Chapter 8 The New Red Sandstone

Lower Division (Permian)

The rocks occurring above the Carboniferous in Arran form a continuous series of red sandstones, breccias, conglomerates, and shales, passing upwards into a more variegated and calcareous group, which may be comprised as the New Red Sandstone. Its main area of distribution is in the southern half of the island, south of the annular belts of older rocks which encircle the two principal Cainozoic igneous centres. There is also a coastal strip extending from Brodick to Corrie, and two outliers near the Cock of Arran. In the south the formation is riddled with innumerable dykes and sills of later date, which complicate and obscure the stratigraphy. Igneous rocks are estimated to cover quite half of the New Red Sandstone region.

These upper red rocks of Arran have been assigned at various times to all the geological systems from the Devonian to the Triassic. Sedgwick and Murchison,<ref>*Trans. Geol. Soc. London, Second Series*, vol. iii., part i., 1829, pp, 32,33 and section, Plate 3.</ref> in 1829, referred them correctly to the New Red Sandstone; and Sir Andrew Ramsay,<ref>*The Geology of the Island of Arran from Original Survey*, 1841, p. 77.</ref> in 1841, adopted the same conclusion for most of the formation, although he referred a part to the Carboniferous. Bryce,<ref>*The Geology of Clydesdale and Arran*, 1859, p. 70.<ref> in 1859, thought that they were interstratified with the Carboniferous, and in the fourth edition of his 'Geology of Arran' identified them with the Calciferous Sandstones.<ref>*The Geology of Arran*, 4th ed., 1872, p. 15.<ref> This view was shown to be impossible, at least for the Cock of Arran areas, when Wiinsch and Thomson,<ref>*Trans. Geol. Soc. Glasgow*, vol. v., part ii., 1877, p. 313.</ref> in 1874, found fossiliferous Carboniferous pebbles in the New Red breccias. They consequently relegated the formation to the Lower Permian. Subsequently Sir Archibald Geikie<ref>*Textbook of Geology*, 3rd ed., 1893, p. 801. Also see his New Geological Map of Scotland, 1892.<ref>referred these rocks to the Upper Old Red Sandstone; but, in 1897, he remarked the resemblance of the Brodick sandstones to those of Permian age on the mainland, and wrote that 'good reasons have been given for classing as Permian the bright red sandstone' of central and southern Arran.<ref>*Ancient Volcanoes of Great Britain*, vol. ii., 5897, pp. 58, 418, 419.</ref> This view was supported in 1897 by W. Gunn<ref>*Trans. Geol. Soc. Edinburgh*, vol. vii., part iii., 1897, p. 273.</ref> for the same reason; and the rocks were represented as Permian on the first edition of the Geological Survey map of South Arran (Sh. 13, issued 1898). On the second edition, 1902, the age was altered to Trias, in consequence of the discovery of Rhaetic fossils in the Central Ring area, in beds associated with typical Triassic marls. In the Survey Memoir on North Arran, South Bute, and the Cumbraes (1903) (p.67), W. Gunn claimed that the discovery of the Rhaetic fossils ' fixes pretty definitely the Triassic age of the upper division of the formation '; but both in the Memoir and the map the whole series is referred to the Trias. Jukes-Browne, in 1911, pointed out that, while the upper beds are Trias, the lower sandstones are probably Permian. This conclusion was fully substantiated by Prof. J. W. Gregory's detailed work of three years later,<ref>The Permian and Triassic Rocks of Arran, *Trans. Geol. Soc. Glasgow*, vol. xv., part ii., 1915, pp. 174–187. *Also see* G. W. Tyrrell, On the Boundary between the Red Rock Series near Whiting Bay and in the Sliddery Water, Arran, *ibid.,* pp. 188–199.</ref> and was reinforced by the discovery of a horizon of volcanic breccia within the Brodick Breccias in 1921.<ref>J. W. Gregory and G. W. Tyrrell, ' Excursion to Arran, *Proc. Geol. Assoc.*, vol. xxxv., part iv., 1924, p. 414.</ref>

The New Red Sandstone is separated by a considerable unconformity from the underlying rocks. Near the Cock these strata rest upon the Lower Coal Measures, as they also do at Corrie and in the woods behind Brodick Castle. But towards' the head of Benlister Glen they repose on the Corrie Limestone, hundreds of feet lower down in the Carboniferous formation, while on the west coast, to the north of the mouth of the Machrie Water, they lie directly on the Old Red Sandstone, all the rocks of the Carboniferous system having disappeared.

In the Memoir on Sheet 21 (p. 67) W. Gunn classified the rocks as follows:

UPPER TRIAS—KEUPER ?	Red and mottled shales or marls with thin beds of white, yellow, or grey sandstone, and occasional thin bands of nodular limestone

LOWER TRIAS	4. Light-coloured and yellowish sandstones, sometimes red, with calcite in cavities
LOWER TRIAS	3. Reddish sandstones with some conglomerates
LOWER TRIAS	2. Conglomerates alternating with sandstones
LOWER TRIAS	1. False-bedded red sandstones of Brodick and Corrie

The classification adopted below is essentially that due to Prof. J. W. Gregory, amended and supplemented in several particulars:

RHAETIC	Black shales and grey limestones (Ard Bheinn)
KEUPER	*7. Levencorroch Marls and Cornstones* Greenish-grey marls (Derenenach) Red shales with green layers and thin sandstones (Torr nan Uain), 60 feet Marls and shales with layers of nodular and earthy limestones, and calcareous sandstones (Levencorroch), 200 feet
BUNTER	6. *Auchenhew Sandstones and Shales* Red and green shales with thin sandstones (Auchenhew), 350 feet Sandstones (Auchenhew), 200 feet Shales, with sharp-grained yellow and blue sandstones (Bennan), 150 feet 5. *Lag a' Bheith Marls and Cornstones* Shales and marls with nodules and layers of cornstone; green and red calcareous and micaceous sandstones (Headwaters of Lag a' Bheith, Brodick; Loch na Leirg plateau) 4. *Glen Dubh Sandstone* White, yellow, and pink, massive, calcareous sandstone; thick-bedded, carious, but with sthooth-weathering surfaces; blocky outcrops. A few lenticles of conglomerate (Southern slopes of Glen Dubh; Whiting Bay–Ballymichael Glen) *3. Lamlash and Machrie Sandstones* Coarse red sandstone, slightly false-bedded, regularly thin-bedded at Machrie; occasional lenticles of conglomerate (Lag a' Bheith, lower part; Lamlash, Machrie Water, and Machrie Burn)
PERMIAN	2. *Brodick Breccia* Coarse quartz- and quartzitic-breccia with horizons rich in basalt and agate pebbles; thick lenticles of red dune-bedded sandstone (Strathwhillan<ref>Strathwhellan on One-inch Geological Map 1910</ref> shore, Brodick; Brodick Bay, southern part; Glen Dubh; Machrie) 1. *Connie Sandstone* False-bedded, brick-red sandstone with rounded wind-worn grains (Cock of Arran; Corrie; Brodick Bay, north side)

Gunn estimated the thickness of the Lower Group or Permian at 2000 feet.

The diagrammatic section (Figure 4) shows the general succession and arrangement of the various members of the New Red Sandstone formation in Arran.

The Corrie Sandstone and Brodick Breccia<ref>Much of the new field-work on the New Red Sandstone in Arran has been done in conjunction with Mr. B. H. Barrett, M.A., B.Sc.</ref>

These groups are treated together as there is reason to believe that they form but one stratigraphical unit. In his MS. notes for Sheet 13, Mr. Gunn stated that in the southern half of Arran 'the lower false-bedded sandstone, and the bands of conglomerate, do not form separate subdivisions, the conglomerates often occurring at the base, and on various other horizons.' This is in entire conformity with the view that the formation represents a desert accumulation, a great mound of dune-bedded desert sand (the Corrie Sandstone) being deposited in one place, whilst desert screes (the Brodick Breccia) were being piled up elsewhere.

The Brodick Breccia is divisible into three horizons which have been found to be remarkably persistent. Its basal parts consist mainly of vein-quartz, quartzite, and schists, of Highland provenance, in a matrix of red sand; and fragments of this nature are found, although in relatively smaller quantity, throughout the entire thickness of the bed. In the central horizons, however, a great number of basalt pebbles come in, sometimes in such quantity and of such sizes as to suggest the near proximity of the distributing volcanoes. These basalts are of well-known Carboniferous and Permian types; the larger manes are generally angular, but a few are sub-rounded and suggest volcanic bombs. The smaller sand grains are usually wind rounded. Basalt pebbles appear in diminishing numbers up to the top of the breccia, but here numerous white-weathering agate pebbles occur, and are everywhere characteristic of the uppermost horizons. G.W.T.

