NOTICES OF MEMOIRS.

I.—Bembridge Limestone at Creechbarrow Hill, Isle of Purbeck.[1]

Report of the Committee, consisting of Professor T. McKenny Hughes (Chairman), Mr. H. Woods (Secretary), Dr. J. J. H. Teall, Dr. J. E. Marr, Professor E. J. Garwood, Mr. Clement Reid, Mr. W. Whitaker, and Mr. H. A. Allen, appointed to investigate the occurrence of the Bembridge Limestone at Creechbarrow Hill.

On the Results of the Further Examination of Creechbarrow Hill.

By Henry Keeping.

(*Abridged.*)

In September, 1910, I was sent by Professor Hughes to collect fossils on Creechbarrow, with a view to determining the age of the limestone which caps the hill, and I obtained a sufficient number of characteristic forms to enable me to refer the rock to the Bembridge Limestone. In the report then published[2] I further suggested that there was plenty of room for the rest of the Tertiary beds which might be expected to occur below the Bembridge Limestone, and I published a section in illustration of that view.

A grant from the British Association has since enabled me to ascertain, by means of excavations and borings, the nature of the strata along the flank of the hill.

The details thus obtained were as follows:—

Pit I (*the highest on the east side of the hill*).

		ft.	in.
(*a*)	Surface soil.		
(*b*)	Mixed clay and gravel with sharp angular flints	3	0
(*c*)	Blocks of hard limestone with *Melanopsis* and *Paludina* .	2	0
(*d*)	Rubbly limestone. This I recognized as the same as the bed which occurs at the base of the limestone on Headon Hill, where it is rich in mammalian remains. I found here a tooth of *Palæotherium* on my last visit, and we now obtained a good tooth of *Dictulumus leporinus* (Owen)	0	9
(*e*)	Caking sand	3	6
(*f*)	Dark-brown sand	14	6
(*g*)	Light-grey sand with a very large flint at the base. This is on the same horizon as the bed in which Mr. Hudleston found the curiously coated flints which he thought were in situ and passed under the limestone	1	3
		25	0

Pit II.

		ft.	in.
(*a*)	Surface soil.		
(*b*)	Clay, sand, and gravel with fragments of weathered limestone at the bottom	16	0

[1] Report communicated to British Association Meeting, Dundee, September, 1912, Section C (Geology).

[2] Geol. Mag., Dec. V, Vol. VII, October, 1910, p. 436.

PIT III.

	ft.	in.
(*a*) Surface soil.		
(*b*) Dirty gravel	3	0
(*c*) Caking sand	3	0
(*d*) Large and small flints	1	0
(*e*) Brown, stiff, sandy clay	3	0
(*f*) Loose flint gravel	2	0
(*g*) Black streaky clayey sand with flint-chips, concretions, and much manganese	7	0
(*h*) Hard irony crust	0	3
(*i*) Clayey sand with perished flints; one large white flint at the bottom of the hole	0	3
	19	6

PIT IV.

(*a*) Vegetable mould	0	9
(*b*) Clay, sand, and gravel with very large flints up to 1 cwt. This much resembles the Middle Headon Venus Bed	9	0
(*c*) Drab sandy clay like that in brickyard; not bottomed	15	0
	24	9

PIT V (*about* 10 *feet below the summit on the west side of the hill*).

(*a*) Surface soil.		
(*b*) Clay with angular flints	2	6
(*c*) Very stiff hardened clay with pieces of rubbly limestone containing much manganese and soot-like patches	9	6
(*d*) Fragments of Bembridge Limestone very rich in fossils. This was where I obtained the chief collection made during my former visit. On this occasion we obtained a good specimen of *Unio*, the first I believe, found at this horizon	2	0
(*e*) Hard crumbling limestone	7	0
(*f*) Sandy clay	9	0
(*g*) Grey sands with quartz pebbles and broken flints. On my former visit I found a large fragment of Bembridge Limestone at a depth of 13 feet not far from this pit	4	0
	34	0

The lowest bed we touched was the drab sandy clay at the bottom of Pit IV, which is the same as that seen in the brick-pit, and the thickness of which I estimate to be not less than 40 or 50 feet. It seems to have been much used for dressing the land, and we found many old pits from which it had been obtained along the west side of the hill. This clay I regard as the equivalent of the Lower Headon formation. The coarse sand, which occurred above this, I take to be the Middle Headon Venus Bed, while the mottled red and green clays or marls which we found about 16 feet below the summit of the hill much resembled the Osborne Series.

