

6. *Theralite*.—The *Bellow* type, occurring in the Lugar sill, is characterised by abundance of olivine, poikilitic fabric, and melanocratic character. The *Barshaw* type, occurring near Paisley, is also melanocratic, but is rich in titanaugite and barkevicite. It is closely allied to the *bekinkinite* of Madagascar (*Glasg. Mem.*, p. 134), and contains numerous veins of lugarite. Other types of theralite are known from this district, but have not yet been investigated in detail.

7. *Essexite*.—The well-known *Crawfordjohn* type, characterised by porphyritic titanaugite, with olivine, labradorite, and nepheline, occurs in the Carclout vent, which fixes its association with Late Carboniferous or Permian vulcanicity. The occurrence at Lennoxton, intrusive in Calciferous Sandstone lavas, and that of Crawfordjohn, intrusive into the Silurian, belong to this type. The Crawfordjohn rock has recently been shown by A. Scott to form an elongated boss, which has nothing to do with the Kainozoic N.W. dykes, as hitherto supposed.

8. *Kylite*.—This is an olivine-rich melanocratic end-facies of the essexites, containing olivine, titanaugite, and labradorite, in roughly equal proportions, with about four per cent. of nepheline and analcite. It forms a homogeneous set of sills and bosses in the Kyle district, near Dalmellington.

9. *Alkali-dolerite, essexite-dolerite, crinanite*.—These names are applied to numerous intrusions which show alkaline affinities by the abundance of titanaugite, with inconspicuous nepheline, analcite, or soda-orthoclase. Some of these rocks closely resemble the crinanite of Argyllshire (*Mem. Geol. Surv.*, *Knapdale*, 1911, pp. 116-8).

Apparently of Late Carboniferous age, but of strikingly different petrological affinities to the foregoing, are the great E.-W. dykes and accompanying sills of quartz-dolerite which outcrop abundantly in the Kilsyth-Croy district (Tyrrell, 1909, No. 3), and appear also at Dumbarton, Rowardennan, Bishopton, etc., within our district.

Kainozoic.—Arran is the great centre of Kainozoic volcanic activity in the Clyde area, although numerous dykes, referable to this period, occur in Bute, the Cumbræ, in the Cowal peninsula, and on the Ayrshire mainland. The granite which forms the circular boss of the northern mountains is by far the largest single body of igneous rock in Arran. It has closer affinities with the granite of the Mourne Mountains of Ireland than with those of Skye and Mull (*N. Arran Mem.*, pp. 104-5). In nearly all parts of the island, sills and dykes, probably representing the

hypabyssal phase of the granite, may be found. Amongst these are felsites, quartz-porphyrines, rhyolites, and pitchstones. Although Arran is the most famous locality for pitchstone in the world, and although there are over eighty separate occurrences of the rock in the island, it is astonishing to record that there is not a single comprehensive investigation or a single first-class chemical analysis extant. Mr. A. Scott has recently (1914, 1915) begun their detailed study and has made several excellent analyses. The writer has described an interesting subacid intrusion in the riebeckite-orthophyre of the Holy Isle, near Lamlash (*Geol. Mag.*, 1913, pp. 305-9).

A further feature of the Kainozoic igneous activity of the the Clyde area is the hitherto unrecognised abundance of composite sills and hybrid rocks of all kinds, especially in the southern half of Arran, where they rival those of Skye. In recent field work the writer has distinguished three groups of these rocks; the first, consisting of varying admixtures of felsite and basalt, or granophyre and basalt, appears to be identical with the Cnoc Carnach group of Skye; the second includes the remarkable composite sill of South Bute, described by W. R. Smellie (1915), and that of Bennan Head in South Arran, in which highly-porphyrific quartz-porphry and dolerite are the interacting rocks; the third type, occurring as far as at present known in the Tighvein complex, near Lamlash, consists of gabbro-granophyre mélanges producing hybrid rocks resembling the marscoite of Skye.

Another remarkable group of igneous rocks in South Arran includes the sills of coarse analcite-dolerite (teschenite and crinanite) at Dippin, Kings Cross, and Clauchland Hills, and certain massive dykes of crinanite at Whiting Bay and Brodick.

Finally we may notice the basic dykes which are numbered by thousands in Arran, and are common in Bute, the Cumbræes, and the Ayrshire mainland. In the last two localities the basic dykes are the only Kainozoic igneous rocks present. They show considerable petrographic diversity, but have not yet been subjected to detailed examination.

IV.—THE CAMPSIE FELLS.

BY PROF. J. W. GREGORY, D.Sc., F.R.S., F.G.S.

A visit to the Campsie Fells illustrates the general structure, petrology and glacial phenomena of the country north of Glasgow. The route crosses first the Carboniferous Limestone Series and boulder-clay drumlins on the floor of the Glasgow basin. At Kilsyth the Carboniferous Limestone Series is traversed by a quartz-dolerite sill, is much faulted, and is