1. The lowest subdivision is well exposed along the shore between Corrie and Brodick Castle, and consists of extremely false-bedded, bright-red sandstones, traversed in many places by ridges formed of hardened joints and crushes, and in others full of ramifying hardened veins which cause the rock to weather with a honeycomb structure. Some of the crushes are certainly faults, but the rock is so uniform in texture generally that the amount of throw is not discernible. Numerous basic dykes cross the foreshore in various directions and discharge the red colour of the rock, making it white or yellow, and hardening it. Some of the ridges are probably in the line of dykes which end at the surface, and some may be due to dykes which have not reached the present surface. The false-bedding conveys a very exaggerated idea of the real thickness of the series. Fine sections in the old sea-cliffs, and in caves, show that the true dip towards the south-east is not more, generally, than 10° to 15°, while the false-bedding has an inclination of twice as much, and is, besides, very variable in direction. The great cliff on the north side of Maol Donn, which is formed of this sandstone, shows a similar gentle inclination of the beds. This great scarp is largely due to an extensive slip, the material from which covers several acres to the northward. There are large quarries in this sandstone at Corrie and in Brodick wood at the back of the school. From the Corrie quarries much stone was shipped to Ayrshire and various parts for building purposes. This sandstone forms the ridge on the north side of Glen Cloy, where both the true and the false bedding dip to the southward or south-east at a high angle, as they do also to the west of the old Brodick Pier near the Castle. The boundary between this rock and the underlying Carboniferous series may be observed on the shore about 200 yards south of the Corrie Hotel, and it crosses the Rosa Burn a little below the bridge. W. G.

Mr. E. B. Bailey has recently described the junction between the Upper Carboniferous and the New Red Sandstone on the shore about 200 yards south of Corrie Hotel.<ref>Subterranean Penetration by a Desert Climate, *Geol. Mag.*, vol. lxiii., 1926, pp. 276–280.</ref> The junction plane is parallel to the general stratification of the underlying Carboniferous and is marked by scattered, minute pebbles of vein-quartz and iron pan, which, mixed with many rounded quartz grains, constitutes an attenuated representative of a basal conglomerate.

The alternating breccias, conglomerates, and sandstones of the south side of Brodick Bay overlie the false-bedded sandstones just described, and the conglomerates of this division are so like in character to the Upper Old Red conglomerates north of Corrie that several observers have classed them with the older formation. They are largely made up of debris of the metamorphic rocks, such as pieces of vein-quartz and angular fragments of schist, with occasional pebbles of quartzite, like those characteristic of the Lower Old Red conglomerates. This subdivision strikes westward up Glen Cloy and forms the ridge between Glen Dubh and Glen Ormidale.

The section in Glen Dubh is noteworthy as containing the best exposure so far known of a horizon of volcanic breccia or conglomerate, the stratigraphical position of which is believed to be near the middle of the Brodick Breccia. The exact

locality is the Glen Dubh Water, about 250 yards above its confluence with the Glen Ormidale Water, and at the point where it receives its first tributary from the east above the confluence. Just at the junction with the tributary there is a small waterfall which is caused by the band of volcanic breccia. The best exposure, however, is about 20 yards farther down the stream, where the breccia forms a ledge on the south bank. An east-north-east fault, occupied by a crinanite dyke, and with a downthrow to the south of about 12 feet, separates the two main exposures (Figure 5). The section is greatly complicated by numerous basalt dykes and a felsite-pitchstone sill.

Some bands of the breccia are bluish in colour; others are stained dull red with haematite. The fragments are basaltic, dark, amygdaloidal, and iron-stained, closely resembling certain Carboniferous and Permian types. The matrix is partly sandy, and partly comminuted volcanic debris. Both below and above the breccia band, which is from 8 to 12 feet thick, the sandstones for some distance are dark red in colour and very basic and tuffaceous. The dip is about 20° to the S.S.W. On the south side of the stream, the breccia band is first overlain by well-bedded, dark-red, tuffaceous sandstones and sandy shale, and finally by a thick band of quartz-conglomerate, which is also seen above the waterfall section. The dark-red tuffaceous sandstones are visible in several of the tributary burns which enter the Glen Cloy Water from the east near Kilmichael, and it has also been found by Mr. W. J. McCallien, in the Lag a' Bheith, about a quarter of a mile south of Brodick Hotel.

Sgiath Bhan, the hill rising between Glen Dubh and Glen Ormidale, consists mainly of the Brodick Breccias, with a capping of the overlying Glen Dubh Sandstones. At the base of the hill, on the north-east side, there are sparsely-pebbly, dark-red sandstones occasionally enclosing large angular slabs of a fine-grained red, argillaceous sandstone. Higher up come dark purplish and reddish tuffaceous greywacke types, very hard and compact. On these there rest quartz-conglomerate and breccia interbedded with red sandstone and containing agate pebbles. Finally, at the top of the hill, the whitish and rusty-speckled Glen Dubh Sandstone appears.

Near the heads of Glen Dubh and Glen Ormidale the Brodick Breccia, along with the false-bedded sandstone below, has been much altered, being often converted to a white quartzite by contact with the intrusive igneous masses there.

On the shore at Springbank, near the Brodick Hotel, the formation is very much broken in two small areas, which were supposed to represent volcanic vents. The larger of these is about 150 feet in diameter and the smaller about 50 feet, though in neither case can the whole circumference of the mass be seen. The smaller is about 100 yards west of the hotel grounds, and the larger is some 150 yards farther west, and the breccia which composes both is entirely made up of fragments of the surrounding strata. The origin of these features is much in doubt. They are hardly volcanic vents in the accepted sense of the term, for there is not the slightest trace of any volcanic material. It may, perhaps, be hazarded that they possibly represent the effects of the explosive emission of gases from small, subjacent, hidden, Cainozoic intrusions, probably dykes. G.W.T.

In this subdivision there is not much false-bedding apparent, and the rocks at Springbank dip southward at about 15°. East of the pier numerous faults as well as dykes cross the outcrop, and the red conglomerate is seen to overlie false-bedded red sandstone of the same type as that on the north side of the bay. One of these faults ranging N. 25° E., which is 50 yards east of the pier, brings up the lower sandstones against the conglomerate. The sandstone occupies the foreshore for 300 yards eastwards when it is cut off by a fault, coincident with a dyke ranging N. 25° W., which throws down the conglomerate again on the east. For about 500 yards eastward from this point we see nothing but conglomerate on the foreshore till a north-west running fault, with a downthrow south-west, again brings the lower sandstone into view. This is continued for 300 yards farther in the most easterly part, being overlain by conglomerate, when a fault ranging N. 25° E. causes the whole of the foreshore to be occupied by conglomerate, but this is only for a distance of 30 to 40 yards, when a powerful fault, N. 30° E., brings up the lower sandstones, which occupy not only the shore for a long distance but the cliffs also, which are much increased in height. Hitherto along this shore the conglomerate series could be seen either on the shore or on the boundary cliffs, but the effect of this large fault, which must have a downthrow west of several hundred feet, is to raise the conglomerate a long way above the top of the crags at this point, and it does not appear again on the shore till the southerly dip causes it gradually to descend and occupy the shore about Corrygills Point. Along this half mile of shore and in the cliffs bounding the raised beach the false-bedded lower sandstones are well exposed, with the same curious spires and ridges which we found characterizing them on the north side of Brodick Bay. The southerly dip is everywhere nearly the same in amount, ranging between 10° and 20°, but

as we proceed the direction gradually changes till, in the alternating conglomerates and sandstones on either side of Corrygills Point, it is nearly S.S.W. W.G.

Re-examination of the Strathwhillan shore, east of Brodick Pier, by Mr. B. H. Barrett and the present writer, showed that, while there are several small faults, there are no traces of the large faults necessitated by Mr. W. Gunn's interpretation of the section as detailed above. His explanation seems to have been called for because the great masses of red, dune-bedded sandstone in the cliffs were regarded as upthrown blocks of the underlying Corrie Sandstone. These masses, however, can be shown to be overlain and underlain by Brodick Breccia, and are best interpreted as fossil dunes, or groups of dunes, against and around which the breccias were banked up and interbedded.