Of the part of the hill explored by us I should say that about three-quarters consisted of Oligocene strata and the rest of sand and gravel. There is everywhere evidence of great disturbance of the strata, whether we refer this chiefly to large movements of faulting and overthrust, or the more superficial action of landslips, soil creep, etc.

[We are glad to print the important details of the Creechbarrow strata that have been obtained by Mr. Keeping, especially as they confirm the original discovery of our old friend Hudleston. (See GEOL. MAG., 1902, p. 241; 1903, pp. 149, 197.)—ED.]

II.—A THEORY OF THE MENAI STRAIT.[1] By EDWARD GREENLY, F.G.S.

RAMSAY'S view of the Strait as a glacial furrow was in the main accepted ; but it was shown, from the general glacial phenomena and from soundings, that the middle reach of the Strait cannot be explained in that way. Evidence was adduced to show that this reach was excavated by glacial waters during the recession of the ice at a time when the mutual relations of the ice of the mountain-land and of the sea-basin admitted of the accumulation of a temporary lake. Post-Glacial erosion and subsequent changes of level have completed the bed of the Strait as it now exists.

III.—NOTE ON THE FISH-REMAINS COLLECTED BY MESSRS. R. CAMPBELL, W. T. GORDON, AND B. N. PEACH IN PALÆOZOIC STRATA AT COWIE, STONEHAVEN.[1] By R. H. TRAQUAIR, M.D., LL.D., F.R.S.

THE fish-remains from Cowie, Stonehaven, consist of :—

1. Small scutes which are about three times as long as they are broad, slightly convex on one side and correspondingly concave on the other, and apparently pointed at both ends. They seem to me to be referable to the category of Cephalaspidian scutes, only the external ornament, where visible, consists of longitudinal and slightly wavy striæ in place of tubercles. That the species to which they belong, as yet unnamed and undescribed, is pretty certain ; but the advent of additional material is necessary before proceeding further in that direction.

2. Several fragments of thin minutely tuberculated plates, which may also be Cephalaspidian, though their nature, indeed, is still problematical.

3. Several specimens of a beautiful *Cyathaspis,* which I herewith dedicate to Dr. R. Campbell, and of which I give a brief diagnosis.

Cyathaspis Campbelli (Traquair).—Shield, ovoid, concave, shallow, broadest part situated behind the point of greatest expanse ; covered with stout ridges running in a longitudinal direction, but also tending to converge a little anteriorly and posteriorly. These ridges are also constantly interrupted, so as to give almost a tubercular appearance, the tubercles being comparatively distantly placed, much compressed, and crenulated.

IV.—THE DOWNTONIAN AND OLD RED SANDSTONE OF KINCARDINESHIRE. By ROBERT CAMPBELL, M.A., D.Sc.

I.—*Downtonian.*

A THICKNESS of nearly 3,000 feet of vertical or highly inclined strata, formerly included with the Lower Old Red Sandstone, but now regarded as of Downtonian age, intervenes between Craigeven Bay and Stonehaven Harbour. Three groups of beds in this succession may be particularly noted :—

1. At the base of the series there is a thickness of about 200 feet of breccias interbedded with fine red mudstones and made up mainly of fragments of the underlying (?) Upper Cambrian rocks. The basement breccias rest unconformably on the (?) Cambrian. The unconformable junction, which is well seen on the north side of the headland at Ruthery Head, was formerly regarded as a line of faulting.

