the Pygasteridæ, so far from converging across the ambulacrum, actually diverge, while Diademoid processes, even when they do not meet in an auricular arch, are always inclined towards one another.

These three points of difference are all in a sense prophetic of the subsequent perignathic changes in Holoctypoida and Clypeastroida. The wide basal separation and increasing divergence of the processes suggest the future shifting of these structures to an interrarial convergence as seen in *Clypeaster*, and more completely in *Echinocyamus* or *Echinarachnius*. The situation of the processes of *Plesiechinus* well back from the peristomial margin is found in a greater degree in the Clypeastroida, and implies a considerable inclination of the lantern away from its typically vertical position in Regular Echinoidea.

The interrarial ridges, feeble though their development is, have strong points of resemblance with the homologous structures of *Discoides* and *Conulus*, as I hope to show in a forthcoming paper.

It thus appears that the perignathic girdle of the Pygasteridæ shows a very close correspondence with that of phylogenetically or ontogenetically young Diademoida as regards the essential disposition of its elements; but that in its details it already indicates a progressive tendency towards the Clypeastroid type of girdle. The development of the short interrarial buttresses, though clearly an adaptation to the requirements of the thin invaginated peristome, represents another foreshadowing of a typically Clypeastroid feature.

III.—SOME TERTIARY DYKES OF THE CLYDE AREA.

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(Concluded from the July Number, p. 315.)

LEIDLEITE AND INNINMORITE.—Typical rocks of these groups are as yet unknown in the Clyde area. A N.N.W. dyke at Barrassie Sands, near Troon (Ayrshire), has points in common with leidleite. It shows anorthite phenocrysts in a subvariolic groundmass of acicular feldspar and augite, enveloped in a partially devitrified glassy base. A north-south dyke at the north end of Loch Fad, Bute, may perhaps be regarded as a doleritic end-variety of leidleite (see Anderson & Radley, 1916, fig. 2*b*, p. 208). A pitchstone-like dyke from the Smurig Burn in the south of Arran has all the characters of leidleite, except that it carries rather abundant granular augite, instead of acicular crystals.

THOLEIITE (BRUNTON TYPE).—This type has been based by the petrographers of the Geological Survey on the so-called "augite-andesite" of the Brunton dyke, Bingfield, Northumberland, figured by Harker (1908, fig. 54, p. 203), and described and figured by Teall (1884, pp. 236-7). It is abundant among the Tertiary dykes of Mull, and two analyses of the type have recently been recorded (Geological Survey, 1914, p. 82; 1915, p. 55). In the brief notes accompanying the analyses these rocks are said to be composed respectively of "small clots of augite and acicular crystals of plagioclase, with interstitial dark-brown glass", and of "augite,

moderately basic plagioclase, magnetite, and of dark interstitial glass". Teall describes the microscopical character of the Brunton dyke as follows: "long, narrow, lath-shaped feldspars, irregular crystalline grains and plates of a nearly colourless pyroxene, and a small quantity of nearly opaque interstitial matter." The rock is figured in pl. xii, fig. 6, of his paper. Judging from the figures given by Harker & Teall, and from thin sections of Brunton types from the North of England dykes in the collection of the Geological Department of Glasgow University, the feldspar and augite are approximately equally developed, with perhaps a slight excess of the pyroxene, and the amount of glass is only slightly subordinate to either of the crystalline constituents. The Tynemouth dyke and several of the Ayrshire examples carry large phenocrysts of bytownite or anorthite of exactly the same characters as in cumbraite or inninmorite. Magnetite may or may not be present, and the texture is typically intersertal or tholeiitic. The type is clearly more basic than leidleite, inninmorite, or cumbraite, a fact reflected in the diminished quantity of glass. Norms calculated from the analyses of the Brunton type published by the Geological Survey show no quartz and 5 per cent of orthoclase in the 1914 analysis, and 4.2 per cent of quartz and 5.5 per cent of orthoclase in the 1915 analysis. Both rocks fall into the subrang *camptonose* (III, 5. 3. 4), showing at once that they are richer in the femic minerals than cumbraite, etc., and that there is only a negligible amount, if any, of excess silica.

