Chapter 4 Trias and Jurassic, Ardnamurchan and North-west Mull

In North-west Mull, sediments underlying the Tertiary basalt lavas are exposed only on the west side of Bloody Bay. They consist of non-fossiliferous sandstones which are tentatively referred to the Jurassic (p. 49). In Ardnamurchan, on the other hand, Mesozoic sediments form outcrops of considerable extent, and range from Trias to the middle of the Jurassic, including Lias, Inferior Oolite and Great Estuarine Series. The area is traversed by innumerable minor intrusions injected into the Mesozoic strata and underlying Highland schists during the Tertiary volcanic period, and the disentangling of the Mesozoic geology is in many respects a difficult matter. Some fifty years ago the late Prof. Judd<ref>J. W. Judd, 'The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands,' *Quart. Journ. Geol. Soc., vol. xxxiv.,* 1878, pp. 686–722,</ref> elucidated the stratigraphical sequence with the aid of fossils and also through his recognition of the similarity of the lithological succession to that of neighbouring areas in the West Highlands. His main conclusions hold good, though the nomenclature has changed in certain particulars. For example, his Infra-Lias is now regarded as entirely Lower Lias and not in part Rhaetic; while much of his Middle Lias has been transferred to the Lower Lias to agree with Woodward's scheme of classification. During the recent survey of Ardnamurchan perhaps the chief addition to our knowledge is the definite recognition of Upper Lias with Raasay Ironstone by means of zonal ammonites. Also, an interesting series of ammonites has been obtained from the lower portion of the Inferior Oolite, including a species hitherto unrecorded from the British Isles. Taken as a whole the area is, however, one of minor interest to the stratigraphical geologist, for its fossil-fauna is relatively sparse and the strata as a rule are considerably hardened by the Tertiary intrusions.

The general sequence together with that established in other districts in the West Highlands is set out in the table opposite, the thicknesses being in feet. The lithological description given of each group refers more particularly to the development in Ardnamurchan.

The main outcrops border the south and north coasts of Ardnamurchan, the more important of which are as follows. Trias and the Broadford Beds of the Lower Lias are well seen on the south coast east of Mingary Castle ((Figure 25), p. 177), and are also worth visiting near Swordle on the north side. At these localities the limestone has been worked in former days for lime. Along the west side of Kilchoan Bay, and for about a mile beyond, strata from the Pabba Shales up to the Inferior Oolite and Great Estuarine Series are well exposed, though the sequence is much interrupted and the beds are also a great deal indurated by minor Tertiary intrusions, chiefly cone-sheets (Figure 3). It may be added that several considerable masses of Mesozoic sediments also occur within vents of Tertiary age, and that blocks of Inferior Oolite and Upper Lias found in the Achateny district on the north coast prove the former occurrence of these strata *in situ* in that neighbourhood.

	Ardnamurchan	**Morven**	**S.E. Mull**	**Raasay And Skye**
Jurassic				
Great Estuarine Series (shales with *Estheria murchisoniae*)	upwards of 10	—	?30	?400
Inferior Oolite (limestone and sandstone)	120	—	100	600–800
Upper Lias (black shales with unworkable Raasay Ironstone)	20	—	30	20–70
Middle Lias Or Scalpa Beds (white sandstone)	about 40	—	200	240
Lower Lias-Pabba Beds (sandy shales)	perhaps 400	160	400	600–700
Lower Lias-Broadford Beds (mainly limestone)	20–100	120	70	240

Rhaetic	not found	? 10	not found	—
Trias (red sandstone, cornstone, breccia, and conglomerate)	0–20	330	thick	? 150

Trias

The presence in Ardnamurchan of Triassic strata, the Poikilitic of Judd, appears to have been first recognized by this investigator. These beds, however, are of small thickness. They include red sandstones and cornstones, with conglomerates and breccias that rest unconformably on the Moine Schists, and are succeeded by fine-grained basal Lower Lias limestones of the Jurassic (Judd's Infra-Lias). No fossils have been obtained from them, and their identification as Trias is based upon their general occurrence, here and elsewhere in the West Highlands, at the base of the Lias. In an exposure in Western Mull, it may be added, they are succeeded by a thin development of fossiliferous Rhaetic<ref>E. B. Bailey and G. W. Lee *in* The Pre-Tertiary Geology of Mull, Loch Mine, and Oban, *Mem. Geol. Surv.,* 1925, p. 64.</ref>

The Ardnamurchan Trias is perhaps chiefly noteworthy on account of its cornstones. These chemically-formed limestones, deposited from solution, are at some localities found at the base of the Trias, and in this position they are seen to have permeated and partly replaced the underlying quartzose and felspathic schistose rocks in an intricate manner. The lime-bearing solutions have attacked the schists more especially along their bedding-planes, so that cornstone is found interleaving with these much more ancient rocks.<ref>For other Triassic examples of the same phenomenon *see* E. B. Bailey *in op. cit.,* p. 70, and A. Heim, Geologie der Schweiz, Band II, 1920, (Figure 50), pp. 150,160. Similar partial replacement of schist by limestone occurs at the base of cornstone of Upper Old Red Sandstone (or Carboniferous) age at Loch Ranza in Arran. *See* W. Gunn *in* The Geology of Arran, *Mem, geol. Surv.,* 1928, p. 47.</ref> The conglomerates with well-rounded pebbles of white quartz are evidence of the abrasive action of water, and are a feature also of the Trias of neighbouring areas. In the sandstones no wind-rounding of sand grains was noted.

In the south-east part of the Ardnamurchan area, Triassic rocks are absent and the Lower Lias overlaps directly upon the schists. A good section is exposed 350 yds. south-east of Mingary Castle, where the island of Rudha a' Mhìle, connected with the mainland at low tide, is largely composed of Trias (*see (Figure 25)*, p. 177). Junctions with the Moine Schists are well seen and a basal breccia mainly consists of these underlying rocks. Similar beds of breccia reappear at higher levels, interbedded with red sandstone and cornstones. Altogether the Trias is here less than 20 ft. thick. Its relation to the succeeding Lias limestone is clearly exposed at the base of a stack at the south end of the island, the upper portion of which is formed of a Tertiary quartz-dolerite sill. The upper limit of the Trias is drawn at the top of a bed of pebbly sandstone, which is succeeded by 6 ft. of white sandstone and sandy limestone that are included with the Lower Lias. At the north-west end of the island the junction of Trias and Lias is again exposed. A cornstone there occurs at the top of the Trias, and is succeeded by similar Lias strata to those just cited.

Three quarters of a mile eastwards of Mingary Castle, in cliffs bordering the 25-ft. Raised Beach, cornstones are well seen at the base of the Trias and permeate the underlying Moine Schists. The same phenomena are also met with half a mile west of Mingary Castle, to the south-east of Kilchoan, a few yards south-west of the office-house at Mingary Pier ((Figure 23), p. 174).

In the Ben Hiant district, Triassic strata a few feet thick are exposed at various localities. For instance, schist-breccia rests on the schists near the shore west of the great quartz-dolerite mass termed the Ben Hiant Intrusion, while quartz-conglomerate, schist-breccia, red sandstone and cornstone are exposed in streams on the south-east side of the hill. J.E.R.