2. About 20 yards east of Cowie Harbour there occurs a thick belt of grey and greenish mudstones and shales which yield *Dictyocaris* in abundance. From this horizon have been obtained also *Ceratiocaris* ; *Archidesmus* sp., and a new genus of Myriopod ; (?) larval form of insect ; *Eurypterus,* sp. nov. ; fragments of scorpion ; plant fragments and worm-tracks. Further, a thin bed of reddish sandy mudstone underlying the above series has yielded numerous plates of a new *Cyathaspis.*

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

3. About 60 feet below the *Dictyocaris* horizon there is a thickness of about 40 feet of volcanic conglomerates and tuffs, the presence of which implies that the volcanic activity, which was so marked a feature in the history of this area during the Lower Red Sandstone period, had already been initiated in Downtonian times.

Neither *Dictyocaris* nor *Ceratiocaris* has been found elsewhere in rocks younger than Upper Silurian, and, apart from the occurrence of tuffs, the lithological characters of the above succession recall at once the typical Downtonian rocks of the south of Scotland. The highest beds of the Downtonian pass conformably up into the micaceous sandstone and conglomerates of Stonehaven Harbour which may be considered as the base of the Lower Old Red Sandstone.

II.—*Old Red Sandstone.*

(*a*) *Lower.*—The Lower Old Red Sandstone Series consists of a great thickness of coarse conglomerates and sandstones with intercalated lavas and tuffs. Palæontological evidence is everywhere meagre, but the recognition of a number of well-marked volcanic zones has been of value in elucidating the structure of the area. The lavas include dacite, hornblende-biotite andesites, augite andesites, hypersthene andesites, hypersthene basalts, and olivine basalts. The tuffs are all acid in character. Minor intrusions of presumably Old Red Sandstone age occur in the form of dykes and thin sills of quartz porphyry, biotite porphyry, dolerite, and lamprophyre. The distribution of the lavas indicates that the centres of eruption lay along two lines—one to the east of the present coast-line, the other over the area of Dalradian Schists to the north of the Highland boundary fault.

The coarse conglomerates, which build up a great part of the succession, fall readily into two groups: (1) those in which boulders of quartzites or other 'Highland' rocks predominate; (2) those which are made up almost exclusively of volcanic rocks—volcanic conglomerates. Two points of particular interest may be noted in the former group—the occurrence of boulders of the 'Haggis rock' type of greywacké, and the abundance of boulders of the 'newer' granites, which have been collected even from the lowest conglomerates. The distribution of the volcanic conglomerates points clearly to the denudation of a thick series of rhyolites and acid andesites which must have extended far to the north of the Highland fault.

The chief structural feature of the Lower Old Red Sandstone area is a continuation of the well-known synclinal fold of Strathmore. In Kincardineshire, however, in the district to the west of Elfhill, there intervenes between the syncline and the Highland fault a steep-limbed anticline, pitching out to the south-west. The southern limb of the syncline is traversed by numerous powerful dip faults.

(*b*) *Upper.*—The Upper Old Red Sandstone occupies a small area on the coast in the neighbourhood of St. Cyrus. Although no fossils have been recorded, the lithological evidence—and particularly the occurrence of characteristic cornstones—leaves no room for doubt that here we are dealing with an outlier of the more extensive tract of Upper Old Red Sandstone of Arbroath. In Kincardineshire the Upper Old Red Sandstone is everywhere faulted against the Lower.

V.—On an Actinolite-bearing Rock allied to Serpentine.[1] By A. W. Gibb, M.A., D.Sc.

THIS rock is associated with the intrusion of basic rocks in Belhelvie, Aberdeenshire. Towards the northern end of this mass, which consists of troctolites, serpentines, and allied types, a rock is occasionally

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

met with which differs in some respects from the varieties common in the district. In its most typical development it shows a large number of dark green rounded spots set in a fine felt of paler green colour, full of glancing needles. Most of the specimens show a more or less clearly defined banding or schistosity. The affinities of the rock are somewhat obscure in hand-specimens. But under the microscope the dark spots are seen to represent olivine, which is still partly unaltered, but partly serpentinized, as well as granulitized and drawn out. The rest of the rock is largely made of actinolite in small crystal flakes; there are also present a green spinel, abundant magnetite, and sometimes other ingredients. In most varieties there is no trace of felspar. This rock passes into varieties in which the spots are much less obvious, and finally grades into a rock that might be described as an actinolite-schist.

