XX.—*Notes on the Geology of Raasay.* By Horace B. Woodward, F.R.S., F.G.S.

(Read 19th February 1913.)

General Remarks—Lewisian Gneiss—Torridonian Series—Trias—Lower Lias—Middle Lias—Upper Lias—Inferior Oolite Series—Great Oolite Series—Tertiary Igneous Rocks—Faults and Landslips—Glacial Drift—Beach Deposits—Peat, Water-Supply, Rainfall, Agriculture.

General Remarks.

The geology of Raasay, although varied, is not of great complexity. The northern end of the island is rugged ground formed of Lewisian Gneiss, but the fundamental rock in the area to the south is the Torridon Sandstone. The Jurassic strata are faulted against this old group of rocks beyond Carn Dearg and South Screapadal on the north; and the red rocks of the Trias are seen to rest on Torridon Sandstone to the south-east of Suisnish Hill, by Eyre Burn, on the south.

Macculloch in 1819 [1] gave a capital account of the general structure of the island, noted the true sequence of the main rock-divisions, and recognised the Liassic aspect of some of the fossils. Eight years later, Murchison, who paid a visit to the Hebrides in company with Sedgwick, determined the occurrence of Lias, Inferior Oolite, and Great Oolite.[2]

Thirty years elapsed before any further attention was given to the subject. Then, in 1857, Sir Archibald Geikie constructed a geological map of Raasay on the scale of about 2⅓ inches to a mile.[3] Six divisions of the Jurassic rocks were represented; these included the Lower Lias limestones and overlying Pabba shales, the Middle Lias Scalpa Beds, and three divisions of the higher sandstones and shales of the Oolitic Series.

This survey was utilised in the preparation of the "First Sketch of a Geological Map of Scotland" by Murchison and Geikie, published in 1861, and in other maps issued by the latter author. The fossils collected at the time were sent to Dr Wright, but there the story ends. No further news of them was received, and the detailed notes on the Jurassic rocks of Raasay remained unpublished. Both map and note-book were kindly lent to me by Sir Archibald Geikie. From 1869 to 1872 Dr James Bryce devoted much time to a study of the Jurassic rocks, both in Skye and Raasay, and he was accompanied in 1872 by Prof. Ralph

[1] "Western Islands of Scotland," vol. i., 1819, pp. 250, 251.
[2] *Trans. Geol. Soc.*, series 2, vol. ii. p. 353, Plate 35.
[3] This map is preserved in the Library of the Geological Survey and Museum of Practical Geology.

Tate, who determined the species of fossils that had been collected, and described a number of new forms. To these geologists we are mainly indebted for our knowledge of the stratigraphical details and palæontology of the Lower and Middle Lias of Raasay.

In the meantime Prof. Judd had commenced his researches in this area (1870-1877), and he added much information respecting Raasay. He showed that the red sandstones and conglomerates, which overlie the Torridon Sandstone and form a foundation to the Jurassic strata, may very properly be regarded as part of the New Red or Poikilitic system. He gave further particulars of the Lower and Middle Lias, recorded for the first time the occurrence of Upper Lias fossils, and gave a general account of the succeeding Oolitic strata.

In 1888 and subsequent years Sir Archibald Geikie published the results of his researches on the volcanic rocks of the Inner Hebrides, with many references to Raasay.

During the years 1892-3 I was engaged in the geological survey of Raasay south of the great fault of Screapadal; Dr J. J. H. Teall surveyed the area of Lewisian Gneiss, and Mr L. W. Hinxman that of the Torridonian Series to the north of the fault. The observations of Messrs Teall and Hinxman were published in the Memoir on "The Geological Structure of the North-West Highlands of Scotland" (1907); notes on the volcanic rocks of Raasay were embodied in Mr Alfred Harker's Memoir on "The Tertiary Igneous Rocks of Skye" (1904); and notes on the southern end of Raasay in the Memoir on "The Geology of Glenelg, etc." (1910).

On completion of my field-work in Raasay I had the satisfaction of finding my survey in harmony with that of earlier workers; the main features depicted on Sir Archibald Geikie's map, which was an Admiralty chart, far from perfect in topography, coincided well with the stratigraphical divisions and faults I had traced on the six-inch map of the Ordnance Survey, which naturally admitted of much more detail. Ultimately the following stratigraphical divisions were determined by the Geological Survey in Raasay.[1]

I. Recent and Pleistocene	Peat and Alluvium	
	Gravel and Raised Beaches	
	Boulder Clay	
II. Tertiary Igneous	Intrusive	Dolerite and basalt (sills and dykes).
		Granophyre (plutonic).
	Contemporaneous	Basalt.

[1] See one-inch Geol. Survey Map, Sheets 71 and 81.

III. Jurassic	Great Oolite Series	Shales, limestones, and sandstones (Loch Staffin Beds).
	Inferior Oolite Series	Sandstones with shale Basement-beds.
	Upper Lias	Shales
	Middle Lias	Ironstone, sandstone, occasional limestone, and shales (Scalpa Beds).
	Lower Lias	Shales (Pabba Beds), limestones, sandstones, and shales (Broadford Beds).
IV. Triassic	Rhætic Beds	Thin shales and sandstones
	Keuper (New Red Series)	Red clays, sandstones, and conglomerates
V. Pre-Cambrian and Archæan	Torridonian Series	Red sandstone, arkose, and conglomerate (Applecross Group)
		Red sandstones, flags and shales (Diabaig Group)
	Lewisian	Biotite and hornblende gneisses with hornblende-schist

The scenery of Raasay is well calculated to please for there is great diversity. There are picturesque pathways through the woodlands of birch and fir and occasional beech trees. Irregular tracts of moorland stretch from south to north, covered with thick heather or peat, diversified here and there with crags and rocky gorges. The Eyre burn and that of Inverarish have cut narrow and deep channels with many a cascade overhung by vegetation, while a wider rocky channel extends from near Storab's Grave through a picturesque gorge cut in Inferior Oolite and Torridon Sandstone to the sea-coast at Inver.

Scattered over the surface of the ground are many blocks of granophyre and white sandstone that have tumbled from the heights above, and mingled with them are occasional ice-borne boulders of Torridon Sandstone. Numerous tarns or lochs add to the beauty of the scenery, and occur up to a height of 1000 feet, while from the rough basaltic crags of Dun Caan (1455 feet) there is on a fine day a grand panorama of the volcanic mountains of Skye and the ancient peaks of Ross-shire.

The general strike of the Jurassic rocks is from the south-west to north-east, but the beds are displaced by several faults, and the two most important of these cause a repetition of the strata, so that we can work upwards from the New Red rocks of Suisnish and again from the New Red rocks that are exposed at Rudha na' Leac.

The igneous rocks in the main rest irregularly in great sheets or sills on the different stratified rocks, and in some instances the granophyre (or felsite of Dr Bryce) and also the basalt are faulted.

On the western side of the island the cliffs are low, and mostly formed of igneous rocks from Churchtown Bay to the north of Holoman Island. The Jurassic rocks, indeed, are almost wholly buried beneath a sheet of granophyre, the bedded masses of which partake of the general north-westerly inclination, forming sloping moory terraces, while the white crusts serve to mimic the appearance of the white sandstones of the Lower Oolites. I found one trace of the sandstone *in situ* on the foreshore south of Oskaig Point.

Nearer to the village of Churchtown or Clachan, to the north-west of Raasay House, the Jurassic rocks are concealed by a mass of dark green coarse-grained basalt, which in places has decomposed into a rich ochreous loam. This rock is faulted on the north side of Oskaig Point against granophyre. Again, further south, there is a large covering of granophyre which forms the elevated tract known as Suisnish Hill.

Innumerable dykes of basalt and dolerite, and some of granophyre, penetrate the Jurassic and older rocks. In most cases the beds exhibit no evidence of faulting and but little sign of alteration.

Along the southern end of Raasay the cliffs are also low, and made up of granophyre, Lower Lias shales and limestones, New Red sandstones and conglomerates, and Torridon Sandstone, with coverings of peat, boulder clay, patches of raised beach gravel, and a belt of scrubby woodland along the slopes above Eyre beach.