At Brodick Pier is typical breccia; immediately to the east is a stretch of red, ribbed sandstone devoid of pebbles, similar to the Corrie Sandstone. Three hundred yards east of the pier the sandstone is succeeded abruptly by breccia on the eastern side of a wall-like edge probably due to a dyke. As the sandstone near by is much disturbed and brecciated, this edge is no doubt the line of a small fault.

The basaltic horizon in the Brodick Breccia is well exposed in the cliff bordering the 10-foot raised beach at a point half a mile east of the pier, and one-sixth of a mile west of a small lagoon on the shore. There is here a considerable thickness of loose, crumbling breccia, consisting of rounded and subangular pebbles of red-speckled vesicular basalts. Some of the larger cobbles resemble volcanic bombs. Associated with the coarse breccias are dark-red tuffaceous sandstones, and hard ribs of dark-red shaly sandstones.

The cliff shows beds of basaltic fragments intermingled with sandstone, exactly as in the Ballochmyle section above the lavas of the Mauchline (Ayrshire) basin.

A fault along which runs a basalt dyke terminates this exposure on the east, and it is succeeded in this direction by apparently upfaulted quartz-breccia. Then, wedging out abruptly amongst the breccias, there occurs an enormous lenticle of red, dune-bedded sandstone, without a band of breccia from top to bottom. This forms cliffs 150 to 200 feet in height, and red sandstone also forms the shore-section at this point. It is suggested that this mass of sandstone represents the remains of a group of dunes. Near Corrygills Point bands of breccia come in, and are seen to be interbedded with red sandstone. The overlying red sandstone is thin-bedded and dips at 25° to the south-east.

In the raised-beach cliff at the back of the big granite erratic near Corrygills Point, quartz-breccia overlies the thinning south-eastern termination of the red sandstone lenticle described above and on the shore quartz-breccia can also be seen to underlie it. One of the best exposures of the agate-bearing horizon of the Brodick Breccia is found on the shore a quarter to half a mile southeast of the mouth of the Corrygills Burn. Fine agates, weathered out from the breccias and the intercalated pebbly sandstones, may be gathered on the foreshore.

The Corrygills Burn provides a slowly-ascending section in the beds at the top of, and immediately above, the Brodick Breccia.

Near its mouth there is quartz-breccia interbedded with red sandstone; and thick-bedded red sandstones with occasional intercalations of breccia, and one ledge of very coarse white sandstone, occupy the burn for a distance of one-third of a mile from its mouth.

West of this point the flaggy and shaly red sandstones of the Lamlash–Machrie group appear, some beds showing occasional flakes of white mica. Rocks of this type also occur by the roadside near Corrygills Bridge. The dip is mainly S.S.W. at angles from 15° to 25°.

The Brodick Breccias are well exposed in the middle part of the Benlister Burn where the conglomerates form occasional cascades. This series also occupies a strip of ground to the northward, west of Brisderg, which is bounded by two large faults The beds in this strip dip to the south-west, and their termination north is in the fine scar of Creag nam Fitheach, on the south side of Glen Dubh.

On the north-east the Creag nam Fitheach section is bounded by a fault trending north-west, which brings the Glen Dubh Sandstone down against the Brodick Breccias. The crags are intersected by a number of dykes which, in some cases, run along small faults. In spite of this disturbance it is clear that Creag nam Fitheach consists mainly of beds belonging to the upper part of the Brodick Breccias. They consist of dark-red streaky basic sandstones with clay galls, interbedded with quartz pebble-conglomerates and quartz-breccias, in which no basalt pebbles were found. There are also some hard, white and green, quartzitic sandstones, above which is a considerable thickness of red, false-bedded sandstone with inconstant pebble beds, and some coarse breccia bands. Agates occur in the pebble beds but are not abundant. Shaly beds in the red sandstones show good suncracks and are occasionally ripple-marked. The sandstones are also ripple-marked and contain mud flakes. These beds are probably on the Lamlash–Machrie Sandstone horizon.

Three good sections of the basement beds of the New Red Sandstone occur in the Machrie district. The evidence shows that they are here considerably thinner than on the eastern side of the island. A junction between the New Red Sandstone and the Old Red Sandstone can be closely located in Machrie Bay, on the shore about 200 yards north of the Post Office. There is nothing representative of the Corrie Sandstone, and the Brodick Breccia rests conformably on the Upper Old Red Sandstone (?), both series dipping S.S.W. at 50°. The Brodick Breccia has a reddish matrix containing scattered quartz and quartzite pebbles which are, however, thickly aggregated in some beds, with occasional pebbles of red-speckled basalts and white-weathering agates. It can be easily distinguished from the Upper Old Red Sandstone (?), which has a dark greenish-grey matrix, contains quartz, quartzite, and schist fragments, but no basalt or agate, and has suffered considerable epidotization. There is a transitional zone a few feet in thickness between the two rock types.

In the Machrie Burn 1 mile east-south-east of the exposures on the shore of Machrie Bay, and half a mile north-north-east of Machrie Farm, unquestionable Old Red Sandstone conglomerate, with rounded cobbles and boulders of quartz and quartzite, and with inconstant streaks of sandstone, occurs at a sharp bend in the stream. It strikes 37° W. of N., with dip 40° to vertical. A few yards down stream a bright-red sandstone appears, which, in a short distance, contains increasing interbeds of quartz-schistbreccias. A quarter of a mile north of Machrie Farm agates occur in abundance. The dip is 65° to the south; hence there is a certain discordance with the Old Red Sandstone. At this point Mr. Gunn drew a doubtful boundary between the New Red Sandstone and the Old Red Sandstone (One-inch Geol. Surv. Map of Arran, 1910), but the actual boundary is 200 to 300 yards farther north as determined by the change in the lithology of the rocks. There is little trace of the basaltic horizon in this section, only a few streaks and thin beds of the typical dark-red tuffaceous sandstones being found. The section passes up into the thin-bedded red sandstones of the Lamlash—Machrie group (p. 93). The estimated thickness of the basal subdivision in the Machrie Burn is 600 feet.

In the Machrie Water section, 2 miles east-south-east of the Machrie Burn section, the New Red Sandstones are first encountered below the deer fence at the north-eastern corner of Machrie Wood, half a mile north-west of Derenenach. Above this point the river bed is occupied by the red and purple sandstones, and coarse quartz-conglomerates of the Old Red Sandstone. The New Red Sandstone begins with a few feet of bright-red, round-grained sandstone, dipping at 30° in a direction 25° W. of S., probably an attenuated representative of the Corrie Sandstone horizon. There is no visible junction with the Old Red Sandstone. This is followed by the usual breccia with quartz, quartzite, and schist fragments, and interbeds of the dark-red tuffaceous sandstones of the basaltic horizon. Dune-bedding is prominent in some of the layers. Within the wood coarse sandstones and fine conglomerates with small basalt and agate pebbles, clay galls, and polished and rounded quartz grains, are abundant. Some of the layers are very rich in agate and basalt; others, on the other hand, appear to be devoid of them. These beds are followed by the thin-bedded shaly sandstones of the Lamlash–Machrie group. The thickness of the Corrie Sandstone and Brodick Breccia in this section is estimated at 600 feet, the same as in the Machrie Burn. G.W.T.

The detached outlier of New Red Sandstone at the Cock of Arran, in the north part of the island, contains false-bedded, bright-red sandstone, like that of Corrie, and beds of conglomerate which mainly overlie the sandstone, though conglomerates occur in the lowest 40 feet of the sandstone itself. The mass of conglomerate is like that on the south side of Brodick Bay, and probably on the same horizon, so that we have in this small area representatives of the lower two subdivisions of the formation, with a total thickness of not less than 1200 feet. The beds generally dip northward and toward the sea, so that several landslips on a large scale have occurred, and the hillsides show gaping fissures.