Farther east, south-east of Loch Mudle, around the margins of an extensive outcrop of Tertiary basalt lavas, the Trias may be everywhere absent. At the northern end of the lava-outcrop its absence at the base of the Lias is in fact demonstrable (p. 40), though immediately to the north, in a stream flowing between Lochan a' Mhadaidh Riabhaich and Loch Mudle there is a small expanse of purplish cornstone. Along the eastern side of the outlier, only partly included in the Memoir-map, thin sandstone and conglomerate frequently separate the lavas from the schists, but have been

tentatively assigned to the Tertiary (p. 105). A 6-ft. calcareous sandstone seen below the lavas on the foreshore west of Ardslignish farm is probably Mesozoic, either Trias or Lias. J.B.S.

Near the north coast about 20 ft. of breccia, conglomerate and sandstone are seen at several places between the Lower Lias and the Moine Gneiss. The material of the breccias and conglomerates is generally a calcareous sandstone or grit, and the pebbles consist of the local gneiss, often but slightly rounded. Exposures are sufficiently numerous along the mapped outcrops, and attention need only be drawn to a type example a little above the mouth of the stream that flows past Ockle. E.B.B.

Jurassic

Lower Lias: Broadford Beds and Pabba Beds (Hettangian, Sinemurian, and Charmouthian)

H. B. Woodward's designation 'Broadford Beds'<ref>H. B. Woodward *in* Ann. Report of Geol. Survey for 1896, *Mem. Geol. Surv.,* 1897, p. 70.</ref>applies to the lower, mainly calcareous division of the West of Scotland Lower Lias, and may be used here conveniently, since some of the chief features of the type district of Broadford in Skye are present in Ardnamurchan. The principal departure from type is the absence of the Ostrea Beds so fully represented in Raasay, Applecross, and Skye. But, since oyster beds depend on definite physical conditions for their formation, the Ostrea Beds of the districts mentioned above may be represented here in point of time by part of the lowest layers succeeding the Triassic cornstones. The gap above the Trias cannot, therefore, be proved to involve much more than the *Pieria contorta* Zone of the Rhaetic.

The term 'Pabba Series' was introduced by Judd to denote the thick series of sandy shales which, according to Woodward's more recent classification, constitute the higher member of the Hebridean Lower Lias. Judd himself treated these Pabba Beds as forming the lower member of the Middle Lias.

In Skye, the Oxynotus Zone is absent, and all Liassic strata below this level have been grouped with the Broadford Beds, while the higher beds of the Lower Lias have been placed in the Pabba Beds.<ref>C. B. Wedd *in* The Geology of Glenelg, Lochalsh and South-east Part of Skye (Explanation of one-inch Map 71), *Mem. Geol. Surv.,* 1910, p. 98.</ref>This grouping agrees with the lithology, except that the top of the Broadford Beds as thus defined consists of shales.<ref>C. B. Wedd *in* The Geology of Glenelg, Lochalsh and South-east Part of Skye (Explanation of one-inch Map 71), *Mem. Geol. Surv.,* 1910, p. 106.</ref>

In Ardnamurchan the same classification is adopted with the qualification that the Oxynotus Zone, which seems to be represented, is placed with the Pabba Beds. Here again, and also in the neighbouring district of Morven, the shale-development begins near the top of the Broadford Beds. On this account, in the Memoir dealing with Mull and Morven,<ref>G. W. Lee *in* The Pre-Tertiary Geology of Mull, Loch Aline, and Oban, *Mem. Geol. Surv,* 1925, p. 75</ref> the Birchi and Obtusus Zones were classed with the Pabba Beds. It is, however, thought better in the present Memoir to adhere to the palaeontological definition as applied in Skye, the type district.

In the following zonal table, which includes the zones identified in Mull and Morven (Loch Mine) as well as in Ardnamurchan, it will be seen that the 'Semicostatus' Zone is retained, though, as Dr. Spath<ref>L. F. Spath, On Lower Lias Ammonites from Skye, *Geol. Mag., vol. lix.,* 1922, p. 171.</ref>has pointed out, *Arnioceras semicostatum* is now known to belong to the overlying Birchi Zone. The term 'Semicostatus' Zone is here retained, within inverted commas, for convenience of comparison with previous literature. All the ammonites mentioned in the text were identified by the late Mr. S. S. Buckman.

ZONES	Sheets 51 & 52. Ardnamurchan	Sheet 44. Morven.	Sheet 44. S.E.Mull.	Sheet 43. W. Mull.	Sheet 52. N. Mull.	Stages
Pabba Beds						
Capricornus			?			Charmouthian
Ibex					x	Charmouthian
Jamesoni			x			Charmouthian

Armatus			x			Charmouthian
Raricostatus			x		x	Charmouthian.
Oxynotus	?					Sinemurian
Broadford Beds						Sinemurian
Obtusus	x	x				Sinemurian
Birchi		x				Sinemurian.
'Semicostatus'	x	x	x			Sinemurian
Bucklandi	?	x				Sinemurian
Rotiforme		x				Sinemurian
Angulatus	x		?			Hettangian
Planorbis	x			x		Hettangian

Broadford Beds

Inthe southern part of Ardnamurchan the lowest Liassic beds, the age of which is indicated by paleontological evidence, consist of a few feet of hardened shales and thin beds of compact limestone on the shore just south of Mingary pier at Rudha Aird an Iasgaich, south of Kilchoan. The pier itself stands on Trias ((Figure 23), p. 174). The Lias here has yielded *Ostrea sp., Mytilus ?* and *Cypricardia ' porrecta* Dum. The latter is a species which belongs in the Rhone Basin to the Planorbis Zone.[3]<ref>. Dumortier, Etudes paleontologiques sur les Depots jurassiques du Bassin du Rhöne,1864, Part 1., Pl. vi., Fig. 4.</ref>Although the actual zonal fossil *Psiloceras planorbis* (J. de C. Sow.) was not found, there can be little doubt that these beds are in or about the Planorbis Zone. It might be mentioned here that, in Scotland, the shaly facies of the Planorbis Zone, with its index ammonite, is known so far only in Western Mull<ref>G. W. Lee *in* The Pre-Tertiary Geology of Mull, Loch Aline, and Oban, *Mem. Geol. Surv.,* 1925, pp. 86–88.</ref> and as blocks in a volcanic neck in Arran.

The beds just referred to are possibly represented in No. 5 of the following section measured by Mr. Richey near the southern extremity of Rudha a' Mhìle, Mingary:

	Feet	Inches
6. Blue granular limestone	5	0
5. Pale compact limestone with partings of shale	*5*	0
4. Sandy shale	0	6
3. Compact limestone	2	0
2. Sandy limestone with white sandstone at base	12	0
1. Yellow cornstone (Trias)		

Modiola hillana, J. Sow., *Cardinia sp.* and *Pleuromya sp.* were obtained from the shales and sandy limestones. The *Pleuromya* is characterized by the nearly central position of the umbones, and is like a form represented in the Jermyn Street Museum by specimens from the Bucklandi Zone.