FIG. 2a.—Tholeiite (Brunton type), N.N.W. dyke, Stairaird, River Ayr, near Mauchline, Ayrshire. $\times 20$. Large phenocryst of bytownite-anorthite; groundmass: grains of augite, and laths of labradorite, in base of dark glass.
 „ 2b.—Olivine-tholeiite (Corrie type), N.N.W. dyke, Birchpoint, Corrie, Arran. $\times 20$. Corroded phenocrysts of bytownite-anorthite; groundmass: laths of labradorite, grains of augite, olivine, and magnetite, in scanty base of dark glass.

The Ayrshire examples of the Brunton type of tholeiite may be represented by a N.N.W. dyke crossing the River Ayr near Stairaird, Mauchline. This rock (Fig. 2a) shows clusters of almost colourless granular augite, intermixed with diversely arranged, short feldspar laths ($Ab_1 An_1$), all held in a black glass. The phenocrysts consist of bytownite-anorthite with a narrow rim of labradorite, exactly similar to those of cumbraite. A rough estimate of relative proportions is about 35 per cent each of the groundmass feldspars and augite, 20 per cent glass, and 10 per cent of anorthite phenocrysts. A very small amount of olivine, fresh in this rock but serpentinized in the others, may be detected. On examination by a high-power objective the "black" glass turns out to be colourless, but charged with swarms of opaque black microlites. N.N.W. dykes conforming to this type, and exhibiting only minor variations in the quantitative relations of the minerals, occur in the River Ayr at Failford, near Tarbolton; in the Broadlie House Burn, near Dalry; and in the Coachford Burn, Cooperhill, Ochiltree.

Tholeiites of the Brunton type do not appear to be common in Arran, only three examples being known in a large suite of the Tertiary dykes. These dykes occur in the South Locherim Burn, Corrie; at 1,538 feet on the Saddle, between Glen Rosa and Glen Sannox; and on the shore near Largiemeanoch, Whiting Bay. Likewise Dr. W. R. Smellie's slides of the Tertiary dykes of Bute show only three examples belonging to the Brunton type, a dyke at the south end of Loch Fad; in the quarry behind the Power Station, Ardbeg, Rothesay; and on the shore south side of Stravannan Bay. Only one dyke of the Brunton type occurs in the Great Cumbrae, a north-west dyke, 11 feet thick, at Portachur Point.

OLIVINE THOLEIITE.—These dykes appear to represent a further and more basic stage than those of the Brunton type, although preserving a sufficient community of character with the foregoing to warrant the view that they are a continuation of the same series. They are characterized by the presence, often an abundance, of fresh olivine, and by the presence of a glassy base in minimum quantity. No chemical analysis of this group has yet been made. Two types are recognized according to the relative abundance of olivine. The first type, characterized by a small quantity of olivine and by its restriction to the groundmass, is represented by a large group of dykes near Corrie, Arran, and may accordingly be known as olivine tholeiite of the Corrie type. A typical example is provided by a dyke at Birchpoint, on the shore south of Corrie. This rock (Fig. 2b) carries numerous small phenocrysts of bytownite-anorthite with narrow labradorite margins. These crystals are often worn and corroded into curiously irregular shapes, and have glassy inclusions arranged in a thick marginal zone which faithfully follows the fantastic outlines of the crystals. The groundmass consists of a diverse mesh of short laths of labradorite ($Ab_1 An_1$), intermixed with granular or short prismatic crystals of a pale, violet-brown augite which is the most abundant constituent of the groundmass. Minute grains of olivine, partially or wholly serpentinized, and of euhedral magnetite, are uniformly scattered over the field, but form

minor constituents of the groundmass. The interstices are filled by a colourless glass, darkened by innumerable globulites. Quantitatively the glass forms probably less than 10 per cent of the total rock. Minute spherical vesicles filled with dark glass are rather abundant.¹

Rocks of this type occur freely near Corrie, but have not yet been found elsewhere. They vary within small limits of quantitative relations and texture.

The second type may be known as the Largs type owing to the occurrence of two beautifully fresh dykes on the shore near the town of Largs, Ayrshire. An extended description of these rocks is unnecessary, as they differ from the Corrie type only in the much greater abundance of olivine, not only as granular constituents of the groundmass, but as large phenocrysts. In the groundmass (Fig. 3*a*) there is an augmented proportion of augite relative to the other constituents, and a diminished, almost vanishing, proportion of glassy base. A dyke of this character also occurs in the gorge known as Creag Bhan, Whiting Bay, Arran. This type may be regarded as the most basic of the tholeiitic series of Tertiary dykes.