In the lowest part of the New Red Sandstone which immediately overlies the Carboniferous formation in the northern part of Arran, there are bands of conglomerate which contain pebbles of Carboniferous limestone from which several derived fossils have been obtained by the Geological Survey. Rather more than a quarter of a mile north-west of this spot, and about 100 yards east of the Cock of Arran, is another locality where derived fossils may be collected. There occurs a very irregular pebbly band, which appears to have accumulated in a hollow of the sandstone during the process of rock formation. It contains, among others, large blocks of trap and white quartz, etc., and from it the following collection was made:

Coral, indet., rugose
Lithostrotion
Crinoid ossicles
Rhabdomeson or *Rhombopora*
Spiriferid
? *Nucula gibbosa* Flem.
? *N. oblonga* M'Coy
Prot oschizodus axiniformis (Portl.)
Bucanopsis

It was probably in the first-mentioned locality that derived Carboniferous fossils were obtained by Messrs. James Thomson and E. A. Wünsch, as reported in the *Trans. Geol. Soc. Glasgow*, vol. v., p. 313 (1874), and described in vol. xi. of the same *Transactions,* p. 30 (1897). W.G.

Lamlash–Machrie Sandstone, and Glen Dubh Sandstone

The Lamlash–Machrie Sandstone and the Glen Dubh Sandstone constitute together the upper part of the lower division of the New Red Sandstone in Arran. With the underlying Brodick Breccias (with which these sandstones appear to interdigitate) and the Corrie Sandstone, they have been regarded by Prof. J. W. Gregory as belonging to the Permian system. In the neighbourhood of Brodick the Lamlash–Machrie Sandstone and the Glen Dubh Sandstone are clearly separable; but in other localities their separation is not so easily effected, for bands of whitish calcareous sandstone of the same character as the Glen Dubh Sandstone are found intercalated in the Lamlash–Machrie Sandstones in increasing numbers towards the top of that group.

The Lamlash–Machrie Sandstone consists of dull-red, soft, thin-bedded sandstones, occasionally micaceous and shaly, often with scattered pebbles and bands of breccia, and with one or two lenticles of conglomerate made up of rounded water-worn pebbles and cobbles. The Glen Dubh Sandstone is a massive, white, yellow, or pink, rusty-speckled sandstone, often coarse, and usually with some calcareous cement. The outcrops weather in blocky fashion, and the rock, while often pitted with large holes, nevertheless preserves a smooth, glazed surface. The red sandstones occupy most of the lower ground from Corrygills, through Lamlash Bay, to Whiting Bay. They are also prominent in sections in the Machrie district. The best and most typical exposures of the Glen Dubh Sandstone are on the high moors between Glen Dubh and the Benlister Burn, and on the high ground west of Lamlash and Whiting Bay. In the west the Clauchan and Ballymichael Glens provide exposures of rocks on this horizon. The Tormore shore-section and a considerable area to the west of Tighvein, may also belong to this subdivision. G.W.T.

Along the South Corrygills shore the alternating conglomerates and sandstones pass gradually up into the beds of the Lamlash–Machrie subdivision, which consists almost entirely of red sandstones, moderately coarse, with only occasional pebbly bands, and with comparatively little false-bedding. The dip inclines more and mor to the west and generally increases in amount, so that in place along the shore east of the Clauchland Hills the dip is as high as 30° or 40° and the strike is parallel to the shore. Near Clauchlands Point the dip is in one place as much as 60°, but this high dip is probably the effect of the intrusion of the great sill of dolerite there. On the south side of the Clauchland Hills the inclination of the beds is much more gentle, generally not more than 10°, and nearly coinciding with the slope of the ground to S.S.E. There are numerous sections in the small streams here, and along the northern shore of Lamlash Bay.

The beds of this subdivision occupy nearly all the area between Lamlash and Glen Cloy, and there is a fairly continuous exposure of them in the Birch Burn (Lag a' Bheith). They also form a marked feature above the wood to the south-east of Bruce's Castle in Glen Dubh,<ref>This is the scarp of Glen Dubh Sandstone referred to below.</ref> and it is probably the higher beds of this series that appear beneath the thick sills of felsite along the west side and at the north end of Holy Island. W. G.

On the south side of Glen Dubh there are a long scarp and terrace descending eastward from The Sheans, which mark the outcrop of a thick band of rusty-spotted, white, felspathic sandstone. This bed weathers into blocky outcrops, and has irregular, carious surfaces, although some bands are well bedded and slabby. The dip is 10° to the S.S.E. The same sandstone is again seen in a bouldery outcrop east of the Brodick–Lamlash Road, north of the Clauchland sill.

The red sandstones of the Lamlash–Machrie series are well exposed at Gortonallister, between Lamlash and Whiting Bay. The rock is a thick, massive, fine-grained, red sandstone, which rests on a softer, more argillaceous sandstone. It has no conspicuous false-bedding, and no interstratified conglomerate bands. The Lag a' Bheith sections, between Lamlash and Brodick, are mainly in the same series. G. W. T.

By the roadside, and in the path near Cordon (Lamlash) some shale bands occur in the red sandstone. Along the coast to the east of Gortonallister the whitish and yellow sandstone is slightly veined parallel to the shore, and forms spiry projections recalling the sandstone of the lowest subdivision north of Brodick. About Fairiebank soft red sandstone, yellow sandstone, and white sandstone, are successively encountered in an eastward direction.

South of Kingscross Point the sandstone is altered by contact with the crinanite sill, and in several places the white and yellow sandstones weather with carious surfaces. In the neighbourhood of Whiting Bay the sandstone is usually soft, red, and often flaggy, and contains occasional bands of red shale. Near the numerous dykes the colour is often discharged, and the sandstones become white and quartzitic.

Sandstone belonging to this subdivision is found in the southern part of Holy Island. On the west coast at St. Molio's Cave massive red sandstone appears, which rises to about 200 feet above sea-level, and must have as great a thickness. To the south this sandstone is covered by screes from the great sill above, but appears again at the Sheep Cave, where it is still massive and partly of a whitish colour. Hardened and altered white sandstone and conglomerate appear, dipping to the south-east, between two sheets of crinanite to the north of the lighthouse. These igneous masses occupy the southern shore, but rise up along the eastern coast, and the sandstone appears below, with a general dip to N.N.W. of from 10° to 20°. In places parts of the sandstone are caught up in the sill and much altered. Beyond this the igneous rock again occupies the shore. W.G. (MS.)

North of the eastern lighthouse the coast is bordered by a fine cliff of bright-red sandstone, worn in curious deep hollows and niches like gigantic honeycomb weathering. It exhibits marked dune-bedding. A 10-foot band of yellow sandstone appears at the north end of the cliff. The whole section shows an apparent shallow synclinal structure. G.W.T.

Inland from Lamlash good sections are visible in Monamore Glen and its tributaries. The higher beds, consisting of yellow and white sandstones [the Glen Dubh Sandstone ?] are exposed in the burn west of Sguiler, and in all the burns north-east of Urie Loch. The lower beds near the junction of these burns with the Monamore Water, and on the sides of Monamore Glen, are more often of a red colour, are more false-bedded, and sometimes contain pebbles [the Lamlash–Machrie Sandstone]. Near Monamore Flour Mill are two good-sized quarries where the sandstone is wrought for building purposes. In each of the quarries there are basaltic dykes, and the sandstone is intersected by faults. In the quarry immediately south of the Mill there are exposed about 25 feet of thick-bedded, reddish sandstone, with partings of thinner-bedded stone, some of which is very micaceous. Below is thick, whitish sandstone, of which 10 feet or more is visible on the west side of a fault which ranges north-west and appears to throw down about io feet on the east side. The sandstone of the more easterly quarry is pierced by two north-west dykes, and crossed by a fault running east-south-east which hades to the south. W.G. (MS.)

In the stretch of country to the west of Whiting Bay the boundary between the lower and upper divisions of the New Red Sandstone occurs, as far as can be ascertained, a little below the base of the Borrach felsite mass. In Glen Ashdale the

main dolerite sill (which gives rise to the waterfall) has been intruded near the junction of the two series; and to the south a thin lower member of the same sill complex is taken as the mappable horizon which marks the boundary.