On the shore, north of Rudha a' Mhìle, compact white limestones and dark shales are faulted against Trias near high-water mark ((Figure 25), p. 177), and have yielded a fauna which although scanty seems to indicate a higher horizon. It consists of a Rhynchonellid, possibly new, a form suggesting a young specimen of *Lima gigantaea,* a gryphaeate *Ostrea,* a large-ribbed *Ostrea* and a *Pecten,* probably undescribed, recalling *P. valoniensis* Defr. by its shape, but with finer ornamentation, specially on the ears. The ribbed *Ostrea* is of the group of *O. arietis* Quenst., and may be allied to an unnamed form from the Angulatus Zone figured by Dumortier<ref>Dumortier, Etudes paleontologiques sur les Depots jurassiques du Bassin du Rhone, 1864, Part 1., P1. xxiii., fig. 6.</ref> This, together with the gryphaeate *Ostrea* and the *Lima,* would point to the top of the Hettangian, that is, either the Angulatus Zone or just above it.

Honeycomb-weathering limestones which are seen on the shore east-south-east of Mingary Castle are characterized by the abundance of *Gryphaea arcuata* Lam. of the large, narrow, strongly in-curved type, with sulcus. The Gryphaea

Limestones have not yielded any ammonites, but an upper limit to their age may be inferred from the fact that stratigraphically higher beds in the vicinity of Mingary Castle, consisting of flaggy shales, chiefly belong to the 'Semicostatus' Zone, though perhaps also including the top of the Bucklandi Zone.

Dark blue flags, that probably immediately succeed the Gryphaea Limestones, are exposed in disconnected outcrops partly enveloped by a Tertiary basic sill on the shore near low-water mark 250 yds. east-south-east of Mingary Castle (*see* (Figure 25)). Ammonites there predominate largely over other fossils, as shown by the following collection made by Mr. Manson:

Rhynchonellid, new

Lima (*Plagiostoma*) *gigantea* (J. Sow.).cf. young of

Agassiceras cf. subtaurus (Reynes)

Agassiceras cf. terquemi (Reynes)

Arnioceras cf. acutidorsale Hyatt

Arnioceras cf. bodleyi J. Buck.

Arnioceras cf. dimorphum Parona

Arnioceras cf. elegans Fuccini

Arnioceras cf. falcaries (Quenst.)

Arnioceras fortunatum S. Buck.

Arnioceras cf. hartmanni (Oppel)

Arnioceras cf. incipiens Hyatt

Arnioceras cf. kridiforme Hyatt

Arnioceras cf. mendax Fuccini

Arnioceras munitum Fuccini

Asteroceras cf. undaries (Quenst.)

Cymbites cf. lævigatus (Reynes)

This list indicates a possible equivalence with Dr. Spath's<ref>L. F. Spath, On Lower Lias Ammonites from Skye, *Geol. Mag., vol. lix.,* 1922, p. 175.</ref> 'bed full of *Arnioceras'* (base of Semicostatus ' Zone or top of Bucklandi Zone), though Buckman pointed out that the presence of *Asteroceras* suggests a much later date.

The Gryphaea Limestones are in faulted contact with higher beds consisting of dark flaggy shales with calcareous nodules which belong, according to Buckman, to the Agassiceras horizon (upper part of 'Semicostatus' Zone). The fault is seen on the shore 50 yds. east-south-east of Mingary Castle, just west of which Mr. Manson obtained the following from the flaggy shales:*Piarorhynchia* cf. *radstockiensis* (Day.), *Piar. sp.,* cf. *P. triplicata juvenis* (Quenst.), *Spiriferina walcotti* (*J.* Sow.), *Agassiceras* cf. *halecis* (J. Buck.), and another ammonite, possibly belonging to a new genus, but resembling *Xipheroceras scoresbyi* (Simpson). The presence of such a form is strange, since Buckman pointed out that a *Xipheroceras* should be very much later than *Agassiceras.*

On the shore south-west of Mingary Castle and below the sill on which the castle stands, hardened flags and shales have yielded a fauna which, according to Buckman, is somewhat later than that just considered, though probably still of *Agassiceras* date.

Piarorhynchia cf. *triplicata juvenis* (Quenst.)

Piarorhynchia cf. *radstockiensis* (Day.)

Rhynchonellid, new ?

Spiriferina walcotti (J. Sow.)

Zeilleria '*perforata*' Auctt.

Pecten liasinus Nyst.

Arnioceras, between*A. miserabile* and *A. spirale* Fuccini

Arnioceras, cf. *mendax* Fuccini

Arnioceras, cf. *spirale* Fuccini

Cymbites sp.

According to Dr. Spath<ref>L. F. Spath, *op. cit.,* p. 172.</ref> still higher beds, with *Arietites* (Obtusus Zone), occur at Mingary Castle, but representatives of that genus have not been met with by the Survey. G.W.L..

Inland, alongside a cross-country track north-east of Beinn na h'Urchrach and in two neighbouring streams, the Broadford Beds lie at l00 ft. above sea-level. The following section has been estimated beside the path:

Blue granular limestone	25 ft
Pale compact limestone	30 ft
Sandy limestone and calcareous sandstone	10 ft

A bed rich in *Gryphaea arcuata* is exposed below the track shown on the Memoir-map in the more easterly of the two streams. In the more westerly stream, Pabba shales occur, but the section is discontinuous.

At the northern extremity of the outlier of Tertiary lavas, to the south-east of Loch Mudle, the Broadford Beds are seen resting on schist and overlain by shales (? Pabba Beds). They consist of 25 ft. of limestone with a basal bed of fine white sandstone. As at Rudha a' Mhile, near Mingary Castle (p. 38), the basal white sandstone is overlain by sandy limestone that forms a link with the succeeding typical Lower Lias limestone. J. E. R.

Along the north coast, near Swordle, the Broadford Beds reach their maximum thickness for Ardnamurchan, about 100ft. They everywhere rest on Trias and are seen covered by Pabba Beds in a road section. At Ockle Point, about 10 ft. of sandy beds, including dark calcareous sandy shales, form the actual base of the group. The limestones are less split up by shale partings than is usual. Fossil fragments are often conspicuous but it is difficult to obtain good specimens. Dr. Lee, in the field, saw specimens which he referred to *Lima gigantea, Ostrea,* and *Modiola.* At one locality, the coastal cliff shows several courses of calcareous shale crowded with *Gryphaea arcuata.* This locality is situated 300 yds. east of a great Tertiary vent, immediately east of a small gorge that has been eroded along a fault. E.B.B.

From the 10 ft. of sandy beds at Ockle Point at the base of the series Mr. Manson succeeded in extracting specimens which may be doubtfully referred to *Modiola hillana* J. Sow. and to *Perna infraliassica* Quenst. This would indicate an horizon either in the Hettangian or low down in the Sinemurian. A poorly preserved coral found on the west side of Garbh Rudha, three quarters of a mile north-east of Kilmory, may belong to *Thecosmilia martini* de From., which in its best Scottish locality, viz. Applecross, is a form belonging to the top of the Hettangian.

The *Gryphaea arcuata* mentioned above belongs to the typical strongly incurved form. A few other fossils were obtained from the same locality. They are:*Modiola sp., Ostrea* cf. *liassica* Strick., *Pecten liasinus* Nyst., *P.* cf. *textorius* (Schloth.), and *Pinna hartmanni* Zieten.