The exposures of this rock, so far as they have been mapped, lie mostly on the outer fringe of the basic intrusion, and therefore close to the line of junction with the metamorphic rocks into which the igneous rocks have forced their way. From its field relations and its general characters it is clear that it represents a type of the basic rock which has undergone actinolitization on an extensive scale. The original rock from which it is derived must in most cases have been an olivine-enstatite rock, more or less completely serpentinized, or else a very basic troctolite. Although actinolitization is widespread in this, as in other metamorphic areas, a rock of this particular type has not been noted in this locality before. It has nowhere been found in large mass, and seems essentially a marginal phase. The most prominent exposure yet met with is, or was, a clump in a field adjoining the Udny Road, immediately south of 'Skelly-hill Wood'. This exposure has recently been entirely blasted away, and it seemed desirable to make a definite record of its occurrence.

VI.—The Archæan Rocks of Lewis.[1] By B. N. Peach, LL.D., F.R.S., and J. Horne, LL.D., F.R.S.

DURING 1911 the authors visited Lewis with the view of comparing its Archæan rocks, previously described by Macculloch, Murchison, Heddle, and James Geikie, with the types of Lewisian Gneiss mapped by the Geological Survey along the western seaboard of Sutherland and Ross. The areas examined comprised sections taken at intervals along the east coast from Tolsta Head, north of Stornoway, to near Loch Bhrollum, opposite the Shiant Isles—a distance of about thirty miles; and along the west side from the Butt of Lewis to Carloway—a distance of twenty-five miles. Traverses were made across the island (1) from Barvas on the west to Stornoway on the east, thence over the Eye peninsula to Tiumpan Head; and (2) from Carloway by Callernish to Keose on Loch Erisort, and Stornoway.

A large series of specimens was collected and submitted to Dr. Flett for examination, who has furnished a valuable detailed report showing wherein they resemble and wherein they differ from types described by Dr. Teall in the Geological Survey Memoir on *The Geological Structure of the North-West Highlands of Scotland* (1907). Dr. Flett has arranged the specimens in the following groups: (1) muscovite-biotite-gneiss, (2) biotite-gneiss, (3) biotite-hornblende-gneiss, (4) hornblende-gneiss, (5) pyroxene-gneiss, (6) hornblende-schist, (7) pyroxenite, (8) pegmatite-gneiss, (9) granite-gneiss, (10) mylonite.

In the various sections examined throughout the island, rocks belonging to groups (2), (3), and (4) are the main components of the Archæan

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

Complex. They are intimately associated with each other, and have a common foliation. The muscovite-biotite-gneisses (1) occur together with the biotite-gneisses, but they are not abundant. The pyroxene-gneiss (5) is recorded only from one locality, viz. Dalbeag, near Carloway, where it forms part of a basic mass which is cut by the foliated granite of Carloway (9). The hornblende-schists (6) constitute basic masses in the complex, with a foliation more or less parallel with that of the contiguous gneisses. The relative age of the members of this group has not been definitely ascertained. The pegmatites and pegmatite-gneiss (8) intersect the other components of the complex, but they are sparingly represented compared with the great development of these types on the mainland between Laxford and Cape Wrath. One example of pyroxenite (7) was obtained in the policies of Stornoway Castle. Mylonites (10) are typically developed in certain sections along the eastern seaboard between Tolsta Head and Loch Bhrollum.

In the areas examined, the north-west and south-east strike, referred to by Murchison, is not characteristic of the gneisses of Lewis. It is prevalent immediately to the west of Stornoway, but exceptional in other tracts. In this connexion the observations of Professor James Geikie in the Eye peninsula were confirmed. The dominant strike over extensive areas runs a few degrees east of north and west of south; in certain localities it is north-east and south-west, and in others nearly east and west.