A typical section is given by the stream (Burn B) which drains into Glen Ashdale from the north-west about one-third of a mile east of Cnoc Mòr (Plate 2). Starting from the path on the north side of Glenashdale Wood, a glaciated exposure shows fine-grained 'blue basalt' weathering in rounded masses with exfoliation, The bed of the stream is occupied for some distance by a dyke of porphyritic basalt. The sill is overlain by soft whitish and buff thin-bedded sandstones — probably red sandstone with its colour discharged by the igneous contact. In these rocks there is a horizon characterized by chocolate-coloured, ferriferous and micaceous sandstones, a band of which forms a small fall. Above these there are a few hard quartzitic bands, which weather in the stream-bed with smooth surfaces. Before the base of a second basaltic sill is reached, the sandstones again become soft and argillaceous, and begin to be intercalated with shales and marls. Above the second sill the sediments become increasingly manly, but still contain a few bands of harder red sandstone. Typical Triassic marls and shales, however, form the whole of the section before the third and last sill is reached (Figure 6). The beds are practically horizontal. This is perhaps the best section for showing that the transition between the upper and lower divisions of the New Red Sandstone is perfectly gradual, and that there is no recognizable discordance. The lower sandstones become softer and more argillaceous on being traced upward, and are intercalated with bands of shale and marl in increasing numbers until the latter constitute the whole of the sedimentary succession. Similar sections are to be seen in the Allt Garbh, Borrach, 1½ miles west of Whiting Bay Pier, and in several other burns tributary to Glen Ashdale.

There is an excellent coastal section in the upper sandstones along the coast to the south of Whiting Bay, from Creag Dubh to Dippin. Creag Dubh consists of a sill of fine-grained dolerite resting upon and overlain by sandstone dipping 22° due west. The section from here to Largybeg Point is in thin-bedded red sandstone, which contains an occasional quartz-pebble and local sprinklings of fragments of green and brown shale. The dip is 20° to 30° slightly S. of W., and the strike a little east of south, so that higher beds are slowly exposed as the observer walks southward along the coast. Some of the sandstones are coarser and grittier than others, and many have a cement of whitish, decomposed, felspathic material. Rocks of this character are to be seen in the quarry east of Largymore, and Prof. P. G. H. Boswell has suggested that they would provide good moulding sand.<ref>A Memoir on British Resources of Refractory Sands for Furnace and Foundry Purposes, Part i., London, 1918, p. 169.</ref>

Other sandstones along this shore have a calcareous or dolomitic cement, and in these rocks occurs a peculiar carious weathering, which may be seen at many places, notably at Largybeg. This feature is often especially well developed where the sandstone is hardened by igneous action. The hollowing is sometimes replaced by a nodular weathering, resulting frequently in clavate or mushroom-shaped projections. This weathering is due to an irregular distribution of the calcareous cement, or to variations in its composition, rendering it more liable to solution in some places than in others. A related phenomenon has been noted by Gunn about 200 yards south of Largybeg Point, where there is a bed of red sandstone 6 inches thick, which contains numerous nests of calcite in cavities on its sloping surface. They are of all shapes and sizes up to as much as 6 inches in diameter, and one lenticle measured more than 12 inches. These sandstones represent the Glen Dubh Sandstone horizon in this locality.

A thin band of bluish shale appears in the small cove just north of Largybeg Point. At the Point itself the section is diversified by a 15-foot sill of basalt, and by a bed of conglomerate 61 feet thick. The full section across the Point from south-west to northeast in descending order, is as follows:

	feet
Thin-bedded red sandstone	42
Basalt sill	15
White gritty sandstone, with line of local unconformity and rock-arch	33
Coarse grit with bands of conglomerate	9
Conglomerate	6½
Carious white sandstone	9

The last bed abuts against a thick felsite dyke hading 45° E., beyond which is the sea. The sedimentary rocks are intersected by three basalt dykes, one of which forms an outstanding wall, and the others trench-like depressions. A curious rock-arch, excavated in bed (*c*), now stands on the 10-foot raised beach well above high-water mark. The section is shown in detail in (Figure 7).

To the south of Largybeg Point the dip of the strata becomes nearly parallel to the shore, and averages 10° to 15° to the southwest. For a hundred yards the section is then covered by shingle, broken only by one small outcrop of sandstone maintaining the same dip. Beyond the shingle comes the outcrop of a small basalt sill, which has protected the strata beneath it. The latter are sandy marls, interbedded with sandstone, and are bent into a flat anticline, whose northern limb dips to the north, and is opposed to the dip of the sandstone of Largybeg Point. The slight flexure and change in direction of dip is probably due to the influence of the little sill, but it is curious that a change of dip should come close to the point where, according to the One-inch Map, the junction of the sandstone and marl divisions takes place.

From this point until the escarpment of the great Dippin sill of teschenite or crinanite sweeps down to the shore, the rocks are covered by shingle. The lower contact of the sill is exposed at the north end of the cliff, and the igneous rock rests upon hardened and burnt shale, dipping about 10° to the north. The southwesterly dip is resumed, however, to the west of Dippin at Torran Clachach, and to the south-west of the sill at Kildonan. It is probable therefore that the small flexure at Dippin is local and due to to igneous intrusion.

It is unfortunate that the critical junction in this section, which occurs a little to the south of Largybeg Point, should be so largely obscured, but what evidence there is available goes to show that the transition between the two divisions of the New Red Sandstone is gradual, and that there is no marked discordance. G.W.T.

There is a wide spread of rocks belonging to the upper part of the lower division of the New Red Sandstone in the interior region of the southern half of the island, between Tighvein and Tormusk, a region centrally drained by the upper part of the Sliddery Water.

This area is much cut up and obscured by the Cainozoic igneous intrusions. There are good sections in all four of the branch streams which run southward into the Sliddery Water above Glenscorrodale, the two best being those exposed in the burns on either side of the isolated hill called Cnoc na Dail. The most easterly stream, which is called the Allt Mòr, exposes a considerable thickness of rock, much- of the sandstone being coarse and pebbly, passing into a conglomerate in places, especially near the junction of the two streams south-east of Cnoc a' Chapuill, where the base of the New Red Sandstone rests on the Carboniferous strata. The beds appear to dip to the west of south at angles of 10° to 20° and this direction of dip prevails in the stream west of Cnoc na Dail, it being south-south-west in the upper part of the section, and south-west in the lower part, the amount being between 20° and 25°. In the higher part of the stream the sandstone is reddish; lower down it varies from yellow to red, and is very false-bedded, and is coarse and pebbly in places. Occasionally a whitish colour prevails, and in the lower part of the burn the rock becomes flaggy, and includes a shale band io inches in thickness.

In the next stream to the west the dip is 20° to 30° and nearly always to the south. The lower part of this section shows very false-bedded white and quartzose sandstone. Reddish, yellow, and white sandstones with the same general dip as before are exposed in places in the next stream above Glenscorrodale. Sometimes the rock is flaggy and fine grained, in places being almost shaly; but in general it is thick bedded and occasionally hard and quartzose. North of the igneous mass of Tormusk, where the same general dip prevails, the sandstone is more often of a red colour.

The main stream of the Sliddery Water gives few and poor sections of the beds under description. Its most easterly exposure is close up against the basic igneous mass which bounds the Upper Carboniferous of its southern headwater. The sandstone here dips west, and is much altered, being hard, white, and quartzitic.

Many of the branch streams entering from the east give fairly good and continuous sections, which are intruded by an immense number of large and small igneous masses. The upper part of the Allt na Tuaidh, which joins ale Sliddery Water opposite Glenscorrodale, shows soft red or yellow sandstone dipping gently W. or W.S.W. Rocks of much the same character crop out in both branches of the head of the Cloined Burn, and near the head of the Kilmory Water to the west

and south-west of Tighvein. The dip varies between W.S.W. and S.W., and the amount is usually from 10° to 20°. W.G. (MS.)

In the Sliddery Water, 200 yards above Glenrie Bridge, a junction of pink banded felsite is seen against sedimentaries. The nearly horizontal joint-planes of the igneous rock curve up until they become nearly vertical at the junction, which may be a fault-plane (Figure 29). The sediments here consist of chocolate, white, and reddish sandstones, interbedded with a little true marl, and other marls of sandier type.

At the right-angle turn in the stream, 200 yards higher up, the sediments are rather hard, whitish, or yellow sandstones dipping downstream at 10° to 20° to the south. They are cut by two north to south dykes, and are not interbedded with shaly material. These sandstones weather with a rough but hardly carious surface. They are in beds about 1 foot thick, and although they are sometimes thinner bedded they do not pass into shaly types. These strata are taken to belong to the lower sandstone division, and the exposure containing marls, at the felsite junction, as belonging to the upper manly division. The junction in this case is occupied by a felsite-pitchstone sill, and should be drawn about a quarter of a mile farther to the north than it is represented on the One-inch Geological Survey Map.

The Burican Section — Thesection commences at the forking of the Allt Burican about three-quarters of a mile above Burican. Nothing can here be seen of the fault, which, according to the Geological Survey map, crosses the stream near the fork. At a right-angle bend below the fork are exposures of thin-bedded and false-bedded red sandstone, dipping due west at about 10°. A small gorge along the strike occurs below this, and is crossed by two thin basalt dykes, causing a cascade.