Fossils were collected by Mr. Manson from dark shales and calcareous flags in the volcanic vent on the shore half a mile north of Kilmory. They are:

Piarorhynchia cf.*radstockiensis* (Day.)

Aria ?

Gresslya ?

? Homomya sp.

Lima hettangiensis Terq.

Ostrea ?

Pecten sp.

Pleuromya sp.

Pteria sp.

Cymbites cf.*laevigatus* (Regnes)

Buckman referred the specimen of *Cymbites* to a position about the *Agassiceras* horizon (top of ' Semicostatus ' Zone). G.W.L.

Pabba Beds. Thesebeds consist mainly of sandy, well-bedded shales, containing scattered flakes of white mica. They are thicker than any other group in the Jurassic of Ardnamurchan. Elsewhere in the West Highlands the Pabba Beds are often richly fossiliferous, but this does not hold good in the present area, though on the west side of Kilchoan Bay, along almost a mile of coast, they are well exposed. They there dip obliquely to the shore line, and extend inland and westwards in a broad outcrop, to meet the coast again west of the headland of Sròn Bheag. Their thickness may be estimated as about 400 ft., and along Kilchoan Bay the following succession may be seen.

		Approximate thickness in feet
	Base of **Middle Lias** Sandstone	—
6	Flaggy, micaceous, sandy shales with encrinites, and calcareous sandstone bands with belemnites	50
5	Calcareous sandstone with belemnites	0 to 25
4	Sandy shales with encrinites; shales with calcareous nodules, containing belemnites, large pectens, etc	100
3	Sandy flaggy shales, with *Gryphaea* of *obliquata* type	100
2	Sandstone	25
1	Sandy shales and fine-grained fissile shales (Base of Pabba Beds)	100
	Total	400

The basal beds, that succeed the Broadford Limestones, consist of greenish-grey shales, fissile and fine grained. They are, so far as known, devoid of fossils. The shales may be seen in stream-sections north and north-east of Ben Hiant,

east of Beinn na h'Urchrach, as well as along Kilchoan Bay.

The shales extending inland and westwards from Kilchoan Bay are considerably baked by Tertiary intrusions, but indications of their identity with the Pabba Beds of the shore-section may be observed at various points. On the hillside south-east of two small lochs, south-east of Beinn na Seilg, calcareous nodules and also traces of large belemnites can be detected, the latter white and chalky in aspect owing to their baked condition. They resemble subdivision 4 of the succession tabled above. Traces of calcareous nodules in highly baked shales can also be seen near to the margin of the Tertiary gabbro east of a valley east of Dubh Chreag. On the summit of Dubh Chreag, next to the gabbro, a highly baked limestone emerges from beneath the thick contact-hardened shales, and may confidently be referred to the Broadford position. Where the baked Pabba Beds again reach the shore, south-west of Beinn nan Codhan, they contain a bed of *Gryphaea.* This locality is somewhat difficult to reach as the coastal slopes are steep. The shell-bed occurs on the north side of a small inlet, 200 yds. east of the Tertiary gabbro.

Two other localities for Pabba Beds have already been mentioned in the descriptions of the Broadford Beds south-east of Loch Mudle, and in the road west of Swordle. More extensive exposures occur on the north coast, west of Faskadale, in the neighbourhood of Rudha Groulin. The strata are very highly baked, but a lithological succession can be established which includes micaceous sandy shales (Pabba Beds) underlying white fine-textured sandstone (Middle Lias). J.E.R.

The state of preservation of the few fossils obtained from Ardnamurchan is so poor that there is little of paleontological interest to be mentioned. The most common fossil is *Gryphaea,* which is represented by *G. cymbium* Lam. and forms intermediate between it and *G. obliquata* J. Sow. Belemnites appear to be next in order of abundance; among these *B.* cf. *apici-curvatus* de Blainv. and *B. clavatus* de Blainv. were recognized. Of lamellibranchs (other than *Gryphaea*), *Cardinia sp., Pecten acuticostatus* Lam., and a small *Pecten* of *aequivalvis* type are all that was obtained. A single ammonite was found, on the shore below Ormsaigbeg, Kilchoan; Buckman was not able to determine it, but he suggested that it may be referred to *Gagaticeras.* If of that genus, the Ormsaigbeg section would then fall within the Oxynotus Zone.

In South-east Mull, Skye, Pabba, and Raasay, the top portions of the Pabba Beds are conspicuously fossiliferous, ammonites being specially abundant, and since baking does not completely obliterate all traces of fossils, it would seem probable that in Ardnamurchan parts of the higher Pabba Beds may have been cut out by faulting. On the other hand, no fault has been found in the required position on the west shore of Kilchoan Bay. G.W.L.

Middle Lias: Scalpa Sandstone (Domerian)

In Ardnamurchan, this group is of little interest, for it consists of only some 30 to 40 ft. of sandstone, in which no fossils have been found. The sandstone is white, fine-grained and well-bedded, sometimes false-bedded. In the only complete outcrop, on the north coast two thirds of a mile east of Rudha Groulin, the sandstone passes gradually downwards, by intercalation with layers of sandy shale, into the Pabba Shales; it is separated from overlying fissile, dark shales, which are evidently of Upper Lias age, by transition beds consisting of sandy shales. The beds are much baked, and no fossils have been found in them, but the lithological succession leaves no doubt as to their stratigraphical positions.

On the west coast of Kilchoan Bay, the Scalpa Sandstone can be recognized in a few disconnected outcrops amongst Tertiary cone-sheets and sills, which intervene between Pabba Shales and fossiliferous Upper Lias. Farther west, around the head of a small bay south of Dubh Chreag, the sandstone is again well seen in coastal cliffs, and appears to be thicker than at other localities mentioned. Along the east side of this little bay, it is directly overlain by the fossiliferous Upper Lias shales; whilst inland to the north it is faulted against the Pabba Shales.

Upper Lias (Yeovilian–Whitbian, in part)

The Upper Lias consists of fine-grained, fissile shales, purplish-black in colour, together with a seam of limy ironstone, which is correlated with the Raasay Ironstone. These strata are of considerable interest, though their total thickness is no more than 20 ft. A number of ammonites have been collected from both shales and ironstone.

The chief fossiliferous exposures are along the west shore of Kilchoan Bay, 1500 yds. south-west of the Landing Jetty, and just beyond a slight headland formed of a plexus of Tertiary basic intrusions (Figure 3). The black shales occur in lenticular masses, a few yards long, amongst a complex of basic cone-sheets and sills.

In two of these, the limy ironstone is exposed. The seam is a bluish, compact stone, largely composed of ooliths. In this character it resembles the Raasay Ironstone, but its thickness is less, being not more than 4 ft. in Ardnamurchan. A mile farther west, south of the angle of the bay south of Dubh Chreag, fissile shales that overlie the Scalpa Sandstone contain a 4-ft. bed of oolitic ironstone with belemnites, which is without doubt the same seam as that just mentioned. It is exposed at low tide with shales in contact above and below, and lies 7 ft. above the top of the Scalpa Sandstone, and 9 ft. below the apparent base of the Inferior Oolite.