The prevalent types of gneiss closely resemble those to be found on the mainland between Loch Laxford and Cape Wrath, without the great series of acid intrusions. The structure is coarsely granular, or granulitic, the mineral grains being rounded and not elongated. The range of rock types seems to be comparatively limited, for there is a marked absence, in the areas examined, of the pyroxene-gneisses with blue quartz, of pyroxene-granulites, and other basic and ultrabasic materials, which are so characteristic of the Fundamental Complex between Lochinver and Scourie on the mainland. The remarkable series of basic and ultrabasic dyke intrusions in the west of Sutherland has not been detected in Lewis.

The flaggy granulitic gneisses of the Butt of Lewis which appear to run southwards along the belt of high ground between Stornoway and Barvas are of special interest. In structure they closely resemble the Moine gneisses east of the Moine thrust-plane, but they differ petrologically from the rocks of sedimentary origin that form the Moine Series of the Geological Survey. The system of over-folding and the direction of the axial planes of the folds approximate to those found in the Moine rocks on the mainland.

The platy rocks or mylonites, noted by Macculloch, occur along definite lines of movement, trending a few degrees east of north and west of south. Actual thrust-planes have been detected, which are inclined to the south of east at low angles, as if the displacements had been in a westerly direction. Various stages in the development of mylonites from the acid and basic gneisses are represented.

VII.—The Origin of Kopjes and Inselberge.[1] By J. D. Falconer, M.A., D.Sc.

DETACHED hills, projecting crags, and isolated rocks are features of almost every landscape, and in the moister regions of the globe their origin has usually been correctly assigned to the ordinary processes of denudation. They may arise either through dissection of earlier

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

plateau-surfaces, as frequently in the case of detached flat-topped and pyramidal sandstone hills, or by the weathering out of the more resistant units where the surface is composed of rocks of different degrees of hardness, as in the case of escarpments and of detached crags and hills of igneous rock. The kopjes and island mountains of the warmer temperate and tropical regions are essentially of similar origin, but on account of the present climatic conditions being in many cases different from those under which they were formed, their actual mode of origin has given rise to considerable discussion. A striking feature of these kopjes and inselberge is that they rise at intervals from an apparently level or gently undulating plain, which in most, if not all, cases should be regarded as a former base-level of erosion. The typical kopjes of South Africa are of sandstone, shot with veins and dykes of igneous rock, which has given them the necessary power of resistance to the agents of erosion. The old crystalline regions of Africa, however, are dotted with domes and turtlebacks of granite and detached groups of granite hills, which represent the more resistant elements of the crystalline complex. Some of these isolated hills possess flattened caps of weathered rock, and it seems probable, therefore, that the sculpturing of the original crystalline surface was due, not so much to the direct erosion of the unweathered rocks, as to the effect of periods of elevation and erosion following upon periods of decomposition in situ at base-level. As the result of erosion a somewhat irregular surface would be produced, but a slight subsequent negative movement would suffice for the obliteration of the minor irregularities and the consequent accentuation of the less weathered portions of the surface. The repetition of such a cycle would lead to the increased prominence of the earlier hillocks and the formation of others of lower level. It has been suggested that a landscape with inselberge is of desert origin, but the various phenomena can be explained more readily as the result of weathering and erosion during successive small oscillatory movements of a regional character in the neighbourhood of base-level.

VIII.—The Heavy Mineral Grains in the Sands of the Scottish Carboniferous.[1] By T. O. Bosworth, B.A., B.Sc., F.G.S.

THESE observations were made at the commencement of an investigation which the author has now no opportunity to carry on.

The chief heavy grains are :—

Garnet, which, though in some sands practically absent, in others is in such excessive quantity as to almost mask the presence of other grains.

Zircon, always present, and sometimes the most abundant species.

Magnetite, always present.

Tourmaline, always present.

Rutile, always present, but varies widely in quantity and characters.

Staurolite, often present, but not plentiful.

Anatase, occasionally present in noticeable amount, as well-formed plates of steel-blue colour.

Barytes, found in a few cases in large amount. It is probably a cement, though well-formed crystal plates occur. Sandstones containing this cement are very hard. I find it in several building stones.

Characteristic of all the grains is their angularity. The garnets have the dodecahedral cleavage developed out in a remarkable manner,

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

so that the grains have elaborate zigzag shapes with innumerable corners and edges. The contrast between these heavy grains and those in desert sands is much more marked than in the case of quartz.