On the eastern side of Raasay, and to the south of Screapadal, the Jurassic rocks are exposed in a grand series of precipices. The cliffs rise in places, with an almost vertical face, to 800 or 900 feet; and with the higher steep slopes beneath Dun Caan, and the rough crag of that summit, they may be said to reach the somewhat dizzy height of 1455 feet. Dun Caan, the most prominent feature in the island, is an outlier of a basalt sill.[1] Tumbled blocks of large dimensions strew the foreshore over a great part of this eastern coast-line, so that only over limited

[1] Harker, "Tertiary Igneous Rocks of Skye," 1904, p. 436.

tracts can the beds be followed on the sea-margin. Some of these immense rock-masses form islets a short distance out at sea. Huge landslips have in places brought down shattered masses of the strata, and although they add considerably to the charm of the scenery, they serve to mask the succession of the beds. The bordering cliffs for some distance inland are broken and fissured in a way that renders it necessary to walk with great circumspection, for the crevices on Hallaig Moor are both deep and wide; and as remarked by Sir A. Geikie, they are "sometimes so treacherously concealed with long grass and fern that in a mist or in the dark a traveller might easily be lost in them." [1]

Further south the height of the cliffs is broken by a terrace along which a road has been made. The lower cliff is almost entirely in the Middle Lias, but it is for the most part vertical and inaccessible, so that only the basement portion and the reefs on the foreshore can be examined. The upper cliff rises up to the fissured summit of Beinn na' Leac (1017 feet); so fissured that were a flow of lava now to overwhelm it, many superficial dykes of igneous material would be formed. The rocks may be studied in cliffs by the road-side, and ascents may be made in places over the talus to the crags above; but in attempting to cross this hill from the southern side I was forced to descend and clamber up again to avoid a fissure that I could not traverse. It would seem that here as on Hallaig Moor the ground is ready to give way, and that other great landslips must take place as the sea gains further portions of the island.

Considerable tracts of the island are covered with a thin peaty accumulation, and this is deeper in the valleys. Tracts of boulder clay and Lias shales serve to form an impervious bottom for the peat in places; but on the higher grounds the peat lies in hollows and patches on the white sandstones and shales of the Oolites and on the granophyre and basalt.

Lewisian Gneiss.

The northernmost part of Raasay, as described by Dr Teall, is formed of Lewisian Gneiss, comprising biotite and hornblende gneisses with many bands of hornblende-schist of later intrusive origin. The tract is monotonous and dreary, bare rocky hills alternating with tracts of peat-bog and heather. In the neighbourhood of Torran, however, the monotony "is relieved by small trees and bushes of birch, hazel, and willow, but this is due in large measure to a small isolated patch of Torridon Sand-

[1] "Scenery of Scotland," ed. 2, p. 36.

stone which fringes the shore below the school-house and runs inland in the form of a tongue as far as Upper Arnish." [1]

Torridonian Series.

The rocks of this series have been described by Mr L. W. Hinxman, the divisions represented in Raasay being as follows: [2]—

Applecross Group.—Chocolate and red arkoses, with pebbles of quartzite, jasper, etc.

Diabaig Group.—Fine red sandstones, mudstones, and dark flags and shales.

The lower division is represented in the neighbourhood of Brochel Castle, where the strata are about 1000 feet in thickness. There also are neck-like masses of breccia, probably volcanic, and of uncertain age, possibly Tertiary, on one mass of which the castle is situated.

The ground formed of Torridonian rocks is rugged and picturesque, terraces or scarps of rock with long westerly slopes traversing the area at various levels, the whole much broken by deep gullies.

At the southern end of Raasay, between Rudha na' Cloiche and Eyre Point, the Torridonian (Applecross Group) consists of hard red and purplish sandstone with seams of quartzose conglomerate. The rocks are more sharply jointed than the overlying New Red strata, but in places the two formations, separated as they are by an enormous interval of time, lie in apparent conformity, and it is not surprising that the older observers made no distinction between them. Elsewhere the Torridon Sandstone is seen to be most violently contorted and to consist of granitic debris or arkose, presenting the aspect of a red granite.[3]

Trias.

New Red Series and Rhætic.

The New Red rocks of Raasay consist of red and variegated loamy clays, red and mottled sandstone with calcareous nodules, and pebbly layers or conglomerates.

Conglomerates are exposed west of Rudha na' Cloiche at the southern end of Raasay, extending from the coast to Eyre Burn

[1] "The Geological Structure of the North-West Highlands of Scotland," pp. 59, 260; see also Murchison and A. Geikie, *Quart. Journ. Geol. Soc.*, xvii., 1861, p. 175.

[2] *Op. cit.*, p. 340; Sir A. Geikie, *Ann. Rep. Geol. Survey*, for 1896 (1897), p. 74.

[3] See H. B. W. in "Memoir on Glenelg, etc.," 1910, p. 64, and *Proc. Geol. Assoc.*, xiii., 1894, p. 256.

along the south-eastern slopes of Suisnish Hill. About a quarter of a mile north of Rudha na' Cloiche a basalt dyke, 1 ft. 6 in. to 3 ft. wide, traverses the conglomerate in a direction 15° N. of W., and where broader it contains quartz and other pebbles derived from the conglomerate.

The conglomerates contain pebbles of quartz, schist, red Torridon sandstone, and compact blue Durness limestone, and they are not at all unlike some of the New Red rocks of Devon and Somerset. On the coast, east of Eyre Burn, they rest on the Torridon Sandstone. Some of the pebbly sandstones are calcareous, and weather in cavernous form, a feature in part due to the weathering out of pebbles. Elsewhere the sandy matrix is eroded, leaving the pebbles in relief.

Many small basaltic dykes traverse the rocks, some vertical, others inclined and curved. As a rule they are hollowed out in the cliffs, as the volcanic rock is much jointed and therefore breaks away. The Red rocks do not appear to be faulted, nor are they altered to any extent by the dykes. Springs are thrown out in places along the fissures, and by boulder clay where it is banked up at a lower level against the strata inland.

It is a curious fact that the passage or junction-beds between the New Red series and Lower Lias are seldom well exposed, no doubt owing to their soft nature and limited thickness.

In Eyre Burn, about 300 yards from the coast, the following strata were, however, observed in 1901 :[1]—

Lower Lias	Thick limestone, with wavy partings of shale. Blue limestones and shaly layers.	
Passage Beds of Rhætic age	Bluish-green shaly limestone, *Modiola*, *Pecten*.	? about 15 feet
	Fissile blue shaly limestone and shale, *Ostrea*, *Avicula* (*Pteria*) ?	
	Hard flaggy greenish-grey micaceous sandstone.	
New Red Series	Buff shaly and micaceous sandstone, alternating with red micaceous clayey sandstone.	15 feet

Among New Red fossils collected *Pteromya* cf. *Crocombeia*, was also recognised by Mr E. T. Newton.

The red clays are not seen directly below owing to obscurity of ground.

[1] See H. B. W., "Geology of Glenelg, Lochalsh, and S.E. Skye," 1910, pp. 91, 97.

A fault extends along the general course of Eyre Burn, a little to the west of the stream, where the Passage Beds and Lias appear.

North of the series of strata before noted, and on descending the burn below a waterfall, the sequence of New Red rocks was as follows :—

Red sandstones.
Pale and fine calcareous conglomerate.
Red and green calcareous sandstone.

Between North and South Fearns, near the mouth of Allt-Fearns, there should have been an outcrop of the New Red rocks and Passage Beds below the Lias, but the ground is obscured by debris.

Continuing northwards the next exposure of New Red rocks is at Rudha na' Leac. There conglomerates are overlain by brick-red and mottled sandstone, pale grey conglomeratic sandstone, hard calcareous sandstones, and red and variegated loamy clays. The highest beds seen are red clays, strata that might be suitable for brickmaking.

The beds dip to the north-west at 10° or 12° and are somewhat tumbled and fissured, stalactitic deposits occurring in a cleft by the shore. An interesting feature is an intrusive mass or irregular sill or dyke of basalt which produces some induration on the conglomerate. No pebbles were noted in the intrusive rock at this locality, as observed at Rudha na' Cloiche. The New Red beds dip towards the Lower Lias cliffs of the Hallaig waterfall, and are succeeded by limestones and shaly beds that clearly belong to the base of the Lower Lias. At this locality there is unfortunately an interval where no beds *in situ* are exposed. This interval marks the very spot where the Rhætic Beds if present should occur. Dr Bryce, it is true, regarded the New Red rocks as representing the Rhætic Beds, but he had no evidence at all to justify this opinion, and the fact that an unknown belt of concealed strata must exist at the spot would in itself have thrown doubt on the correlation.