Fig. 3*a*.—Olivine-tholeiite (Largs type), N.N.W. dyke, shore $\frac{3}{4}$ mile south of Pier, Largs, Ayrshire. $\times 20$. Phenocrysts of anorthite and olivine; groundmass: laths of labradorite, grains of augite and olivine, in scanty base of dark glass. $\times 20$.

.. 3*b*.—Crinanite, N.N.E. dyke, high road above Cordon, Lamlash, Arran. $\times 20$. Ophitic plexus of titanite and labradorite laths, with abundant olivine and magnetite. Fresh, colourless analcite in triangular interstices between the feldspars.

OPHITIC OLIVINE-DOLERITE AND CRINANITE (Fig. 3*b*).—The dykes of this group stand apart from those belonging to the tholeiite series, and, as far as present knowledge goes, appear to belong to an earlier phase of Tertiary volcanic activity in the Clyde area. A crinanite dyke from Whiting Bay, Arran, was described some years ago (Tyrrell, 1913); but a large number of these dykes have since been

¹ For a figure of this rock see Tyrrell, 1909, Pl. XIX, Fig. 5.

discovered all over the Clyde area. The true crinanites are inseparably associated with, and may be shown to pass into by a graduated series of sections, ophitic olivine-dolerites, which differ from them only in the absence of analcite or radial zeolites. The group is typically non-porphyrific, free from glass, and rich in olivine. In general the rocks are so fresh that it is difficult to believe that the interstitial analcite and zeolites can be other than primary constituents. The crinanites are ophitic olivine-analcite-dolerites of mafelsic composition, i.e. the feldspars are quantitatively approximately equal to the combined olivine, augite, and iron-ores. The chemical analysis of a typical crinanite from Inver, Jura (Flett, 1911), gives a norm which falls into the subrang *auvergnose* of the American Quantitative Classification, but very close to *ornose* (III, 5 (3)4.5). It shows 1.5 per cent of nepheline, and consequently the rock falls into the "unsaturated" group of Shand, whereas the tholeiites are quartzose and fall into the "over-saturated" group.

A typical example from Whiting Bay is described in the above-cited paper. The feldspar is much in excess of the augite, so that the small plates of the latter mineral are cut up into thin, detached, triangular strips by the feldspar laths. The augite is always the deeply coloured, brown-violet, titaniferous variety. The olivine is generally quite fresh, and occurs in rounded grains which are uniformly distributed over the field. The interstices are filled with analcite or radial zeolites, but the amount is always small, much smaller than in the teschenite group. When the olivine happens to be serpentinized, the green material appears to migrate into the interstices and obscures the presence of analcite. Some of the dykes may thus be set down as olivine-dolerites when they are really crinanites. The rocks vary in coarseness of texture from almost gabbroid to basaltic types, according to the size of the intrusion. They usually occur as broad, massive dykes, which may in some cases have feeder relations to the great crinanite sills of the south of Arran. Besides the Whiting Bay dyke mentioned above, crinanites are now known to occur in Arran at the following places: Kingscross Burn, a quarter of a mile south-west of Kingscross Bridge; by the high road above Cordon, Lamash (Fig. 3*b*); on the shore south-east of Cordon, Lamash; the shore a quarter of a mile north of the Pier, Brodick; Invercloy, Brodick; and An Sgriob Quarry, 2 miles south of Corrie. Related olivine-dolerites occur at the first fall in Glen Ashdale, Whiting Bay, and on the shore near Dunfion, Corriegills.

In Bute a N.-S. crinanite dyke extraordinarily rich in fresh olivine occurs on the road 2 miles north-east of Dunstrone; and a 3 ft. N.N.E. dyke on the shore at Kerrytonlia is probably also a crinanite, but contains much diffused serpentinous matter. The related olivine-dolerites also appear in several places. In the great Cumbræ two crinanite dykes are known, and two of the related olivine-dolerites (Tyrrell, 1917). Both here and in Bute the dykes of this group trend in a N. to S. or N.N.E. direction. On the Ayrshire mainland crinanites are known from the shore near the Heads of Ayr.