The heavy mineral contents prove the sands to belong to at least two entirely different kinds :—

(*a*) Sands in which the heavy mineral grains consist mainly or largely of garnets.

(*b*) Sands in which garnet is absent or scarce.

Vertical and Lateral Distribution.—The amount of evidence yet collected is only sufficient to be suggestive of the kind of results which may be obtained.

In the following list o denotes garnetiferous, × denotes non-garnetiferous. (Measurements in bore sections are actual, and are not corrected for inclined strata.)

Red Measures.		
o	Rutherglen.	
Coal-measures.		
o	Cambuslang	above Humph Coal.
o	Chapelhall, Shottsburn	24 feet above Lower Drumgray Coal.
o	Chapelhall, Shottsburn	just above Lower Drumgray Coal.
o	Chapelhall, Shottsburn	,, ,, ,,
o	Fauldhouse Quarry	above Crofthead 4 feet Coal.
×	Chapelhall, Shottsburn	below the Coals, faulted, and near Millstone Grit.
Millstone Grit.		
×	Bilston Burn, near Edinburgh	Roslin Grit.
×	Glasgow, Blochairn Quarry	above fireclays.
×	Muirhouse Bore, Lanarkshire	depth 30 feet.
×	Muirhouse Bore, Lanarkshire	depth 174 feet.
×	Levenseat	above Curdley Ironstone.
×	Balfour Bore, Fife	12 feet above Levenseat Limestone horizon.
o	Bilston Burn	6 feet above Castle Carey Limestone horizon.
Carboniferous Limestone Series.		
o	Balfour Bore, Fife	36 feet below Calmy Limestone horizon.
o	Bilston Burn	100 ,, ,, ,,
o	Balfour Bore	360 feet above Index Limestone.
×	Giffnock	270 ,, ,, ,,
o	Balfour Bore	150 ,, ,, ,,
o	Bilston Burn	12 ,, ,, ,,
o	Bishopbriggs, Hunters' Hill	just ,, ,, ,,
×	Kirkintilloch	40 feet below Index Limestone.
o	Linlithgow	200 ,, ,, ,,
×	Bilston Burn	540 ,, ,, ,,
×	Balfour Bore	798 ,, ,, ,,
o	Balfour Bore	1,242 ,, ,, ,,
×	Balfour Bore	1,374 ,, ,, ,,
o	Bilston Burn	5 feet below Hosie Limehouse horizon.
×	Bilston Burn	10 feet above North Greens Limestone.
Calciferous.		
×	Milngavie	above the Traps and below Hurlet Limestone.
×	Burntisland, Grange Quarry	about Burdiehouse horizon.
×	Hailes Quarry.	
×	Craigleith.	

Conclusions and Suggestions.—The sands containing such an extraordinary quantity of angular garnet have been derived from the Highland schists to the north and north-west of the basin, whilst the sands devoid of garnet are likely to have come from the north-east, east, or south.

It may be possible by a study of the heavy mineral grains and of the current-bedding, and the thickening and thinning of the beds, to subdivide the whole of the Carboniferous accumulation into a number of great lens-shaped or wedge-shaped bodies of sediment, which have been introduced from various directions and are interdigitated in a complex manner. These great lenticles might be expressible on maps, and might be helpful in explaining the lateral changes and the distribution of the coals.

IX.—A MULL PROBLEM: THE GREAT TERTIARY BRECCIA.[1] By E. B. BAILEY, B.A., F.G.S.[2]