The strata are here greatly baked by the Tertiary gabbro, and the ironstone is converted into magnetite. In consequence, no fossils other than the belemnites in the ironstone have been obtained from these strata. Their reference to the Upper Lias is, however, unquestionable, for they agree, apart from metamorphism, in rock-type and also in stratigraphical position between a sandstone group (Scalpa Sandstone) and an overlying thick limestone (Inferior Oolite). The outcrop affords the only complete section in Ardnamurchan of the Upper Lias. An exposure of fossiliferous, fissile shales, 200 yds. west by north of Kilchoan Established Church, also belongs to the Upper Lias. J.E.R.

The indurated shales along the west shore of Kilchoan Bay, mentioned above, have yielded:

cf. Stolmorhynchia sp.

? Pseudomonotis substriata (Zieten)

Dactylioceras cf. angulatum (J. Sow.)

Dactylioceras cf. annuliferum (Simpson)

Dactylioceras cf. commune (J. Sow.)

Dactylioceras cf. holandrei (d'Orb.)

Dactylioceras sp.

Harpoceras aff. falciferum (J. Sow.)

Belemnites sp., elongate form.

On the whole, these species indicate the Falcifer Zone.

The shales from the exposure 200 yds. west by north of Kilchoan Established Church are of the same age, and they contain:

Inoceramus dubius J. de C. Sow.

Pecten (*Amusium*) cf. *paradoxus* Goldf.

Dactylioceras cf. *holandrei* (d'Orb.)

Dactylioceras cf. *raristriatum* (Quenst.)

Dactylioceras sp.

Harpoceras aff. falciferum (J. Sow.).

In addition to these Mr. Manson obtained a fragmentary impression of an ammonite which suggests a likeness to *Dumortieria meneghinii* Zittel (in Haug). But Buckman has pointed out that if this '*Dumortieria*' is to be dated with other members of its genus, then it must be considerably *post-striatulum* in date, a conclusion which seems difficult to accept.

As already mentioned the ironstone at the first locality is fossiliferous, its fauna consisting of Cephalopods, which are:-

Alocolytoceras cf. *perlaeve* (Denckm.)

Dactylioceras cf. *holandrei* (d'Orb.)

Grammoceras aff. penestriatulum S. Buck.

Grammoceras aff. *toarciense* (d'Orb.)

? Phylloceras sp. [or perhaps *Paroniceras*]

Belemnites sp., conical form

Belemnites sp., cylindrical form

There is also in the collection a new ammonite, which Buckman was unable to place. The above list is of great interest as regards the light it throws on the age of the Raasay Ironstone. The fossils found in the ironstone of the type district are derived,<ref>G. W. Lee, The Mesozoic Rocks of Applecross, Raasay, and North-East Skye, *Mem. Geol. Surv.,* 1920, pp. 32 and 67.</ref> the latest indicating *Subcarinatum*-time, or a little later, as presumed date of deposition. Here, the *Alocolytoceras* and the *Grammoceras* indicate the very much higher Striatulum Zone, while the Dactyliocerates are derived from the Falcifer Zone, with perhaps something a little earlier and later. Referring to this, Buckman wrote: 'There is in any case a very big non-sequence, represented by deposits elsewhere totalling 400–500 ft., between the Ironstone and the hardened shales, which shows the danger of concluding that derived fossils must come from a bed immediately previous in date'.

Inferior Oolite (Yeovilian, in part–Aalenian–Bajocian, in part)

Strata of Inferior Oolite age are found in situin the Kilchoan district only, where they form the bulk of the faulted outlier of Maol Buidhe, 1½ miles south-west of Kilchoan. They are irregularly exposed along a distance of about one mile on the shore on either side of Srtm Bheag Point. East of this headland the beds are less metamorphosed and best seen. Although this section is much complicated and interrupted by intrusions and faulting, the ascending sequence is observed to be from east to west. The total thickness is difficult to estimate, but probably does not exceed 120 ft. The lower half, which is fossiliferous, consists of limestones, calcareous shales, and calcareous mudstones, with shaly beds below and above. The upper portion, some 60 ft. thick, is a massive yellow or reddish sandstone in which no fossils were seen. Palontologically, the sequence is not unlike that of the Inferior Oolite in the Isle of Raasay, where the fossiliferous layers are confined to more or less calcareous and shaly beds at the base, while the bulk of the series, presumably of *Blagdeni* and *Sauzei* date, is a yellowish sandstone with but few fossils.

In the lower, mainly calcareous subdivision of the Ardnamurchan Inferior Oolite the following palaeontological zones have been identified:

Bajocian	Discites
Aalenian	Concava
Aalenian	Bradfordensis
Aalenian	Murchison
Aalenian	? Ancolioceras
Aalenian	Scissum
Aalenian	Aalensis
Yeovilian	Moorei

As regards thickness, the development of the Ardnamurchan Inferior Oolite is intermediate between that of Mull, which is thin — under 100 ft. — and that of Raasay, some 700 ft. thick.

The clear section afforded by the east coast of the Isle of Raasay proves the presence of a considerable non-sequence between the Upper Lias ironstone and the Aalenian shales which rest directly on top of it. The extent of such a non-sequence in Ardnamurchan, if any, cannot be estimated, because here an intrusion separates the ironstone from the lowest bed referred to the Inferior Oolite, viz. the Moorei Beds, of which the Ardnamurchan occurrence is the only one known in Scotland.

The identification of the Moorei Beds by Buckman rests on the following:

Catulloceras ?

cf. *Dumortieria brancoi* S. Buck.

Dumortieria exacta S. Buck.

Dumortieria cf. *subexcentrica* S. Buck.

Belemnites ellipticus Miller.

These were obtained by Mr. Manson from the lower portion, containing occasional cementstone doggers, of a bed of dark, hard, sandy flags or shales, 500 yds. E. 6° S. of Maol Buidhe Trigonometrical Station. From the top of the same bed ammonites of the Aalensis Zone were found. They are:

Canavarina sp.

Cotteswoldia ?

cf. *Pleydellia aalensis* (Zieten)

cf. *Pleydellia fluens* S. Buck.

Belemnites cf. quinquesulcatus de Blainv

In the Isle of Mull strata of the Aalensis Zone were not detected. Here they are under 5 ft. thick, whilst in the Isle of Raasay they reach 632 ft. Evidence of the presence of the Opaliniforme Zone, known in Mull and Raasay, was not got, but the succeeding Scissum Zone is well represented by typical forms, from the same locality, in sandy beds at the base of the limestone series:

Rhynchonelloidea cf.*subangulata* (Day.)

Lioceras gracile S. Buck.

Lioceras opalinum (Rein.)

Lioceras partitum S. Buck.

Lioceras plicatellum S. Buck.

Lioceras uncum S. Buck.

Lioceras undulatum S. Buck.

Lioceras aff. *costosum* (Quenst.)

Lioceras aff. *lineatum* S. Buck.

Lioceras cf. *thomsoni* S. Buck.

The collection contains also two examples of an ammonite which Buckman considered might be new, a form intermediate between *Canavarella* and *Lioceras.* Other Scottish Scissum Beds are known at Port nam Marbh and in the Ardnadrocket Glen, Lochdonhead, Mull, and on the path one mile south of Dun Caan, Raasay, in which latter locality the stratum is little over 1 ft. thick, but crowded with ammonites.