Prof. Judd remarked that the zone of *Avicula contorta* "does not appear to be distinctly developed," [1] and he did not record any fossil evidence of the strata.

The thickness of the New Red series was estimated by Prof. Judd at about 200 feet at Rudha na' Leac (Ru-na-Leac) and by Dr Bryce at 150 feet.

There are, however, no clear and continuous sections of the higher New Red strata, and their thickness cannot be given with certainty.

[1] *Quart. Journ. Geol. Soc.*, xxxiv., 1878, p. 697.

	Passage Beds of Rhætic age	about 15 ft.
New Red Series	Buff and red shaly and micaceous sandstones	about 15 ft.
	Red and variegated clays and loamy clays with bands of calcareous sandstone.	
	Brick-red and mottled sandstones and pale grey conglomeratic sandstone, more or less calcareous.	
	Thick masses of conglomerate with occasional layers of sandstone	30 to 35 ft.
	Red and mottled sandstone with calcareous nodules and pebbly layers	20 to 25 ft.

Lower Lias.

Broadford and Pabba Beds.

In many respects the Lower Lias presents features common to the equivalent strata in England.

The lower beds comprise compact and shelly limestones and shales with *Gryphæa* beds, but they include also beds of sandstone.

The higher beds consist mainly of dark pyritic shales and sandy shales, which give rise to a sulphurous spring at Hallaig.

For convenience of local description the term Broadford Beds [1] was applied to the lower series of limestones and sandstones with alternating shales so well developed along the coast at Broadford in Skye.

There the thickness was estimated at 250 feet, including possible representatives of the Rhætic Beds and without them there would probably be about 240 feet. The approximate maximum thickness of the equivalent strata in Raasay may be about 200 feet.[2]

The higher division, known as the Pabba Shales, consists of greenish-grey and dark grey micaceous shales with rusty joints. The beds contain numerous ferruginous nodules, which frequently enclose Ammonites, and some of the nodules are bored. The shales, though much more micaceous than those of the midland counties of England, are otherwise much like those of the *Ammonites raricostatus*, *A. armatus* and *A. Jamesoni* zones.

[1] H. B. W. in *Ann. Rep. Geol. Survey* for 1896 (1897), p. 70.

[2] Judd, however, reckoned the Lower Lias limestone series to be about 350 feet, *Quart. Journ. Geol. Soc.*, xxxiv., 1878, pp. 697, 703.

Occasional lenticular bands of sandy and shaly limestone occur towards the upper part of the Pabba Shales, and they merge thence into the fissile sandy and calcareous rocks of the Middle Lias (Scalpa Beds).

The thickness of the Pabba Shales may be about 300 feet.

Since the writer was engaged in field-work in Raasay and Skye, and since the fossils he collected had been identified by Messrs G. Sharman and E. T. Newton, many changes in nomenclature have been made and species have been more and more split up. This process has its advantages to the student of the genesis of species, but is by no means so satisfactory to the field-geologist, and to those interested in the history of geology. None but a specialist can deal with the more modern species.[1]

In order to render their investigations of value the process of collecting must necessarily be carried out in far greater detail than was the case when most of the fossils recorded from Raasay were obtained. It is necessary not merely to ascertain in one series of strata the successive forms therein preserved; the horizontal distribution must equally be ascertained, otherwise the results may be very misleading. This can only be satisfactorily done by prolonged research.

As the translation of old names into the newer ones is seldom satisfactory without a renewed and careful examination of the specimens by a specialist, it has been deemed advisable here to retain the names given by Messrs Sharman and Newton, as well as those recorded by Dr Bryce, Prof. Tate, and Prof. Judd. Their significance can be understood.

At the southern end of Raasay the lower or Broadford Beds are exposed beneath the granophyre on the coast S.W. of Inverarish, where they consist of flaggy and sandy limestones and shaly beds with crushed *Pholadomya*. These are overlain further south at Suisnish and onwards to Suisnish Point by the Pabba Shales, dark micaceous shales with hard ferruginous nodules, from which Tate obtained the following fossils :—

Belemnites elegans.
Cardinia attenuata.
Gryphæa obliquata.
Ostrea.
Pinna folium.

On the foreshore there are many basalt dykes which stand out like walls, and the Pabba Shales are jointed and exhibit in places a rude cleavage.

Inland above Suisnish Point the lower portion of the Broadford

[1] See names of Ammonites given in "Memoir on Geology of Glenelg, etc.," pp. 182, 183.

Beds, comprising sandstones, shales, and compact limestones, are exposed beneath the main mass of granophyre. There the limestones have been worked for lime-burning; they are hard and splintery and sharply divided by rhomboidal joints with greenish serpentinous coatings. The intervening shales, which contain *Ostrea*, are indurated into a kind of lydian stone, like the altered Lias of Portrush.[1]

The general dip of the Lower Lias is westerly or a little north of west, 10° to 14°. The continuity of the exposures is broken by coverings of granophyre, boulder clay and also gravel and sand, in part glacial drift and in part raised beach. West of Rudha na' Cloiche a small tract of Broadford Beds occurs on the foreshore with a westerly dip of 15° to 22°. The same strata were exposed below the waterfall in Eyre Burn to the east of the fault.

To the north of Suisnish Hill the Lower Lias is probably faulted against the Middle Lias in the area covered by granophyre at Inverarish and eastwards.

The Broadford Beds of the Lower Lias may again be seen by following up the burn of Allt Fearns from the sea-coast. The beds, however, are practically inaccessible, as there is a deep gorge below the waterfalls where the limestones, sandstones, and shales are chiefly exposed.

Just above the waterfall the Pabba Shales are seen in the banks of the burn, beneath a covering of boulder clay.

After crossing the Fearns road, the shales are well shown in the banks and braes of the burn along the western side of Beinn na' Leac.

The sections and ledges of the shales afford a fine opportunity of studying the beds, and numerous fossils, indicating the zones of *Ammonites armatus* and *A. Jamesoni*, may be obtained. Here and there basaltic dykes cross the stream like walls and form cascades, and there is a difficulty in deciding if there is one continuous series of shales or if the beds are to some extent repeated by faults. Judging by the fossils there seemed to be evidence of repetition of the zones of *A. armatus* and *A. Jamesoni*.

The dykes form little conical hills here and there in the broad exposure of Pabba Shales to the west of Allt Fearns. The ground is there much covered by peat and there are traces of boulder clay.

The best place for studying the Broadford Beds is in the cliffs to the east of Hallaig Moor, north and south of the waterfall, whereat the Hallaig Burn reaches the sea.

The general sequence is as follows :—

[1] "Geology of Glenelg, Lochalsh, and S.E. Skye," 1910, p. 112.

Lower Lias Broadford Beds	Zones of *Ammonites semicostatus* and *A. Bucklandi*	Calcareous and sandy stone beds with occasional shaly beds, fucoidal markings, and tiny quartz pebbles	25 ft. to 30 ft.
		Limestones and sandy beds with doggers and pyritic shaly marls: *Ammonites semicostatus*	15 ft.
		Massive grey limestones with *Gryphæa arcuata* in profusion in certain layers, and micaceous shaly beds: *Amm. Bucklandi*	30 ft.
		Sandy and sparry limestone with *Pinna, Gryphæa arcuata, Rhynchonella*	
	Probable zones of *Ammonites angulatus* and *A. planorbis*	Dark shales and Ostrea-beds: irregular grey limestones, weathering like the Purbeck "Cinder-bed."	
		Irregular pyritic limestone, with ? *Modiola* . . .	
		Compact blue limestones with dark indurated shaly partings: *Cardinia, Ostrea.* . . .	

These lower compact limestones are not unlike in texture the Sun Bed at the top of the Rhætic Beds in Somerset, but they did not yield any distinctive Rhætic fossils.

The lowest beds, which were grouped by Dr Bryce and R. Tate with the zones of *A. planorbis* and *A. angulatus*, are exposed in scarps that stretch northwards from the pinnacle at Hallaig (Gualann na' Leac) towards the waterfall, but there are gaps that are concealed by talus.

We can walk northwards over tumbled blocks of Lias and over ledges of the rock towards the waterfall, but cannot proceed further along the coast. It is necessary to retrace steps and descend again to the north of the waterfall, and then, when the tide is out, the upper beds of the limestone can be examined, dipping a little N. of W. at 12° to 14°.