THERE is in Eastern Mull a great breccia formation, with, in places, several intercalated rhyolite lavas. The breccia consists for the most part of an unbedded assemblage of blunted blocks and fragments of gneiss, granophyre, gabbro, and basalt, often associated with rhyolitic debris, for which latter a truly volcanic origin can be readily admitted. The problem is whether the non-rhyolitic material of the breccia has been derived through explosion or erosion. If the former alternative is adopted, many of the breccia outcrops must be regarded as marking the sites of volcanic vents, since in several cases the boundaries of the breccia are frankly transgressive. At the present time it is considered that the evidence favours an alternative view, that the breccia is an unconformable formation later than the basalt lavas of Mull, and that its transgressive relations are due to erosion which preceded and accompanied its formation. The basalt lavas of Mull have been violently folded into a series of anticlines and synclines, and it is in one of these synclines that the main outcrop of breccia in Eastern Mull is preserved, with every appearance, moreover, of approximate conformity to the surrounding basalts. Here it is difficult to escape the conclusion that the breccia is a thick layer overlying the basalts and folded with them. Alongside of the syncline is an abrupt anticline, in which are exposed all the rocks commonly recognizable as fragments in the breccia. The anticline has a core of gneiss, flanked locally by upturned Mesozoic sediments, and these by steeply dipping basalt lavas; intruded, chiefly into the gneiss, are granophyre and gabbro. Patches of breccia, distributed without reference to geological structure, occur in this anticlinal region, and rest upon or against all the rocks mentioned above. Although no positive conclusion can be drawn, it is suggested that the breccia has in large measure resulted from erosion, which operated during the period of upheaval of this and neighbouring anticlinal ridges.

X.—THE SEQUENCE OF VOLCANIC ROCKS IN SCOTLAND IN RELATION TO THE ATLANTIC-PACIFIC CLASSIFICATION OF SUESS.[1] By JOHN S. FLETT, M.A., D.Sc., F.G.S.

THE recognition of two great families of igneous rocks, the Atlantic and the Pacific, and their relation to certain types of earth-movement, which we owe to Harker, constitutes one of the greatest advances in rational petrology.

In Scotland we may take the Carboniferous volcanic rocks as typical Atlantic, while the volcanic rocks of Lower Old Red Sandstone age are characteristic of the Pacific group. We may add to the Atlantic two other series, the Permian or late-Carboniferous volcanic rocks of Ayrshire and East Fife and the nepheline-basalts (presumably Tertiary) of Caithness, with their associated camptonites and monchequites.

The Tertiary volcanic rocks of the Hebrides are Atlantic, and are associated with movements of Atlantic types. There is much reason in ascribing also to this period the north-west dykes, so abundant in Scotland, which contain not a few nepheline-bearing rocks.

The remaining volcanic rocks of Scotland are of distinct type. They comprise the Tayvallich lavas (perhaps pre-Cambrian), the Upper Cambrian volcanic rocks of the Highland border, and the Silurian (and

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.
[2] With the permission of the Director of the Geological Survey.

https://doi.org/10.1017/S0016756800115894 Published online by Cambridge University Press

Ordovician) lavas of the Southern Uplands. Pillow-lavas with keratophyres, etc., characterize this group. They are not connected with movements either of Atlantic or of Pacific kind, and may be placed in a special family.

XI.—On Buckled Folding.[1] By G. Barrow.

A NUMBER of descriptions have been published of portions of areas of regional crystalline metamorphism in which the dip of the bedding, or in some cases the dip of the foliation, is described as being at a low angle over a considerable area. These descriptions are at times so worded as to convey the impression that this represents the original and but slightly disturbed bedding of the altered sediments. Experience is gradually proving that the altered sediments in such areas are always intensely folded, and the detailed examination of the Highlands suggests that in place of these long-continued low dips being due to small disturbance, they really represent the most complicated form of structure, for which the name of 'buckled folding' is suggested.

The best-known illustration of the phenomenon in this country is afforded by the gneissose-flagstones or Moine gneisses. The deceptive nature of the dips in the rocks was soon recognized by the officers of the Geological Survey of Scotland, who found that in cliff sections the beds really ascended the cliffs by a zigzag course to which the term 'lightning-structure' was applied.