At the 'hairpin bend' lower down, red and green sandy shales and marls are seen interbedded with sandstone. These rocks appear at intervals in the stream-section down to nearly opposite Burican. Here, however, after a blank interval, a whitish, thick-bedded sandstone occurs dipping 20° to 30° downstream. This looks very much like the white rough-weathering sandstone of the Sliddery Water. Between the ford and the footbridge opposite Burican there are bands of red sandy marls interbedded with white and red sandstone, the latter having distinct carious and nodular weathering. Below the footbridge occur typical soft, unctuous red marls, 2 feet thick, interbedded with red sandstone in a small exposure. Below this the section for a long way is in pink felsite.

Near the 254 feet O.D., about 250 yards above Glenrie Bridge, the only indication of a fault is seen in an exposure of red marls, interbedded with carious sandstone, with nearly vertical dip. Below this the section passes again, into felsite, which continues to the junction with the Sliddery Water. According to the Survey map, the Burican Burn runs along the line of a fault separating the lower sandstones from the upper many series, but of a fault direct evidence was obtained at one point only, in spite of good exposures. It is more probable therefore that the fault crosses the stream at an angle.

In the west, rocks belonging to the upper division of the lower part of the New Red Sandstone occur in the Clauchan and Ballymichael Glens, on the coast at Machrie Bay and Tormore, in the Machrie Burn, and in the Machrie Water. A strip of ground lying between two N.N.W. faults, and extending across the Ballymichael and Clauchan Glens in the same direction, is assigned to the above division. Prof. J. W. Gregory has described a good section in the burn about one-fifth of a mile south of Ballymichael Glen, near Ballymichael. Green-spotted red shales with thin sandstone bars, and sharp-grained greenish sandstones, are seen at levels below 300 feet, dipping west at 20°; but the carious sandstones which mark the top of the Permian begin to appear on the moor to the east of a stone wall and beyond a felsite dyke at the height of about 450 feet. The junction between the Lower and Upper divisions of the New Red Sandstone should therefore be placed farther up the stream than it is placed on the One-inch Geological Map.<ref>J. W. Gregory, The Permian and Triassic Rocks of Arran, *Trans. Geol., Soc. Glasgow*, vol. xv., part ii., 1915, pp. 181–182.</ref>G.W.T.

Similar rocks are exposed in the Clauchan Glen, and also in a small burn which joins it from the south. On the eastern side they are bounded by the Upper Old Red Sandstone; on the west by the marls of the Triassic. The breadth of the strip is nearly 500 yards, and the dip is generally to W.S.W. at angles of 15° to 20°. On the west side is found a fine-grained, yellow, calcareous sandstone which weathers in a carious manner. Higher up there are flaggy yellow and whitish sandstones, and a little below the foot of the branch burn are some red or mottled marly bands, some of which appear in the branch stream where, in one place, alternations of red shaly bands and thin sandstones occur. Above the

foot of the small burn the sandstone is fairly well bedded, pinkish or yellowish in colour, becoming harder and approaching to white, as the position of the bounding fault is ,neared. It cannot be said that the lowest of these beds differ materially from much of the older formation east of the fault, especially as between 100 and 150 yards above the little burn there occur three calcareous bands which are not unlike in character to the cornstones of the Old Red Sandstone. On the whole it appears more probable that the beds containing the calcareous bands are parts of the Trias, and belong to the higher part of the lower division, where calcareous concretions are known to occur in other places. W.G. (MS.)

The soft, thick, and rather false-bedded sandstones near the top of this division, which are carious (having many cavities in places), have been quarried west of Traighliath, where they form a narrow gorge in the Ballymichael Burn, and by the side of the Machrie Water about a mile from its mouth. At the latter locality the cavities are of various shapes and sizes, some of them very irregular, and one was observed more than a foot in length and upwards of an inch in breadth. The natives call these cavities *moss-holes.* These upper beds are finely exposed along the Tormore shore for about a mile south of Leacan Ruadh. The sandstone varies from a deep or almost brick-red colour to yellow or white, and the changes, sometimes rather abrupt, are not easily accounted for. At the north end of the section the beds dip to the north-east at 10°, and this direction continues for some distance, so that as we advance southward lower and lower beds successively rise from the shore and form the cliff. Then the beds for some distance remain horizontal, but before reaching An Cumhann the strata begin to dip gently to the south-east, and we observe the rocks a second time as we proceed southward. The carious and false-bedded sandstones enclose lenticular masses which seem slightly calcareous, and the weathering of some of the rock is very curious and irregular, sometimes not unlike bunches of grapes. Much of the sandstone is quartzose and rather coarse, but the bunches and lenticles are formed of a finer and harder rock, concretionary in structure. The massive red and yellow sandstones in which the large caves are formed are the highest part of this series, and a short distance to the southward we find these beds passing under the marls of the Trias. W.G.

In the Machrie Burn the typical, soft, thin-bedded, red sandstones of the Lamlash–Machrie group are well exposed in a gorge 300 yards north of Machrie Farm, and in a newly-opened quarry in the same locality. The dip is 27° to the south-south-west. Sun-cracked shales with sand 'dykes' occur in the stream bed near the farm. At the bridge adjacent to the farm, white, yellow, and pink massive sandstone dipping at 5° to the south-west no doubt represents the base of the Glen Dubh Sandstone horizon.

A similar section is seen in the Machrie Water five-eighths of a mile west of Derenenach. The sandstones here are soft, red, shaly, flaggy, and thin bedded, and have a dip to the south-south-west of 20°. At a little gorge below the boundary of Machrie Wood, coarse, thick-bedded, felspathic, pink to white sandstones, with the usual blocky outcrop on the adjacent moor, and smooth-weathering, but carious, surfaces, occur dipping south-west at 5°. Boulders of this rock may be traced across the moor for at least half a mile to the north-west. G.W.T.

Lithology of the breccias and conglomerates of the Lower New Red Sandstone

Mr. B. H. Barrett<ref>The Permian Breccia of Arran, *Trans. Geol. Soc. Glasgow*, vol. xvii., part ii., 1925, pp. 264–270.</ref> has studied the lithology of the Brodick Breccias as developed along the Corrygills shore, in Glen Dubh, the Machrie Water near Derenenach, and at the Cock of Arran. At Corrygills it was found that fully 75 per cent. of the pebbles were vein-quartz, and a varying proportion of the remainder were quartzites. Schistose grits like those of the Highland border, quartz-biotite-schists like those of the north of Bute, slates, greywackes, a dolomite very similar to that occurring in the Highland Border Series at Aberfoyle, cherts, and white and red sandstones, were also found. This assemblage of pebbles seems to have been derived from regions to the north and north-west of the island. In the Machrie Water the pebbles were almost entirely schists and quartz, and the best example of a pebble of Ben Ledi Grit was found here. In Glen Dubh, jasper and felspar-porphyry were relatively common in addition to the ubiquitous schists and quartz. At the Cock of Arran, schists and quartz again constitute the prevailing pebbles with red and white sandstone, shales and limestones of Carboniferous types. This is the exposure whence Messrs. Wunsch and Thomson obtained the derived Carboniferous fossils (p. 84). Mr. Barrett's conclusions are that the Brodick Breccia is of local derivation, and was deposited by infrequent river floods, which came from the north (Cock of Arran; Brodick; Corrygills), from the north-east, bringing Bute material, and from the west (Machrie Water and Glen Dubh).

The horizon on the Corrygills shore which is taken as marking the base of the Lamlash Sandstone or the top of the Brodick Breccia, contains numerous agates, associated with granite pebbles of Old Red Sandstone types, and with felsite and mudstone, besides the usual schists, quartzites, and quartz. The pebbles in the band of conglomerate at Largybeg Point (p. 89) consist mostly of white and pink vein-quartz, with quartzites similarly coloured, and a few of red felspar-porphyry, flinty quartz-felsites, grey mudstone, red sandstone, and chert. The igneous and quartz pebbles range between 1 and 2 inches in diameter, and are mostly of a well-rounded shingle type. A few pebbles, however, show distinct facetting in three or four directions, with a flat base, and are unmistakably dreikanter. Nevertheless, the edges of these are frequently well rounded, and they have evidently suffered some water erosion in addition to their original wind-facetting. The igneous and quartzitic pebbles, whatever their present shape, are of distant origin. On the other hand, the sandstone and mudstone fragments, which are large and angular, are clearly of local derivation. The matrix is a coarse sandstone consisting mainly of rounded and polished grains of quartz and an occasional cleavage fragment of fresh felspar, embedded in a whitish, decomposed, felspathic base.