The Pabba Shales are well shown in places along the foreshore to the north, and fine specimens of *Ammonites Jamesoni* may be obtained, as well as many other fossils. It was here that Dr Bryce and Prof. Tate collected most of their specimens from this division of the Lower Lias.

It is nowhere easy to get at the junction of the limestones and shales, though it may be seen near Hallaig, where the water sinks underground along the dip-slope at the junction with

the sandstones and sandy limestones of the Broadford Beds with the overlying Pabba Shales.

I failed, as others have failed, to find any indication of the zone of *Ammonites oxynotus*, but the failure may be due to the few and small exposures of strata on the horizon where this zone might be expected. I obtained no fossils in the shales just above the limestones in the Allt Fearns burn.

It is probable that the Pabba Shales occur on the foreshore about a mile south of Screapadal and again just south of the Screapadal faults. Murchison recorded *Gryphæa gigantea* and *Plicatula spinosa* from "Scrapidale"—probably from the cliffs. In the burn I found dark shales with *Gryphæa arcuata* indicating Lower Lias, which occurs as a wedge between two faults into which the main northern fault here splits. The ground here is mostly covered with debris from the bordering heights.

The information respecting the zones in the Lower Lias may be summarised as follows :—

1. The zones of *Ammonites planorbis* and *A. angulatus* may be represented in point of time by the lowest beds of Lower Lias, as suggested by Tate (p. 339), who records among other fossils *Lima punctata*, Sow., *Pecten pollux*, d'Orb., and *Ostrea irregularis*, Münst.

2. The zone of *Ammonites Bucklandi* is represented in the Gryphæa-beds.

These strata have yielded :—

Ammonites	*Bucklandi*, Sow.	(GS.)
,,	*Conybearei*, Sow.	(Murchison, Suisnish)
,,	*sauzeanus*, d'Orb.	(Tate)
Cardinia Listeri, Sow.		(Tate)
Gryphæa arcuata, Lam.		(GS.)
Lima gigantea, Sow.		(Tate)
Spiriferina Walcotti, Sow.		(Tate)
Cidaris Edwardsi, Wright		(Tate)

3. The zone of *Ammonites semicostatus*, as noted by Prof. Judd (p. 703), is represented in the higher part of the limestone series (Broadford Beds) at Hallaig.

4. The zones of *Ammonites obtusus* and *A. oxynotus* have not been observed. The former zone has, however, been recognised in Skye.

5. The zones of *Ammonites raricostatus*, *A. armatus*, and *A. Jamesoni* are represented in the Pabba Shales.

Tate remarked (1873, p. 342) that "the community of species is so great that there is not much value in detaching the beds with *A. armatus* from those with *A. Jamesoni*"; he therefore gave one list of species, and with the general locality of Raasay.

The following are the more characteristic and abundant fossils of the Pabba Shells in the zones above mentioned :—

	Zone.	Allt Fearns.	Suisnish Raasay and Fearns Road.	Hallaig.	Authority.[1]
Ammonites armatus, Sow.	..	A	..	H	GS.
„ *brevispina*, Sow.	Arm.	..	R	H	Bryce, Judd
„ *Davœi*, Sow.	..	..	..	H	Bryce
„ *densinodus*, Quenst.	..	..	R	H	GS.
„ *Henleyi*	..	..	..	H	Bryce
„ *Jamesoni*, Sow.	..	..	R	H	GS.
„ *nodotianus*, Sow.	..	A	..	..	GS.
„ *raricostatus*, Ziet.	..	A	..	..	GS.
„ *Valdani*, d'Orb.	Jam.	..	R	..	GS.
„ *ziphus*, Ziet.	..	..	..	H	Bryce
Belemnites acutus, Mill.	..	A	..	..	GS.
„ *elegans*, Simp.	..	..	S	..	Tate
„ *elongatus*, Mill.	..	..	..	..	Tate
„ *paxillosus*, Schloth.	Arm.	..	R	..	Judd
Amberleya (*Encyclus*) *imbricata*, Sow.	..	A	..	..	GS.
Cryptœnia solarioides, Sow.	Arm	A	R	..	GS.
Arca Stricklandi, Tate	..	A	..	..	GS.
Arcomya	..	A	R	..	GS.
Cardinia attenuata, Stutchb.	..	..	S	..	Tate
„ *Listeri*, Stutchb.	..	A	..	..	GS.
Gryphœa obliquata, Sow.	Arm.	A	RS	H	GS., Judd
Hippopodium ponderosum, Sow.	Arm.	A	R	H	GS., Tate
Lima	..	..	..	H	GS.
Modiola scalprum, Sow.	..	..	..	H	GS.
Ostrea	..	..	S	..	Tate.
Pecten lunularis, Roem.	..	A	..	..	GS.
Pholadomya ambigua, Sow.	..	A sp.	..	..	Tate, GS.
„ *decorata*, Goldf.	..	A	..	..	Tate
Pinna folium, Y. and B.	Arm.	..	RS	H	Tate
Rhynchonella furcillata, Theod.	..	A	R	..	GS.
Waldheimia numismalis, Lam.	..	..	..	..	Tate

6. The zone of *Ammonites capricornus* appears to merge into the base of the Middle Lias, as noted by myself, also by Prof. Judd, who thought that the intermediate series probably included the zones of *Ammonites Davœi* and *A. Ibex* (1878, p. 711). Tate (1873, p. 343) records *A. Henleyi* from Raasay, and Bryce (1876) further records *A. Davœi*.

Middle Lias.

Scalpa Beds.

The Lower Lias (Pabba) Shales pass into the Middle Lias strata as they do in England. In shales that may be grouped with

[1] GS. indicates specimens collected by H. B. W. and named by Messrs Sharman and Newton.

the Middle Lias, I found *Ammonites margaritatus* and small examples of *A. capricornus* in the same layer; and this is the case also in Yorkshire. There is no great thickness of shales at the base of the Middle Lias of Raasay, perhaps 10 feet; but as the division is a palæontological one we have here as elsewhere to draw an approximate boundary which however cannot deviate very far from the same horizon.

In mass the Middle Lias consists of rock beds, of hard and soft more or less calcareous sandstones, with occasional beds of sandy shale and large doggers.

It can be best seen in the cliffs below North Fearns in a tract that is faulted on the south against the Lower Lias limestones and shales, and on the north against the New Red rocks of Rudha na' Leac.

As before mentioned one can see the beds, but cannot get at the whole of them owing to the inaccessibility of the cliffs. The beds are seen to undulate, but the general dip is towards the west-north-west.

It is probable that the Pabba Shales extend along the foreshore for a short distance beneath the south end of the Middle Lias cliffs, but the shales are wholly concealed by debris of Middle Lias, drift boulders, and beach deposits. Further on the sandy shales that form the base of the Middle Lias may be seen along the lower part of the cliffs; but the clear upward sequence is interfered with by dislocations in the strata and by several dykes. About midway along these Middle Lias cliffs there is a ravine and waterfall, on the south side of which the strata are dislocated, and to some extent they have slipped. Shales with many Belemnites appear on the foreshore, and these I take to belong to the upper part of the Pabba Shales. These are succeeded by other shales and shaly sandstones that form the lower portion of the cliffs and foreshore to the fault near Rudha na' Leac. It was in a reef on the foreshore near the fault that I found *Ammonites capricornus* and *A. margaritatus* together. The higher portions of the Middle Lias may be seen in banks by the road that runs on top of the cliffs below Beinn na' Leac.

The highest beds seen *in situ* were in a hollow to the north-east of Gualann na' Leac, and consist of greenish-grey sandstones with *Rhynchonella*.

Beds with numerous examples of *Gryphæa cymbium* (or *Maccullochi*) occur at a lower horizon.

Fine sections of Middle Lias may be seen along the course of the Inverarish Burn from a little south of the church, northwards to the waterfall on the Dun Caan footpath. The general dip is westerly about 10°. For a great part of its course, the burn

rushes rapidly over ledges of rock between two walls of the Middle Lias.

South-east of the church the more calcareous beds are seen that belong to the lower portion of the Middle Lias; higher up we come to beds with *Gryphæa cymbium* and crinoidal layers, and further on to the greenish sandstones with *Rhynchonella*. Very fossiliferous beds with *Gryphæa cymbium* and *Pecten æquivalvis*, that occur about the central portion of the series, outcrop on the moors north-west of Beinn na' Leac between Allt Fearns and the Inverarish Burn. A little faulted tract of Middle Lias occurs also at the southern end of Beinn na' Leac, and to the north-west the beds may be traced in various places on the moors, in higher portions of Inverarish Burn, above the main waterfall, and in the broken ground to the west of Hallaig. North of the great Hallaig landslip we may trace the Middle Lias in places on the foreshore and here and there in the cliffs. Thus about three-quarters of a mile north of the angle in the cliffs marked Druim an Aonaich, there were to be seen greenish calcareous sandstones with doggers, yielding *Belemnites*, *Pecten æquivalvis*, *Pholadomya*, *Rhynchonella*, and crinoids.