The Ancolioceras Zone may possibly be present in 8 feet of limestone on the east side of a gully 416 yds. E. 21° S. of Maol Buidhe Trigonometrical Station, where a doubtful *Ancolioceras* (immature) was found, together with two forms of *Astarte,* one resembling *A. depressa* Goldf. and a species of *Pteria.*

Limestones on the shore 450 yds. E. 15° S. of the above Trigonometrical Station have yielded a rich fauna of the Murchisonae Zone. The lower one, blue and sandy, is 1 ft. 6 in. thick, and has yielded:

Rhynchonellid

cf. *Zeilleria anglica* (Oppel)

Pecten articulatus Schloth.

Pecten demissus Phill.

Pecten cf. *laeviradiatus* Waag.

Unicardium sp.

cf. *Hyattia pustulifera* S. Buck.

cf. *Hyattia wilsoni* S. Buck.

Hyattia sp.

Ludwigia gradata S. Buck.

Ludwigia murchisonae (J. de C. Sow.)

Strophogyria cosmia S. Buck.

This assemblage indicates early *Murchisonae* date, while the higher hard limestone 1 ft. thick is rich in forms of late *Murchisonae* date:

Astarte, 2 spp.

Goniomya angulifera (J. Sow.)

Pecten demissus Phill.

Pecten laeviradiatus Waag.

Pleuromya jurassi Ag.

Tancredia ?

Unicardium gibbosum Lye.

Apedogyria platychora S. Buck.

Apedogyria subcornuta S. Buck.

Brasilina baylei S. Buck.

Brasilina sp. nov. ?

Crickia reflua S. Buck.

Ludwigia cf. *murchisonae* (J. de C. Sow.)

Ludwigina patula S. Buck.

Ludwigina umbilicata S. Buck.

Lugwigoid, [? new]

Manselia subacuta S. Buck.

Manselia between *M. subfalcata* and *M. trichina* S. Buck

Nautilus sp.

Belemnites ellipticus Miller

A hardened limestone 2 ft. thick on shore 390 yds. E. 25° S. of the Trigonometrical Station belongs to the Bradfordensis Zone. Fossils are:

Goniomya angulifera (J. Sow.)

Pecten cf. *demissus* Phil.

Pleuromya jurassi Ag.

cf. *Brasilia decipiens* S. Buck.

Brasilina crinalis S. Buck.

Brasilina between *crinalis* and *tutcheri* S. Buck.

cf. *Brasilina baylei* S. Buck.

cf. *Ludwigella flexilis* S. Buck.

cf *Ludwigella impolita* S. Buck.

Belemnites cf. *aalensis* Voltz

Belemnites ellipticus Miller

At the same locality another hardened limestone 1 ft. 9 in. thick with platy top belongs in the main to the *Ludwigella cornu* horizon of the Concava Zone. The fossils obtained from this locality are all ammonites:-

cf. *Asthenoceras nannodes* S. Buck.

cf. *Brasilia bradfordensis* S. Buck.

cf. *Brasilina tutcheri* S. Buck.

? *Lucya marginata* S. Buck.

Ludwigella attentuata S. Buck.

Ludwigella cf. arcitenens S. Buck.

Ludwigella cf. cornu (S. Buck.)

Ludwigella cf. *rugosa* S. Buck.

Ludwigella cf. *subrudis* S. Buck.

cf. *Ludwigella arcuata* S. Buck.

cf. *Ludwigella casta* S. Buck.

cf. *Ludwigella flexilis* S. Buck.

cf. *Ludwigella impolita* S. Buck.

?*Ludwigella* sp. nov.

This limestone also contains indications of the Discites Zone, as shown by the presence of *Platygraphoceras* cf. *carbatinum* S. Buck. and *P.* cf. *latum* S. Buck.

The *Ludwigella cornu* horizon was also detected in a hard white limestone with platy layers, 6 ft. thick, seen on the east side of the gully mentioned on p. 46. Its fauna is slightly different from the previous one:

Pholadomya fidicula J. Sow.

Pholadomya heraulti Ag.

Unicardium ?

cf. Brasilina crinalis S. Buck.

Ludwigella cf. attenuata S. Buck.

Ludwigella cf. cornu S. Buck.

cf. Ludwigella micra S. Buck.

cf. Ludwigella vibrata S. Buck.

Ludwigella sp. [new] cf.

Paineia sp.

Belemnites cf. aalensis Voltz

Belemnites spp.

At the same locality a white-weathering limestone with hard shaly layers, 4 ft. thick, is referred to the *Platygraphoceras* horizon of the Discites Zone.

Although the Discites fauna of the South of England is contained in one thin bed, Buckman considered it capable of chronological division, and adduces the evidence of the Ardnamurchan strata.<ref>S. S. Buckman, Jurassic Ammonites and Chronology, 1925, P. 74 Reprinted with corrections from 'Type Ammonites', vol. v</ref> His *Reynesella* horizon is represented in 6 in. of baked calcareous beds and limestones 390 yds. E. 25° S. of the Trigonometrical Station, where Mr. Manson obtained:

Homoeorhynchia sp. nov. [cf. *H. cynomorpha* S. Buck.]

Braunsina cornigera S. Buck.

cf. *Braunsina aspera* S. Buck.

elegantula S. Buck.

cf. *Haugia curva* S. Buck.

Lopadoceras between L. jurcatum and L. arcuatum S. Buck.

Reynesella juncta S. Buck.

cf. Reynesella piodes S. Buck. [or sp. nov.]

Belemnites sp.

An ammonite resembling *Depaoceras fallax* S. Buck, found in another calcareous bed at the same locality, suggests Buckman's *Depaoceras* horizon.

The highest fossiliferous beds of the Ardnamurchan Inferior Oolite Series consist of baked blue shales or flags, 15 ft. thick, weathering in parts into soft ferruginous sandstone, and seen in the shore cliffs 358 yds. E. 25° S. of the Trigonometrical Station. They fall in the *Docidoceras* horizon of Mr. Buckman's hemeral scheme, and have yielded:

cf. *Docidoceras cylindrodes* S. Buck.

cf. *Docidoceras perfectum* S. Buck.

cf. *Docidoceras planulatum* S. Buck.

cf. *Mollistephanus*

Ammonite [*new ?*]

Belemnites cf.*aalensis* Voltz

In this account of the Ardnamurchan Inferior Oolite only the definitely localized fossils have been mentioned. The collection, however, contains additional specimens from loose blocks and ill-defined localities. These fossils add nothing new to our knowledge of the sequence, and only one deserves special mention — a Hammatoceratid ammonite suggesting *Eudmetoceras,* a faunal element scantily represented in Scotland. G. W L.

On the north coast, the sequence of Mesozoic strata is interrupted by the Tertiary Vent-agglomerates. In the latter, on the coast opposite Achateny, east of Port Ban, much sedimentary material occurs as blocks. One of these, a limestone, was found to contain abundant belemnites, large and small in size, exactly as in the Inferior Oolite limestone near Kilchoan. It seems, therefore, that Inferior Oolite strata were present on the north coast prior to the formation of the Tertiary Vent-agglomerates.