The whole aspect of the conglomerate suggests that it represents an accumulation of pebbles and sand brought together by the occasional rain-bursts which occur in a desert or sub-desert region. This would account for the mingling of rounded shingle pebbles and angular dreikanter in a matrix of desert sand.

Two specimens from the basaltic horizon in the Brodick Breccias of the Glen Dubh exposure were collected and sliced, one of the purplish-red type (S24387) [NR 995 344], the other of the greenish-grey type (S24388) [NR 995 344]. The former is made up mainly of comparatively fresh basaltic fragments up to i cm. in diameter, many of which show traces of wind-rounding. The larger fragments, however, are generally angular. Mugearitic typeS constitute the majority of these fragments, but there are some typical red-speckled olivine-basalts like those of the Mauchline basin (Permian) on the mainland. Along with the basaltic fragments are a few angular chips of quartz-sericite-schist and quartzite, all embedded in an abundant carbonate matrix which appears to be dolomitic from its behaviour with acid.

The green rock (S24388) [NR 995 344] differs from the above in its greater relative abundance of basaltic fragments, in their much more advanced decomposition (hence the green colour), and in the more calcareous nature of the cementing material. G.W.T.

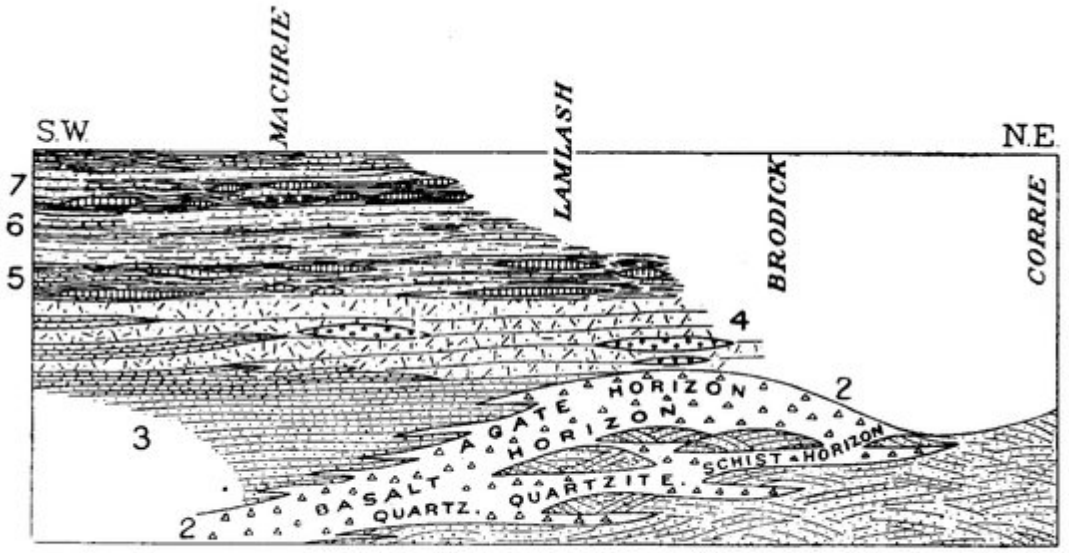


FIG. 4.—*Diagrammatic section showing the general structure and arrangement of the New Red Sandstone formations* (*c.f.* pp. 76–77)

(Figure 4) Diagrammatic section showing the general structure and arrangement of the New Red Sandstone formations (c.f. pp.76–77)

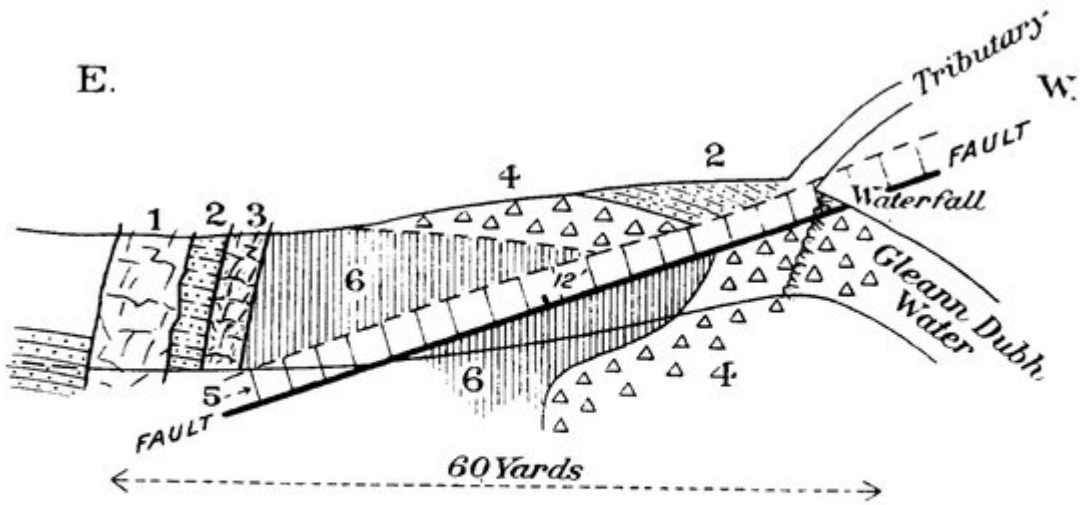
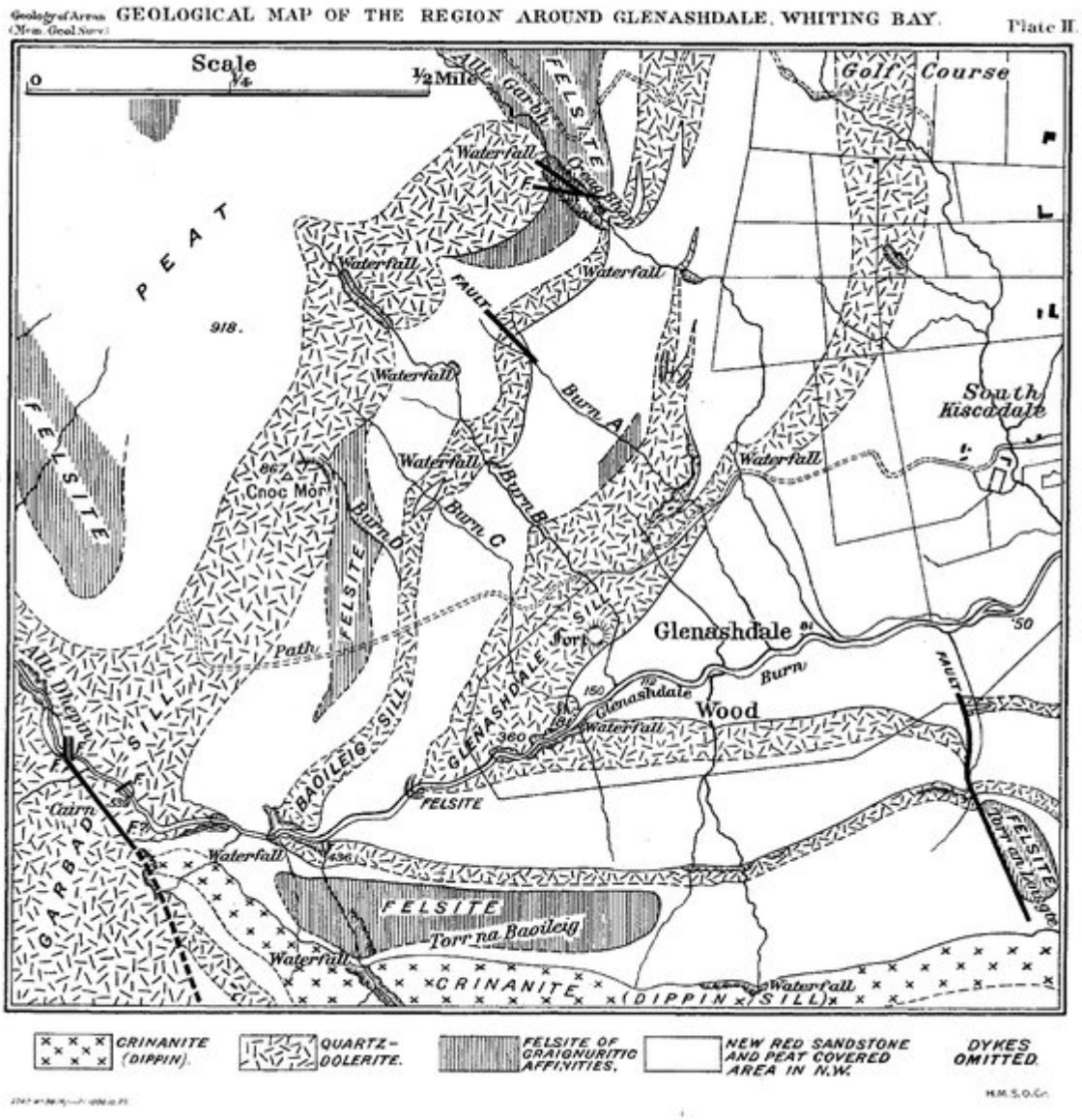