On the coast no junction could be found of the Middle Lias with the overlying beds. It is clear, however, that the shales of the Upper Lias come on top. I first saw these beds on the eastern slopes of Beinn na' Leac, and subsequently traced them all along that scarp until they are faulted out both on the north and south. Nowhere, however, was the actual junction with the Middle Lias shown.

The tract that gave most trouble was an area of rather less than a square mile that lies to the east and north-east of the church.

The beds are faulted, and in places they have slipped. There are some coverings of peat and boulder clay, as well as portions of the great sheet of granophyre of Suisnish Hill.

There are three or four scarps of calcareous sandstone that present very similar characters. Along the Inverarish Burn occur, as already noted, fine sections of the Middle Lias, and the beds are fossiliferous; but the two more prominent scarps of calcareous sandstone, both dipping approximately in the same direction, yielded no distinctive fossils, and it was difficult to fit the beds into proper stratigraphical sequence by the process of mapping alone.

The clue however came in time. There were dark shales in a small side ravine, beneath a cascade to the west of the fault that brings granophyre against Middle Lias, and on the western side of Inverarish Burn; but the beds were only partially exposed amid a heap of tumbled blocks of sandstone, and no fossils at first rewarded the search. Higher up the Inverarish Burn,

beyond Macdonald's Glen, above the main waterfall, where the stream tumbles over a crag of granophyre, in a ravine that stretches a short way to the south, and about a third of a mile south-west of the point where the footpath turns directly north to Dun Caan, I came across an outcrop of oolitic ironstone.

A thickness of 4 feet 6 inches could be measured, but the base was not seen. The outer beds were brown and rusty; the mass of the rock was greenish-grey, suggesting at once an equivalent of the Middle Lias ironstone of Cleveland and the midland counties of England. The rock dipped towards the burn, the shape of the ground corresponding with the dip of the strata. Investigation was now made of a portion of the main burn about 300 yards to the north, that had not as yet been examined. If Upper Lias was present it ought to show at this particular place, and there to my great gratification was an exposure of dark shales, in a low bank bordering the stream below the Dun Caan footpath. For a long time the search for fossils was made in vain, but at length it was rewarded by the discovery of serpentine ammonites. After this all difficulty seemed to vanish. Another visit was paid to the dark shales of the small waterfall about a third of a mile west, that had been previously searched for fossils, and now there was found a ledge of oolitic ironstone just below the spot where the shales would naturally outcrop, by the footpath leading from Loch a' Mhuilinn towards Dun Caan. I procured some masses of the shale, and after splitting up many portions received my reward in finding serpentine ammonites.

In other places near by the same oolitic ironstone was discovered directly beneath the shales, and indeed wherever there was found an exposure near enough to the base of the shales there was the ironstone. Tumbled blocks of it also were met with on the eastern slopes of Beinn na' Leac above the North Fearns road, and one block to the N.E. of Gualann na' Leac.

The outcrops along the east of Beinn na' Leac are mostly concealed by debris and vegetation, and further north all along the great cliffs on the eastern side of Raasay, from Hallaig to Screapadal, the junction of Upper and Middle Lias is almost wholly obscured by slips and talus from the crags above, and no clear junction was accessible. The ironstone itself yields a few poorly preserved fossils—*Ammonites* (species not determinable), *Belemnites*, *Astarte*, *Pecten*, *Rhynchonella*, and pieces of fossilised wood.

The mass of the iron-ore attains a thickness of 5 feet. It is a greenish-grey oolitic stone, that weathers to a brown iron-ore where exposed at the surface.

Occasionally a thin layer of oolitic ironstone occurs above the main mass, at or near the base of the Upper Lias shales, and

from this horizon were obtained *Ammonites annulatus* and *A. communis*.

The position of the Raasay iron-ore, therefore, corresponds as nearly as possible with the Cleveland iron-ore, although in Yorkshire the upper part of the Middle Lias contains a series of ironstone-bands. In composition, as well as in general structure, the Raasay ore compares well with that of Cleveland, for analyses made by Mr A. B. Dick showed 29 per cent. of metallic iron in the grey ore (carbonate) and 37 per cent. in the brown ore.[1]

The general sequence in the Middle Lias (Scalpa Beds), based on records of various sections, appears to be as follows, the thickness, difficult to determine, being estimated at 150 feet by Dr Bryce :—

Oolitic ironstone (fossils as noted, p. 180).

Greenish-grey, buff, and brown sandstones, more or less calcareous and ferruginous, in thick beds often wedge-like, with no conspicuous partings. Some beds are carbonaceous, and there are occasional huge doggers and ferruginous (pyritic) nodules,[2] giving rise to rusty springs. The following fossils occur :—

Ammonites spinatus.
,, *margaritatus.*
Belemnites.
Avicula inæquivalvis.
Gresslya.
Gryphæa cymbium.
Lima.
Ostrea.
Pecten æquivalvis.
Pholadomya ambigua.
Pleuromya costata.

Shaly beds, crinoidal, yielding :—

Gryphæa cymbium.
Pecten.
Rhynchonella acuta.
,, *tetrahedra.*
Terebratula punctata.
Waldheimia quadrifida, var. *cornuta.*

Calcareous sandstones with fucoidal markings, sandy and micaceous limestones, occasional doggers : beds much jointed and the joints sometimes curved (Gryphæa Beds), yielding :—

Ammonites margaritatus.
Belemnites (abundant).
Gasteropods.
Cardium.
Pecten æquivalvis.
Pholadomya.
Pleuromya.
Plicatula spinosa.

[1] See H. B. W., *Geol. Mag.*, 1893, p. 494.

[2] Dr Bryce (p. 336) described the upper bed of the Middle Lias as "Yellow calciferous sandstone with nodules."

Gryphæa cymbium (abundant).
Lima.
Ostrea.
Rhynchonella.
Spiriferina.
Crinoid fragments in clusters.

Sandy and micaceous shales, with some layers of calcareous shaly sandstone, and nodules or lenticular beds of shaly limestone. yielding :—

Ammonites margaritatus and *A. capricornus* in same layer (small specimens).
Belemnites (a few).
Cardium truncatum.
Lima.
Modiola scalprum.
Pecten liasianus.
Pinna.
Pleuromya.
Rhynchonella.
Crinoid fragments.

Pabba Shales, with profusion of Belemnites.

The more abundant and characteristic fossils of the Scalpa Beds are as follows :—

		Authority.	
Ammonites Engelhardti, d'Orb.			Judd.
,, *margaritatus*, Montf.	GS.	Tate,	Judd.
,, *spinatus*, Brug.	GS.		Judd.
Belemnites breviformis, Ziet.		Tate,	Judd.
,, *paxillosus*, Schloth.		Tate.	
Avicula inæquivalvis, Sow.	GS.		
Cardium (*Protocardium*) *truncatum*, Sow.			
Gresslya Seebachi, Brauns		Tate.	
Gryphæa cymbium, Lam.	GS.	Tate,	Judd.
,, *gigantea*, Sow.	GS.	Tate,	Judd.
Lima			
Modiola scalprum, Sow.		Tate.	
Ostrea			
Pecten æquivalvis, Sow.	GS.	Tate.	
,, *liasianus*, Nyst		Tate.	
Pholadomya ambigua, Sow.	GS.	Tate.	
Pleuromya costata, Y. and B.	GS.		
Plicatula spinosa, Sow.	GS.	Tate.	
Rhynchonella acuta, Sow.	GS.	Tate.	
,, *tetrahedra*, Sow.	GS.	Tate.	
Spiriferina rostrata, Schloth.		Tate.	
Terebratula punctata, Sow.	GS.	Tate.	
Waldheimia quadrifida, Lam. var. *cornuta*, Sow.	GS.		
Pentacrinus	GS.		

Upper Lias.