The mode of production of this 'zigzag' structure can be traced on the cliffs between Stonehaven and Muchalls, in Kincardineshire. The rocks in these cliffs consist of alternations of grits, gritty shales, and shales, becoming more and more crystalline as we proceed northward. Nearer Stonehaven the bands of grit may be seen to ascend the cliffs in an unbroken or unbent course from bottom to top, having a high dip in a northerly direction. The limbs of the folds are thus isoclinal and unbent. But as we proceed northwards the course of the grit bands up the cliff face is no longer straight; a small overfold or 'buckle' is developed on it. At first only one is seen in the whole height of the cliff; further north two occur; then three, and so on, till at last they are so close together that the still straight portion of the fold is little, if at all, longer than the 'buckled' or overfolded portion. If the upward course in the cliff of each grit band be carefully followed it will be found that the oncoming of this 'buckling' structure does not alter the dip of the band as a whole; it still descends at much the same angle, only it pursues a more zigzag course. The overfolds or buckles all face the same direction right up to Muchalls, and a little consideration will show that this 'buckling structure' must have been produced after the isoclinal folding was completed. There is thus no evidence to suggest that the rocks in which the buckling structure has been developed should be separated as a different series from those in which it does not occur. In the interior of the South-Eastern Highlands this structure is present in all but the southern margin of the area, till we reach the first outcrop of the Highland quartzite, where the buckling rapidly ends and the earlier isoclinal folding is left unaltered. For a distance of some seven or eight miles the buckling structure is either very rare or absent, but it sets in again in the quartzite close to Braemar. It is there also shown both by the marginal sandy beds, known as the Moine gneisses, and the dark schist next them. There also is no justification for separating the beds with the superinduced 'buckling structure' from those without it, as has been generally done. A key to the connexion between the 'buckled' and 'non-buckled' areas occurs in the ground about Shiehallion and to the north (Sheet 55, Scotland). At Shiehallion we have the quartzose beds forming the

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

margin of the quartzite, and containing the boulder bed and the limestone close by; further north we have the same group again. In the first case we have isoclinal folding; in the second, buckled folding, or Moine gneiss.

REVIEWS.

I.—The Permian Amphibia and Reptilia of North America.

THE recent appearance of three[1] very important works dealing with the fauna of the 'Permian' of Texas and the traces of that fauna which have been found in New Mexico, Pennsylvania, etc., enables us for the first time fully to appreciate its importance and its many remarkable features. Evidence has been recently accumulating to show that this fauna is really largely of Upper Carboniferous age. Williston has pointed out that the fauna is an isolated one, apparently developed quite out of touch with the rest of the world; and although Broom has shown that it is composed of fundamentally the same stocks as the Permian fauna of South Africa, there is no doubt that his general argument is correct.

It is a very remarkable group of animals which on a ground plan of very primitive structure have built up astonishing specializations, so much so that types like *Cacops*, *Dimetrodon*, and *Edaphosaurus* are amongst the most bizarre animals known. These animals, and many others, seem to exhibit all the features which usually occur in the last individuals of a race: they are phylogerontic, and it is improbable that they left any descendants.

The 'Texas' amphibia and reptiles are then in general precociously specialized examples of the early stocks which in South Africa slowly developed along many lines and gave rise to the mammalia amongst other groups. In the light of these ideas it is of interest to examine some of them in more detail. *Diplocaulus*, now nearly completely known, is an extraordinarily specialized type with an enormous flat head, much produced over the ears, with a slender body and very reduced pectoral limbs. Nothing like it is known elsewhere, but it seems to be a terminal member of the line of Microsauria represented by *Ceraterpeton* and *Diceratosaurus*, which occurs in Europe and North America.

The imperfectly known *Trimerorachis* is a rather unspecialized type, interesting because of its close similarity with the South African Upper Permian *Bothriceps Huxleyi*, now more completely known. The large and very well-known *Eryops* is a specialized representative of a type represented in Europe by *Actinodon*, and in South Africa by *Rhinesuchus* or *Myriodon*, a type whose structure as completely shown by specimens in the Pretoria Museum is thoroughly Eryopid, although much more generalized.

The extraordinary type *Trematops*, very reptilian in appearance, has no recognizable allies elsewhere, and the still more remarkable

[1] E. C. Case, *A Revision of the Amphibia and Pisces of the Permian of North America*, Carnegie Institution, Pub. 146, Washington, 1911; *A Revision of the Cotylosauria of North America*, Carnegie Institution, Pub. 145, 1911. S. W. Williston, *American Permian Vertebrates*, University of Chicago Press, 1911.