In the Ben Hiant district and south-east of Loch Mudle, the Inferior Oolite as well as the greater portion of the underlying Lias are absent owing to erosion in pre-Tertiary, probably pre-Upper Cretaceous times.

Bloody Bay Sandstone

Prof. Judd drew attention to a red sandstone quarried in the west cliff of Bloody Bay, close to the east margin of Sheet 51. The locality is about a quarter of a mile southeast of Ardmore farm and of easy access from above, or by boat from Tobermory. Judd, speaking of the sandstone, justly remarks that 'the eroded surface of these beds is seen to be directly covered by the... basaltic lavas'.<ref>J. W. Judd, The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands, *Quart. Journ. Geol. Soc., vol. xx*)*dv.,* 1878, p. 715.</ref>

'The sandstone is of good quality and has been used in the wall of the path leading to Rudha nan Gall Lighthouse (Sheet 52). It is at least 50 ft. thick, current-bedded, and red in colour, with a small proportion of rounded grains. It also carries irregular concretionary bands of iron-ore. The outcrop can be traced for about 200 yds. and is terminated in both directions by what appears to be a fault running almost parallel with the cliffs and bringing basalt lavas down to sea-level.<ref>Quoted from G. V. Wilson *in* Summary of Progress for 1920, *Mem. Geol. Surv.,* **1**921, p. 38.</ref>

The sandstone is comparable with the thick sandstone, locally reddish, which forms the upper part of the Inferior Oolite of Ardnamurchan (p. 45). The Ardnamurchan sandstone, if originally red, may have lost much of its colour through contact metamorphism. E.B.B.

Great Estuarine Series

A small mass of black, fissile shales surrounded by Tertiary intrusions occurs in a sea-cliff on the west side of the promontory of Sròn Bheag, south-west of Kilchoan Bay. The thickness seen is 8 ft., and the dip is at a high angle eastwards. The shales are perhaps separated from Inferior Oolite beds, that outcrop both to west and east, by faulting of prior date to the enveloping intrusions. Dr. G. W. Lee obtained from these shales *Estheria murchisonae* Jones, a form characteristic of the Great Estuarine Series of the Island of Skye. Moreover, the Sròn Bheag shales are lithologically different from any Inferior Oolite or Liassic strata exposed near by along the Kilchoan coast, and it seems reasonably certain that they belong to the Great Estuarine Series. J.E.R.

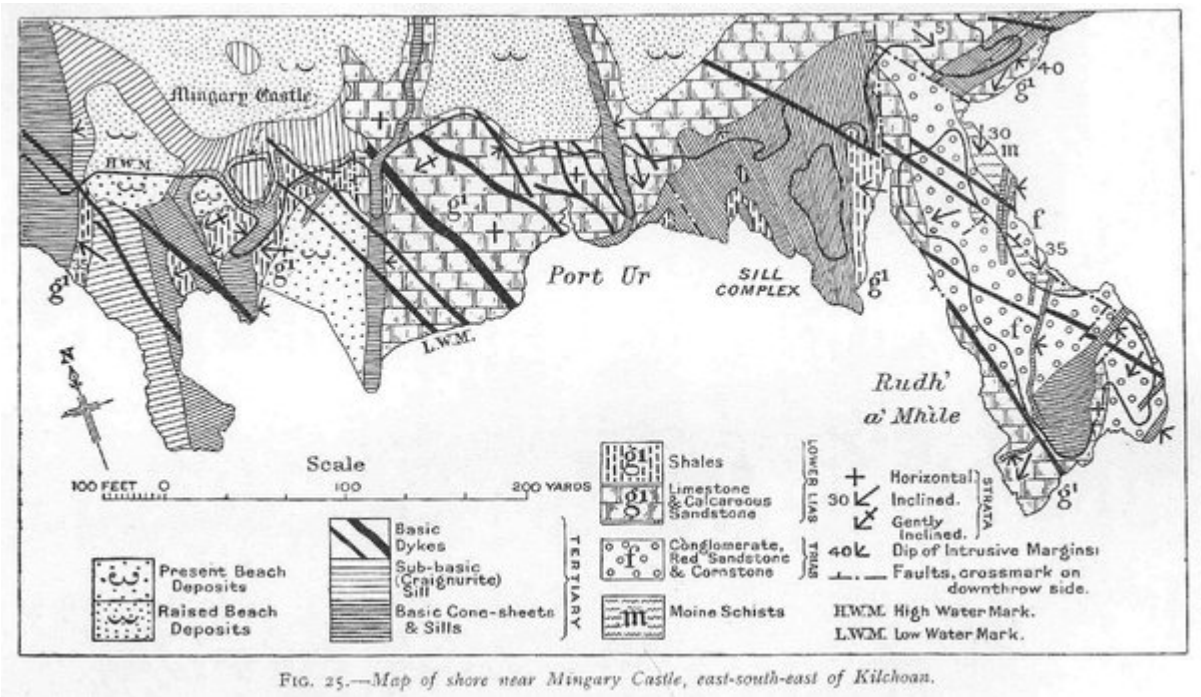

FIG. 25.—*Map of shore near Mingary Castle, east-south-east of Kilchoan.*

(Figure 25) Map of shore near Mingary Castle, east-south-east of Kilchoan.

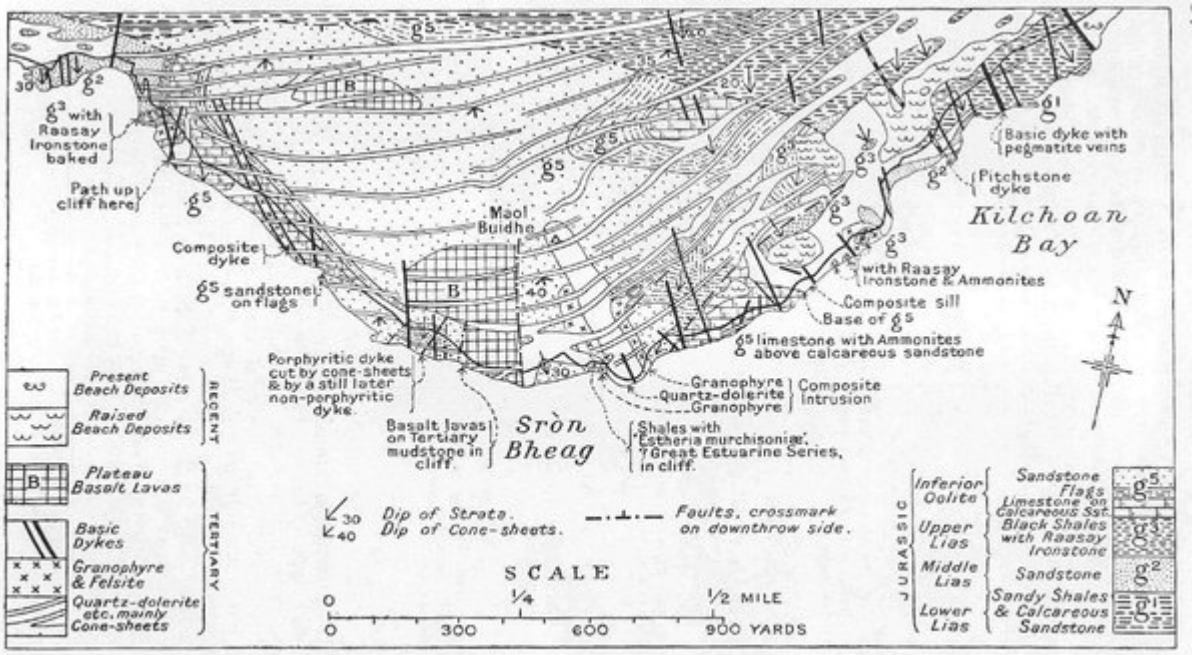

FIG. 3.—*Map of Mesozoic strata and Tertiary basalt lavas cut by Tertiary minor intrusions, west of Kilchoan Bay.*
NOTE.—Tertiary cone-sheets are mainly represented diagrammatically.