The Upper Lias of Raasay is nowhere well exposed to any considerable thickness, but was reckoned by Prof. Judd to be from 80 to 100 feet. Where seen it consists of dark micaceous and ferruginous shales, and usually contains serpentine ammonites and belemnites. It occurs beneath the basement beds of the Inferior Oolite (sandy, flaggy, and nodular limestones and calcareous sandstones) east of Beinn na' Leac, by the Inverarish Burn (as before noted), on the steep slopes west of Hallaig and beneath Dun Caan, as represented in section by Dr Bryce.[1]

The following fossils have been recorded :—

		Inverarish Burn.	Beinn na' Leac, Fearns.
Ammonites	*annulatus*, Sow. .	GS.	
,,	*communis*, Sow. .	GS.	
,,	*exaratus*, Y. and B. .	GS.	
,,	*falcifer*, Sow. . .		Judd.
,,	*serpentinus*, Rein. .	GS.	Judd.
,,	*subplanatus*, Oppel .	GS.	
Belemnites	*Voltzi*, Phil. . .		Judd.

Inferior Oolite Series.

This division comprises a great series of white, grey, and yellow sandstones, in massive beds, also thin-bedded and current-bedded sandstones, some beds calcareous and shelly. In the higher portion there occur beds of dark shale. Towards the base, and forming passage beds between the Upper Lias and Inferior Oolite there is a group of sandy shales with bands and nodular masses or doggers of calcareous sandstone, about 30 feet thick. It was everywhere traceable at the base of the great series of white sandstones, etc., that form so conspicuous a feature in the geology of Raasay, and was mapped separately as the Basement Beds of the Inferior Oolite. The strata yielded an Ammonite of a type that characterises that horizon in England, and was identified as *Ammonites variabilis* by Messrs Sharman and Newton. Thus in Raasay as in the west of England we have passage beds between the Upper Lias and Inferior Oolite of very similar lithological character.[2]

Springs occur at or near the base of the series.

These Basement or Passage Beds varied in character in places, the calcareous sandstones passing into grey sandy limestones

[1] *Trans. Geol. Soc. Glasg.*, vol. iv., 1874, plate xi., Fig. 3.
[2] See also Judd, 1878, p. 720.

and being of a much less interrupted or nodular character in some places than in others. They were not very fossiliferous. Lithogically, moreover, they resemble some of the Middle Lias rock beds.

The Basement Beds were well seen on the eastern side of Churchtown Bay and near the manse beneath the white sandstones. There they consist of a thin bedded series of calcareous, flaggy, and carbonaceous sandstones and grey limestones with fucoidal and ripple markings, occasional large doggers, and belemnites.

To the north at Clachan, and in the woods west of Loch a' Mhuilinn, the white sandstones are exposed in quarries, dipping W., 10° N. to W. 40° N. from 15° to 20°. The stone is more or less fissile and false-bedded and is not obtained in large blocks, but is evidently durable as the edges remain fairly sharp.

East of Raasay manse the stone is hard and flaggy, almost a quartzite where covered by granophyre.

Some of the lower beds are shelly, containing gasteropods, *Pecten*, etc.

In the area south, east, and north-east of Dun Caan the general dip is westerly or a little north of west at angles of 12° to 15°. Large fissures occur on the edge of the cliffs east of Loch na Mnà.

An old freestone quarry below Druim an Aonaich may have been worked in tumbled blocks of the white sandstone or possibly in the Middle Lias—probably the former.

Beinn na' Leac is formed of a mass of white sandstones with a general dip near the south of about 10°, W., 10° to 20° N., and in this tract some wide and deep clefts traverse the upland in a north-westerly direction.

Along the faulted boundary on the west, white sandstone, calcareous sandstone, and shelly grit with spines of Echinoids, also some layers of grey and reddish felspathic grit 6 or 7 feet thick, occur. The sandstone is rendered black in places by peaty staining. Some beds on the north are minutely false-bedded and fissile.

The Basement Beds with more or less shaly calcareous sandstone and sandy limestone yielding *Ammonites variabilis* were seen to the north-east overlying the Upper Lias shales.

To the south-west of Dun Caan there were exposed about 15 feet of massive white sandstones resting on 15 feet of thin false-bedded sandstones. A tract of white sandstone extends along the south-eastern borders of the great fault alongside the Torridon Sandstone.

On the coast near Carn Dearg the strata are much broken and bent as well as jointed and false-bedded, the general dip

being 15° a little west of south. The highest beds there seen are false-bedded flaggy calcareous sandstones, fine and coarse grained, with ironstone kernels and Belemnites, resting on white sandstones with red stainings.

The vicinity of Storab's Grave is difficult to interpret. Along the Inver gorge west of Brae, the sections show white and red-stained sandstone, calcareous sandstone doggers, and (adjacent to the fault) beds of shaly sandstone that indicate the Basement Beds. The general dip is to the south-west at 18° to 20°.

To the east-south-east of Storab's Grave there are sections in the banks of the stream showing clays with *Nucula* and dark sulphurous and rusty shales with thin bands of hard earthy limestone. These strata pass up into even beds of pale carbonaceous sandstone with pyritic nodules resembling the Basement Beds of the Inferior Oolite. They are faulted against sandstone, while beyond is an irregular mass of granophyre with an intermediate band of dark shales, 6 feet thick.

About a third of a mile to the north-east of Storab's Grave beneath boulder clay there is exposed (by the burn) sandstone with plant remains, faulted against strata that appeared to represent the Inferior Oolite Basement Beds and Upper Lias shales, the sequence being as follows :—

Calcareous sandstone.

Shales with fissile sandy and ferruginous doggers and thin calcareous sandstones.

Shales.

In the loop of the burn north of Druim an Aonaich there is another exposure of dark shales bordered to the east by the white sandstone of the Inferior Oolite dipping westwards.

So far as I could judge these shales appeared to represent the Upper Lias brought up by a fault traversing the ground N. and S.

There was no definite appearance of the overlying Basement Beds on the west, but white sandstones of Inferior Oolite, dipping to west at 19° were exposed to the south-west of the main loop ; higher up to the south-west there were greenish clayey shales, and fissile white and rusty sandstone, false-bedded ; then shales with nodular limestone and "beef," belonging to the Great Oolite Series.

No fossils were found in the supposed Upper Lias shales, and I am now disposed to group them with the upper part of the Inferior Oolite, as the sequence corresponds with that afterwards observed by Mr C. B. Wedd in Strathaird, the higher portions being, as he remarks, "a well-defined series of estuarine strata" : [1]—

[1] "Geology of Glenelg, Lochalsh, and South-east part of Skye," 1910, p. 116.

	Feet.
Hard white and light grey granular sandstone, more or less calcareous, with few seams of quartz pebbles, rootlets, and other plant-remains	35 to 45
Dark grey shaly micaceous flags	about 30
Black shale with pyritous nodules and ammonites (*Garantiana* or allied forms) .	
Massive sandstone series, with calcareous doggers in lower part [=Basement Beds]	700

It should be noted that R. Tate described the "Middle Series" of the Inferior Oolite as consisting of "Red-yellow varying to white sand-rock, grey where resting on the lower series, with plant remains, and calciferous sandstones and shales."[2] He did not, however, state any locality, whether in Skye or Raasay, in his descriptions of the Inferior Oolite and its fossils. His "Upper Series" contains fossils that indicate Great Oolite.[1]

Further research is required among the estuarine sandstones and shales of Storab's Grave and Druim an Aonaich on Raasay.

Great Oolite Series.

Loch Staffin Beds.

The Great Oolite Series or Great Estuarine Series on Raasay may be observed in many isolated exposures near Dun Caan and northwards in a belt of ground traversed by the great sheet of basalt of Meall Daimh, and extending to the great fault south of Beinn a' Chapuill.

To the east of the highest point of that hill of Torridon Sandstone, shales are exposed, with sandstone and shelly limestone at a higher level to the south. It is possible that these shales may be identical with those now grouped with the Inferior Oolite, but the evidence was not clear. The ground is obscured by much peat and here and there by a few feet of Boulder Drift.

In mass the Great Oolite Series comprises shales with bands of "beef" (fibrous carbonate of lime), hard layers of compact limestone, sometimes oolitic and often very fossiliferous, together with beds of sandstone, some calcareous, and brown sands with doggers.

Probably only the lower divisions (Nos. I. to III. or IV.) recognised by Mr Wedd in Strathaird, Skye, are represented in Raasay, but it was not possible to build up a sequence owing to the absence of any clear and continuous sections.