FIG. 5.—*Map of exposures in Gleann (or Glen) Dubh Water, one-eighth of a mile above confluence with Glen Ormidale.*

1. *Porphyritic basalt dyke ;* 2. *New Red Sandstone ;* 3. *Dyke of dense basalt ;* 4. *New Red Sandstone volcanic breccia ;* 5. *Crinanite dyke ;* 6. *Felsite sill.*

(Figure 5) Map of exposures in Glen Dubh Water, one-eighth of a mile above confluence with Glen Ormidale. 1. Porphyritic baslt dyke 2. New Red Sandstone 3. Dyke of dense basalt 4. New Red Sandstone volcanic breccia 5. Crinanite dyke 6. Felsite dyke.



(Plate 2) Geological map of the region around Glenashdale, Whiting Bay.

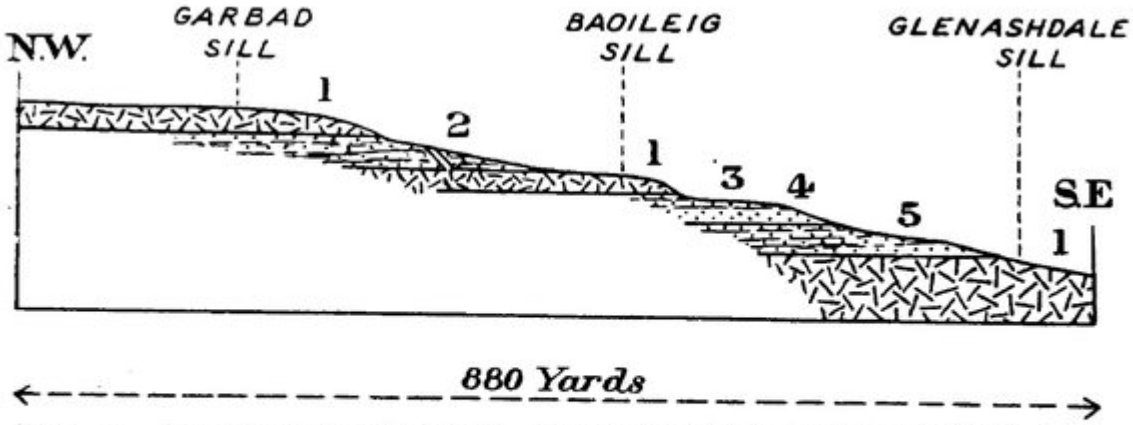


FIG. 6.—*Section along Burn B., one-third of a mile east of Cnoc Mòr, north of Glenashdale Wood.*

1. *Quartz-dolerite and craignurite sills ;* 2. *Shales and marls ;* 3. *Quartzitic sandstone ;* 4. *Chocolate-coloured ferriferous sandstone ;* 5. *Thin-bedded red sandstone.*

(Figure 6) Section along Burn B., one-third of a mile east of Cnoc Mòr, north of Glenashdale Wood 1. Quartz-dolerite and craignurite sills 2. Shales and marls 3. Quartzitic sandstone 4. Chocolate-coloured ferriferous sandstone 5. Thin-bedded red sandstone.

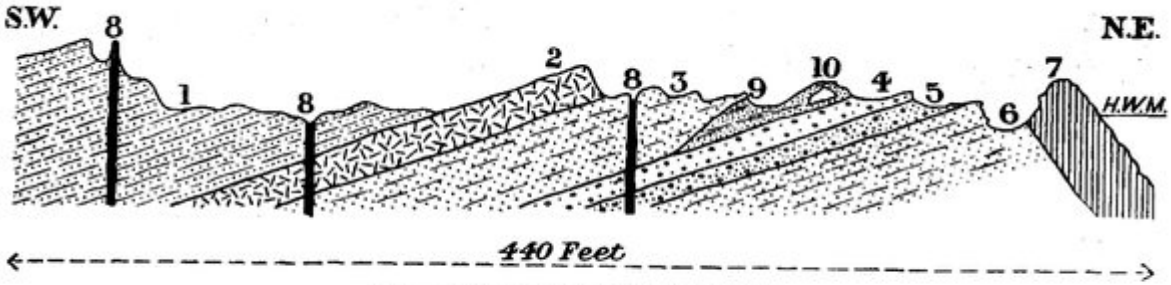


FIG. 7.—*Section across Largybeg Point.*

1. *Thin-bedded red sandstone ;* 2. *Quartz-dolerite sill ;* 3. *White sandstone ;* 4. *Coarse grit with bands of conglomerate ;* 5. *Conglomerate ;* 6. *Carious white sandstone ;* 7. *Thick dyke of craignurite-felsite ;* 8. *Basalt dykes ;* 9. *Line of local erosion ;* 10. *Rock-arch on raised beach.*

(Figure 7) Section across Largybeg Point. 1. Thin-bedded red sandstone 2. Quartz-dolerite sill 3. White sandstone 4. Coarse grit with bands of conglomerate 5. Conglomerate 6. Carious white sandstone 7. Thick dyke of craignurite-felsite , 8. Basalt dykes 9. Line of local erosion o. Rock-arch on raised beach.

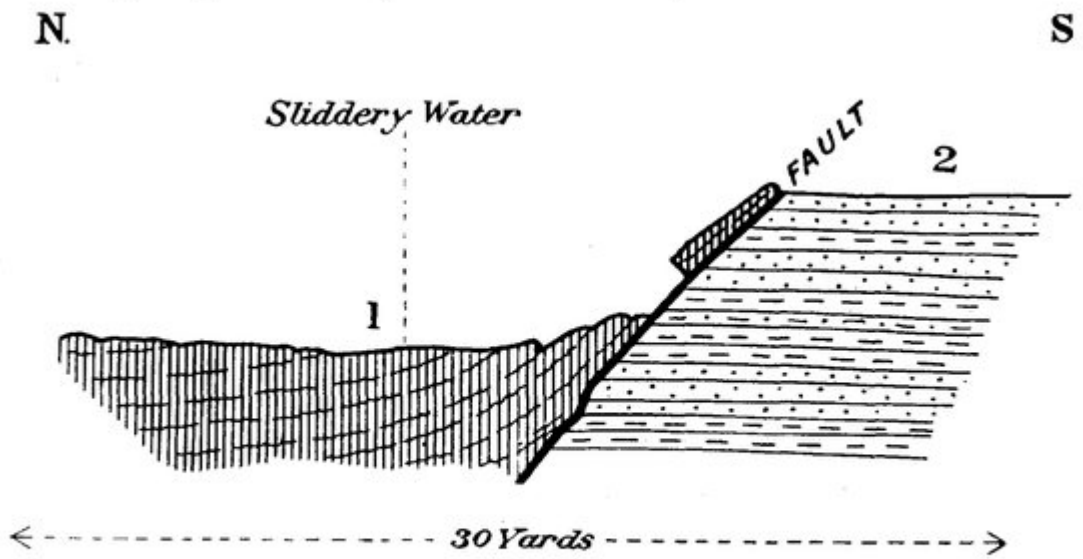


FIG. 29.—*Junction of felsite against Triassic sediments, Sliddery Water, just above Glenrie Bridge.*

1. *Felsite, with slabby jointing ;* 2. *Triassic sediments.*

(Figure 29) Junction of felsite against Triassic sediments, Sliddery Water, just above Glenrie Bridge. I. Felsite, with slabby jointing 2. Triassic sediments.