(Figure 3) Map of Mesozoic strata and Tertiary basalt lavas cut by Tertiary minor intrusions, west of Kilchoan Bay. Note. Tertiary cone-sheets are mainly represented diagrammatically.

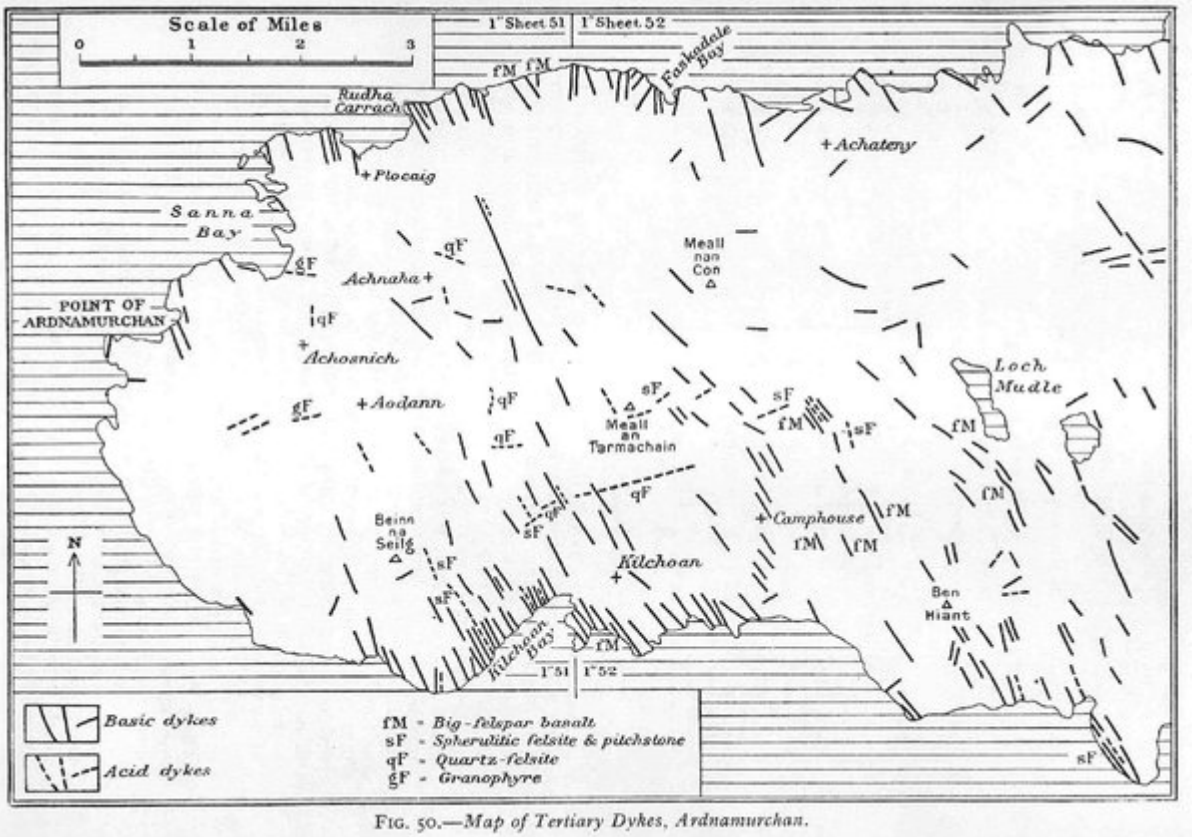

FIG. 50.—*Map of Tertiary Dykes, Ardnamurchan.*

(Figure 50) Map of Tertiary Dykes, Ardnamurchan.

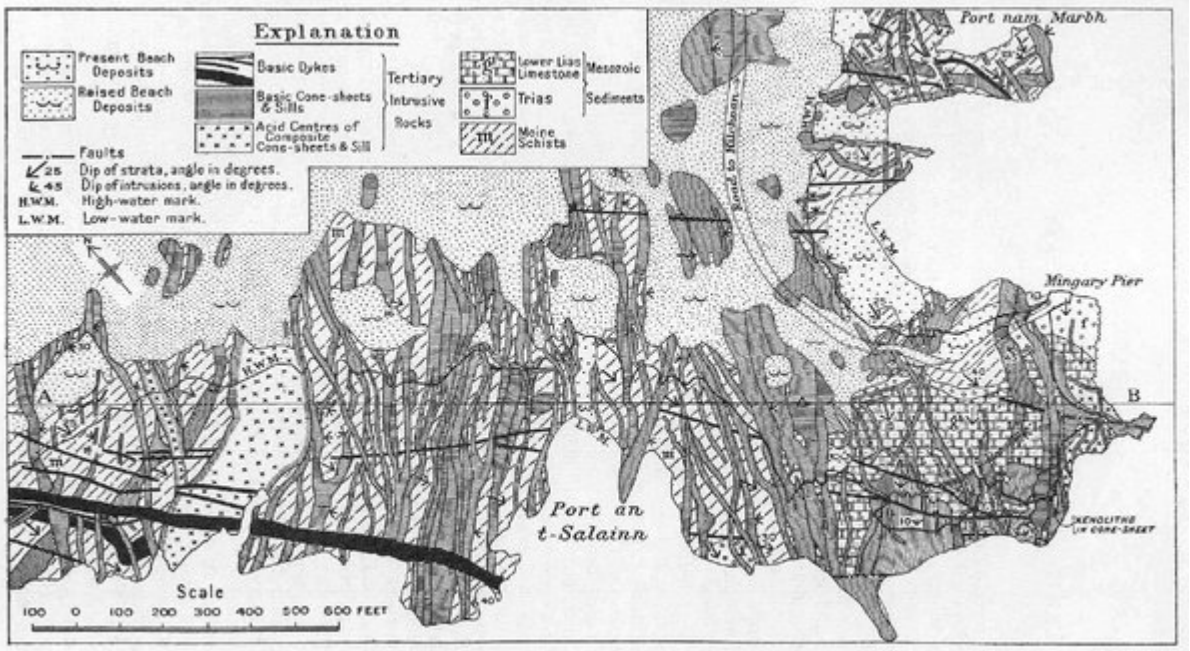

FIG. 23.—*Map of Outer Cone-sheets of Centre 2, shore south of Kilchoan.*

(Figure 23) Map of Outer Cone-sheets of Centre 2, shore south of Kilchoan.