The general sequence of the Loch Staffin Beds as determined

[1] *Quart. Journ. Geol. Soc.*, xxix., 1873, p. 346.

in Strathaird by Mr Wedd, is as follows, the total thickness being estimated at about 400 feet:[1]—

		Feet.
VI.	Blue shaly marl with calcareous nodules	30 or 40
V.	PALUDINA SCOTICA LIMESTONES. Blue fine-grained argillaceous limestones, weathering cream-coloured, with shales, fibrous carbonate of lime "beef," and thin beds of calcareous sandstone	37
IV.	Black and blue shales and mudstones, with occasional thin limestones	40
III.	OSTREA HEBRIDICA BEDS. Calcareous shales or limestones, crowded with *Ostrea hebridica* .	17
II.	CYRENA LIMESTONES. Massive blue sandy and crystalline limestones and calcareous sandstones with small lamellibranchs. Dark shales and occasional bands of "beef." *Cyrena* generally crushed	70
I.	CYRENA SHALES. Black laminated shales with numerous beds of *Cyrena*, thin bands of blue limestone and calcareous sandstone . .	200

North-east of Dun Caan the following succession of beds was noted:—

Basalt with veins of siliceous material 1 to 8 inches,	25 ft. or more	
Sandstone, indurated on top	1 ft.	3 in.
Shelly sandstone	1 ,,	0 ,,
Shelly siliceous rock	0 ,,	2 ,,
Basalt	1 ,,	0 ,,
Indurated shelly layer		
Fibrous carbonate of lime ("beef") .		
Shelly limestone	2 ,,	0 ,,
Fibrous carbonate of lime . . .		
Shelly limestone		
Basalt	0 ,,	4 ,,
Shell-limestones in three bands, the lowest 2 feet thick, and shales.		

Ostrea hebridica and *Cyprina* were the only fossils recognised.

Some of the shelly layers have been baked into a kind of lydian stone, like the shales in the Lower Lias before mentioned.

In the belt of the Great Oolite series which outcrops east of the Meall Daimh basalt, and above another basalt sill to the east, white sandstones, shelly in places, also shelly and gritty limestones, were exposed here and there. Further north there were outcrops of shales and sandstones, and at the north-western end of the

[1] "Geology of Glenelg, Lochalsh, and S.E. part of Syke," 1910, p. 121.

Meall Daimh basalt there were exposures of compact limestone, shell-limestones, granular limestone, and flaggy calcareous grit, together 15 feet and more in thickness, dipping a little west of south at angles of 20° to 25°.

Sandstones, sands, shales, doggers of calcareous sandstone and hard shell-limestones were exposed on the eastern side in tracts where the surface layers of peat had slipped downhill.

Some of the hard grey shelly limestones appeared suitable for polishing.

Macculloch thus described the main features in this northern tract of peaty moorland: "In the interior of the island, narrow as it is, are many irregular eminences, mixed with others of a character so peculiar as to be worthy of notice. These are long narrow ridges parallel to the sides of the island, divided by deep valleys in such a manner, that the toil of traversing them can only be compared to that of alternately descending and surmounting the ridgy waves of a long and deep-rolling sea." [1]

Tertiary Igneous Rocks.

Although at one time the columnar basalts intercalated in the Jurassic strata, were regarded by some authorities as contemporaneous, it has been generally recognised during the past fifty years that like the rocks of the Giant's Causeway they are of later date than the Cretaceous period, and are intrusions in the form of sills.

Sedgwick and Murchison in 1828 remarked that "There may have been several periods of eruption: for the greatest part of the trap of the Hebrides is newer than the Oolitic series, and in the north of Ireland it is newer than the chalk." [2]

It is now held from the evidence of plant remains associated with some of the volcanic accumulations that the igneous rocks are for the most part of Eocene age.

Mr A. Harker has dealt in detail with the phenomena and, confirming the general conclusions of Sir Archibald Geikie, recognises three phases of igneous activity:

(1) The Volcanic Phase represented by the great basaltic plateaux.

(2) The Plutonic Phase, marked by the intrusion, first of laccolitic masses of gabbro, and afterwards of granophyre, and "consolidated beneath a very considerable superincumbent mass."

(3) Minor Intrusions in the form of sills, sheets, and dykes. The great group of basic or dolerite sills were intruded later than

[1] "Western Islands of Scotland," vol. i., 1819, p. 241.
[2] *Trans. Geol. Soc.*, ser. 2, iii. p. 35.

any of the volcanic or plutonic rocks. They include diabase, dolerite, and basalt, also tachylite from Screapadal [1] (Screpidale).

The coarse-grained basalt of An Aird, west of Raasay House, and that of Cnoc an Ratha to the north-east, decomposes into a kind of fine gravelly sand used for mending paths.

Near the fault which brings the basalt against the white sandstones of the Inferior Oolite, by the poultry yard, north of Raasay old chapel, there are traces of red ironstone of no commercial importance, probably a vein.

Where the fault extends to the coast N.W. of Oskaig the basalt is brought against the granophyre and slickensided faces of the former rock are seen in a cleft by the shore.

The following notes are by Mr Harker :—

"*Decomposed coarse-grained basalt, Raasay.* This is too incoherent to admit of slicing. The yellow green colour suggests that the alteration here has followed the epidotic line, and a rough examination of the powdered material confirms this observation. The material consists chiefly of augite and a little hornblende, epidote, and some relics of felspar. The epidote has doubtless been produced largely at the expense of a lime-bearing felspar, iron being taken up from magnetite or augite. There is little sign of chloritization."

These and other notes by Mr Harker were made in January 1896.

The granophyre is likewise decomposed in many places into a loose gravelly material, and the "gravel pit" marked on the six-inch map N.E. of Inverarish has been opened in coarse debris.

"*Loose material forming soil and subsoil in granophyre area of Raasay.* This is a gravel or coarse sand evidently derived in the main from the disintegration *in situ* of a coarse granophyre. Fragments of this rock up to $\frac{1}{2}$ inch in diameter occur, in which the felspathic element shows a dull white, opaque appearance. The form of the fragments indicates crumblings rather than fracture, but the breaking up has been aided by a drusy character in the parent rock, still to be detected on some of the fragments by the occurrence of quartz crystals with good facets. In much of the material the distintegration has gone farther, giving rise to isolated quartz-grains of diameter about $\frac{1}{8}$ inch. These show no sign of attrition, and their generally rounded outline agrees with that of the grains embedded in the rock-fragments. Much of the quartz has a milky or semi-opaque appearance. This, which is common in the detritus of granitoid rocks, is due, as Daubrée has remarked, to flaws in the quartz : on crushing it, the splinters

[1] Harker (1904), pp. 4, 5, 340.

are found to be transparent. Felspar fragments also occur in the sand, always white and opaque. There is very little finely divided material in the sample, and no relics of mica are to be detected in isolated flakes, though the mineral, in a partly altered state, is seen in the rock-fragments. This proves, what is otherwise evident, that the destruction of the parent rock has been effected by *chemical* processes. The felspar, as well as the mica, must have been attacked in this way, the finely divided solid products, whether kaolin or mica, having been washed away: hence the preponderance of quartz among the products of disintegration. The layers of coarse quartz-sand, sometimes two or three inches deep, found on the exposed summits of the granophyre hills in Skye, represent the final result of the processes here involved.

"The present specimen contains a minor proportion of material which cannot be derived from the granophyre. This consists of subangular fragments of a compact, rusty brown rock, probably a decomposing basalt."

The granophyre of Raasay has been in old times utilised for millstones.

It is interesting to note that Macculloch referred to the weathered basalt of Dun Caan in Raasay as exhibiting appearances of contortion which "give reason to suspect a mechanical disturbing force, acting in this case also, upon a semifluid mass."[1] The phenomena were observed by Sir A. Geikie, who has remarked on the evidence of flow structure.[2]

The basaltic rock of Meall Daimh, which in places is much decomposed, should have been coloured on the Geological Survey map, sheet 81, as intrusive: it is thus described by Mr Harker:[3]—

"Sill, N. of Meall Daimh, Raasay; Specimen No. 6774 (856): 6″ sheet 30, 1″ 81. This is a dark medium-grained diabasic rock of sp. gr. 2.92.