CONCLUSION. — Although much still remains to be discovered

concerning the thousands of Tertiary dykes in the Clyde area it is already clear that they show considerable petrographic diversity, and that the various groups have differing relations in regard to their size, length, direction, age, and degree of connexion with the local centres of Tertiary volcanic activity. Only rocks of andesitic or basaltic composition have been dealt with in this paper. There is a well-marked division into two groups: (a) a tholeiitic group, characterized by the presence of glass, intersertal texture, phenocrysts of basic felspar, and presence of occult quartz; and (b) a crinanite-olivine-dolerite group, with coarse ophitic texture, with interstitial analcite or radial zeolites, rich in olivine, and free from glass or phenocrysts. The tholeiitic group ranges in chemical composition from sub-acid types (Anderson & Radley, 1916, p. 210) to thoroughly basic types such as those of Corrie and Largs. The crinanite-olivine-dolerite group, however, shows no significant variation, and remains uniformly basic. It is probable that other groups will be found as investigation proceeds, especially in Arran, where only a tithe of the dykes (and related sills) have been closely examined. It will be necessary in future to define the relation, if any, between the great pitchstone-felsite group of Arran and the tholeiitic series. There may also be a relation between the crinanites and the basalt-felsite composite sills and dykes of the south of Arran.

I must acknowledge with gratitude the assistance received in this work from Dr. H. H. Thomas, Petrographer to the Geological Survey, who has not only loaned to me all the Survey slides bearing on the subject, but has looked through many of my slides and compared the rocks with the types occurring in Mull. I am also much indebted to Mr. Chetai Yu and Dr. Alex. Scott for the excellent chemical analysis of cumbraite in this paper.

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IV.—OBSERVATIONS ON THE RECONSTRUCTED SKELETON OF THE DINOSAURIAN REPTILE *DIPLODOCUS CARNEGIEI* AS SET UP BY DR. W. J. HOLLAND IN THE NATURAL HISTORY MUSEUM IN LONDON, AND AN ATTEMPT TO RESTORE IT BY MEANS OF A MODEL.

(PLATES XXII AND XXIII.)

By the Rev. H. N. HUTCHINSON, M.A., F.R.G.S., F.G.S., F.Z.S., etc.

IN the following pages the writer has endeavoured to consider this skeleton in a common-sense way, and to arrange the limbs with reference to ordinary mechanical principles, and also by comparison of the bones with those of different mammalian and reptilian types. A good many years ago, Von Meyer was so struck by the colossal and rather straight hind-limb bones of the Dinosauria and their superficial resemblance to those of elephants, that he proposed the term *Elephantopoda*; but at that time the group had not been classified by Marsh and others into distinct sub-orders, with very different limbs.

The writer maintains that Dr. W. J. Holland,¹ Professor Osborn,² Dr. Marsh, Hatcher,³ and others who are responsible for the present reconstruction (see Plate XXII) have been, perhaps unconsciously, influenced by Von Meyer's interpretation, and consequently were somewhat too anxious to produce something very big and imposing. He has endeavoured to give a more natural interpretation of this skeleton, and to bring it more into harmony with other types of reptiles. The restorations by Tornier and Holland are given in the *American Naturalist*, vol. xlv, 1910.

Before proceeding to discuss the details of this colossal skeleton, 81 feet long or more, it will be convenient briefly to summarize the broad conclusions which have been arrived at.

1. With regard to the general pose of the skeleton. There are grave reasons for considering that it stands too high.

2. The limbs, instead of being placed in a vertical plane, should be inclined at an angle to the body, somewhat as we see in lizards and crocodiles. Such an arrangement involves bringing down the vertebral column into a lower position, such that the

¹ W. J. Holland, *Memoirs of the Carnegie Museum*, vol. ii, No. 6, *The Osteology of Diplodocus*, Marsh.

² "A Review of some recent criticisms of the restorations of Sauropod Dinosaurs existing in the Museums of the United States, with special reference to that of *Diplodocus Carnegiei* in the Carnegie Museum": *American Naturalist*, vol. xlv, May, 1910.

³ Dr. J. B. Hatcher. *Memoirs of the Carnegie Museum*, vols. i and ii.