"The slice shows it to be intermediate between an olivine-diabase (or olivine-dolerite) and an augite-picrite. Magnetite is rather plentiful. It is in rough octahedra and in shapeless grains, and has not all crystallised at one stage. Part is enclosed by the olivine; part is moulded on the olivine and enclosed by augite; and part is clearly later than the felspar prisms. Olivine is very abundant, building more or less rounded and irregular grains. Like the other constituents, it is almost quite fresh. The augite is in irregular crystal-plates enwrapping and enclosing

[1] *Trans. Geol. Soc.*, ii., 1814, p. 439.
[2] "Ancient Volcanoes of Great Britain," vol. ii., 1897, p. 192.
[3] See also Harker (1904), p. 385.

olivine, magnetite, and prisms of felspar, and giving an ophitic structure to the rock. It is of a brown colour with a purplish tone and slight but distinct pleochroism. The colour is not uniformly distributed, and there is in places an irregularly developed 'hour-glass' structure, the interior part being as usual paler than the exterior. In colour the mineral resembles that of the Inchcolm and some other picrites, and the abundance of olivine is another point of similarity. There is, however, more felspar than is found in the true picrites. Most of it occurs in lath-shaped prisms with rather fine albite-lamellation and extinction-angles corresponding with labradorite. There is, however, some felspar of later consolidation in more shapeless grains of interstitial occurrence. These are less closely lamellated and have a strong zonary banding.

"Rocks of this type do not seem to be common in Skye. One forms a dyke 1 m. S.E. of Drochaid Lusa (sheet 47 W.). It is very like the present specimen, except that the augite is very pale yellow-brown in thin section (slice 5076; coll. Clough)."

Faults and Landslips.

Two prominent faults traverse the island. The principal fault, towards the north, brings the Torridon Sandstone against the Jurassic rocks, and was reckoned by Prof. Judd (1878, p. 724) to have a throw of about 1000 feet; this may be taken as fairly approximate.[1]

The curved fault that bounds Beinn na' Leac, the Hallaig Fault of Prof. Judd, was estimated by him (1878, p. 691) to have a throw of about 700 feet, and this also appears to be a fair reckoning. On the north the beds are much broken, fissured, and slipped and there may be minor faults. The entire mass presents the appearance of a huge partially slipped area: possibly the outpourings of igneous material in Tertiary times, may have facilitated displacement.

Attention has been called to the great fissures along the eastern cliffs north and south of Dun Caan, and on Beinn na' Leac.

The huge landslips of Hallaig extend for more than a mile in a northerly and southerly direction to the east of Loch a' Chadha-chàrnaich, from Hallaig to the seashore. Loch Chadha, which contains a rushy island with birch trees, is being filled up by the growth of rushes and of tumbled blocks.

[1] In studying the tectonic structure of the area reference should be made to the observations of Mr C. B. Wedd on parts of Skye. See "Memoir on Geology of Glenelg, etc.," 1910, pp. 9, 149.

Glacial Drift.

The enormous erosion of the Tertiary igneous rocks prior to the Glacial period has been commented on by Mr Harker.

The general evidence of glaciation in Raasay indicates a movement of ice from south-east to north-west.

The glaciated surfaces on the Torridon Sandstone west of Brochel Castle were noted by Mr Hinxman to vary from 25° to 40° W. of N.

The great sheets of granophyre which extend from Carn nan Eun to Holoman and Dun Caan are bare over large tracts and exhibit smooth and glaciated surfaces, trenched by streams in deep rocky gullies. The white sandstones of the Inferior Oolite south of Dun Caan again display in their bare surfaces marked evidence of glaciation, in some places nearly N. and S., and N. 10° W., but in general over these areas the grooves and striæ have a direction N. 20° to 30° W.

On Beinn na' Leac the white sandstones present a hummocky appearance up to 970 feet, with faint glacial markings here and there.

Numerous small lochs occur on the broad area of granophyre, including Loch Storab. The largest loch, that of Loch na Meilich occurs at an elevation of 1058 feet, on a tract of the Great Oolite series between the granophyre and the basalt of Meall Daimh, to the west of Dun Caan; and to the south is Loch na Mnà. Their general direction coincides with that of the glaciation.

Boulder clay occurs in patches here and there on the Torridon Sandstone at Doire Domhain and Glam, also to the east of Storab's Grave, in Screapadal, and on the moory uplands to the south. The erratic blocks and stones on the Torridonian area of northern Raasay were observed by Mr Hinxman to have been derived chiefly from the Secondary and igneous rocks of the southern part of the island; but sheared epidotic grit occurred near Glam Burn, and foliated hornblende-rock at Lochan Uachdair.[1]

Perhaps the best section is on the road west of North Fearns, above the waterfalls, where the dark rusty Pabba Shales with ferruginous nodules, are overlain by boulder clay to a depth of about 6 feet. The shales are bent over towards the north-west in a form known as "terminal curvature."

The Boulder Clay occurs over a considerable tract to the south, towards Eyre Burn, and again near Rudha na' Cloiche, where along the cliffs to the east beneath thin cappings of raised beach gravel, it consists of rough loamy clay with many stones and large boulders, and is in places 30 or 40 feet thick.

[1] *Ann. Rep. Geol. Survey* for 1896 (1897), p. 84.

Perched on the cliff at Rudha na' Cloiche is a large boulder of Torridon Sandstone, measuring roughly 9×6×6 feet.[1]

Beach Deposits.

Patches of gravel occur on low cliffs bordering the coast at Suisnish, at the southern end of Raasay, extending up to about 50 feet above sea-level.

Some are old beach deposits; other patches appear to be gravelly detritus washed from the boulder clay. In the low cliff at Eyre Point at Stone Cist, there is about 30 feet of beach gravel and sand. Raasay House is situated on a tract of sand and gravel which extends from the shore to 65 feet above sea-level at the house.[2] Another tract of old beach borders the coast from Oskaig southwards; and there is a small patch at Holoman.

On the foreshore south of Oskaig Point the modern beach is cemented in places into a conglomerate.

A small tract of beach gravel borders the coast at Inver, and another small tract (of the 100-foot beach) was observed by Mr Hinxman on the Torridon Sandstone of the coast further north.

On Goat Island (Eilean Aird nan Gobhar), west of Churchtown Bay, there are hollows in the coarse basalt; one was 9 inches deep, 9½ to 10 inches across with smooth sides sloping inwards. Twenty or more of these holes may be observed at different levels; all would hold water, and water was present in some.

Peat, Water-supply and Rainfall, Agriculture.

Peat is found in thin coverings, and occasionally in thicker masses, from one end of the island to the other. On the Torridon Sandstone it is mostly thin, while thicker beds occur on the boggy uplands south of Screapadal.

There are tracts of peat, which has been dug in places, bordering the road from the east of the Free Church and of Inverarish Burn towards North Fearns. Much peat likewise occurs over the broad outcrop of the Pabba Shales west of Beinn na' Leac and at Hallaig. Peat has also been dug on Holoman Island.

Water is obtained in wells sunk in the gravel by Raasay House, and in the white sandstones of the Inferior Oolite at Clachan.

The rainfall for 1896 was recorded by Mr Minty, gardener, as

[1] All interested in the glaciation of Raasay should study the fascinating and most instructive essay on "Ice-Erosion in the Cuillin Hills, Skye," by Mr Alfred Harker, *Trans. Roy. Soc. Edin.*, xl, 1901, p. 221.

[2] See also Macculloch, "Description of the Western Islands of Scotland," vol. i., 1819, p. 242.

80.28 inches. Rather more than 12 inches fell during October and on one day as much as 2.64 inches. This rainfall, as I was informed by the late A. E. Stewart, was considerably above the average, which is about 62 inches.

From an agricultural point of view it is not considered that the island is adapted for profitable arable farming. The late Mr E. R. Wood commenced in 1878 to reclaim a tract of waste land at Glam, north of Storab's Grave—a tract of Torridon Sandstone, Inferior Oolite sandstones and shales, with coverings of boulder clay and peat, rising 500 to 600 feet above sea-level. Mr James Ross has stated that "the cultivation of this farm was continued for three years at a heavy loss. The grain crops, though heavy, never ripened properly, and had to be cut in a half green state and dried for winter fodder for the cattle. Turnips grew well up to the middle of August, but did not bulb well. Potatoes were a failure." [1]

Much of eastern Raasay is fenced off as deer forest, deer and sheep being in the same ground. Some of the best land no doubt is that on the Middle Lias of North Fearns. The chief areas of woodland are near Raasay House, Loch a' Mhuilinn, and the Free Church, along Eyre Cliff, and near Brochel Castle.

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