Chapter 3 Tertiary sediments of Mull and Loch Aline

Introduction

As regards bulk, sediments play an almost insignificant role in the Tertiary accumulations of the Mull district. At the same time, they furnish particularly interesting information concerning the climatic conditions which attended and preceded the outpouring of the Mull lavas; and they also date with some degree of precision the earlier stages of the volcanic history.

The band of sediment which includes the Ardtun Leaf-Beds, at the mouth of Loch Scridain (Sheet 43), has been familiar to all students of geology since its description by the Duke of Argyll and Professor Edward Forbes in 1851, and its fuller treatment by Mr. Starkie Gardner in 1887. Its field-occurences will be dealt with in the present chapter; but its palaeobotanical contents, more especially as represented in material collected by Mr. Tait for the Geological Survey, are treated separately by. Professor A. C. Seward and Mr. R. E. Holttum in Chapter 4. The general geological conclusions arrived at by these two authors may be summarized as follows: The leaves of the Ardtun Leaf-Beds seem to have fallen into the waters of a still lake; the climate was temperate, though perhaps warmer than is met with in most of the British Isles to-day; the date was Eocene, possibly Lower Eocene.

Chapter 4, although mainly concerned with the fossil plants of Ardtun, deals also with beetles from the same locality and with additional plants from near Carsaig.

The Leaf-Beds of Ardtun form part of a thin sedimentary intercalation near the base of the lavas in South-West Mull. In the same district, impersistent seams of lignite, or inferior coal, are met with sporadically at various levels in the Plateau Basalts. These presumably accumulated under the warm-temperate conditions responsible for the plants of the leaf-beds. To the same genial climate may be referred the repeated weathering of basalt-lava to red soil, to which attention is frequently directed in succeeding descriptions of the Plateau Basalts. In keeping. with this evidence of inter-basaltic weathering and development of bole, is the recurrence of a singularly widespread mudstone actually at the base of the Tertiary lavas. So far as exposures afford a chance of judging, there are comparatively few places in Ardnamurchan, the Loch Aline district, and Mull where such a basal mudstone, a few feet thick, is not to be found. Its appearance very strongly suggests the lateritic decay of basic igneous rock. It is difficult to regard it as a product of decay of lava in mass, since nowhere is there any suggestion of a pre-existing lava-flow. The four-fold hypothesis here advanced is: that the basal mudstone is the result of lateritic decay of a wide-spread basaltic ash; that this ash was the initial product of vulcanicity in the district; that the climate of the time was warm and moist; and that a long interval of volcanic repose followed the initial explosion. Dr. Lee was the first for the Geological Survey to suggest an ash-origin for the basal mudstone. He also points out in the sequel that the deposit seems to have undergone subsequent alteration within the Pneumatolysis Limit of (Plate 3). The analysed specimen (15 p. 34) comes from the area of alteration, and this perhaps accounts for the marked preponderance of FeO over Fe_2O_3.

The evidence of moist conditions during, and immediately preceding, the accumulation of the Plateau Basalts is further shown by the occasional occurrence of conglomerates with rounded pebbles of flint (sometimes, it is thought, including silicified chalk). Such conglomerates had long been known associated with the Leaf-Beds of Ardtun, and on what is very probably the same horizon near Carsaig Arches of the south coast of Mull. Other earlier examples, ante-dating the Basal Mudstone, have been met with during the course of the Survey in the east corner of Mull.

Passing back in time, one seems to enter upon the record of a desert climate. Locally the bottom Tertiary accumulation consists of a few feet of sand in which what are taken to be wind-rounded grains are prominently represented. It is pointed out in the Memoir dealing with the Mesozoic rocks of the district that desert conditions probably prevailed along neighbouring shores during the accumulation of a large portion of the Upper Cretaceous marine deposits of the districts. It is therefore very difficult to say whether the Tertiary sands here dealt with may not be re-assorted Upper Cretaceous sands. The evidence which most strongly supports the view that the desert climate continued after the upheaval of the chalk is supplied, not so much by the sands themselves, as by a prevalence of silicification attributable to the period. This evidence may be summarized as follows:

1. The chalk was elevated as a limestone for it has weathered in carious fashion with fissures everywhere.

2. Its cavities are filled-in locally with sand including many wind-rounded grains which cannot be matched in Cretaceous or other sediments of the immediate vicinity; silicification has replaced the chalk by some cherty substance, and this latter often serves as matrix for quartz-grains of the fissures.

3. Locally, the chalk has disintegrated into fragments which are enclosed in sand; here again silification of the chalk has been instituted, and the sand has been involved to some extent, so that each fragment of silicified chalk is surrounded by a cherty halo enclosing quartz-grains.

4. The quartz-grains of the sand, where not enclosed in chest, show a pronounced tendency to develop crystalline facets which, when examined in sunlight under a lens, are seen to glitter brightly.

The silicification-phenomena outlined above are exceptional in degree. They recall accounts given by Rogers and others of surface-quartzites, etc., from South Africa. S. Passage in *Die Kalahari* accepts silicification as characteristic of a desert climate, and offers a theoretical explanation based upon the tendency for solutions under desert conditions to dissipate by evaporation rather than by drainage.

In accordance with the above, it is here suggested that the desert climate of late Cretaceous times continued after the elevation of the chalk. In the absence of direct evidence, the emergence of the chalk is taken as marking the beginning of Tertiary times. It is fairly certain (from analogy with Morven and Antrim) that this elevation happened at some date later than the Upper Chalk zone of *Belemnitella mueronata.* Possibly the elevation actually occurred near the end, rather than at the end, of Cretaceous times; in which case the desert climate may belong wholly to the Cretaceous. Be this as it may, there are obviously good grounds for accepting Professor Judd's suggestion that Tertiary follows Cretaceous, in the Hebridean record, without any striking time-interval. This suggestion has, since Judd wrote, been much strengthened by Gardner's dating of the Ardtun leaves as Lower Eocene—a claim which Professor Seward and Mr. Holttum tentatively accept.

Before passing on to the more detailed discussion of the various exposures, one may notice a very difficult question that arises in connexion with the silicification of the chalk. It is not clear what was the source of the silica. It seems very improbable that much of it has been derived from the chalk itself; Professor Rupert Jones supplied Professor Judd with descriptions of foraminifera and *Inoceramus*-prisms,easily recognizable in thin slices of silicified chalk from Mull and Morven, so that it is clear that to some extent the chalk has been pseudomorphed rather than its silica concentrated; moreover, fragments of silicified chalk embedded in sandstone and surrounded by a hail) of cemented grains (which betokens silicification after enclosure in the sand) are not flattened. Nor is it at all probable that the silica has been derived from solution of the Tertiary sand, since in one case silicified chalk is to be seen with its cavities infilled by a mudstone of later date than the sand. Probably the main source of silica is the underlying sediments, and the solutions concerned have been brought up by capillarity.

In the preceding remarks, the familiar Ardtun Leaf-Beds have been taken as a starting point. Now that the general nature of the evidence has been given in outline, it is convenient to group the detailed consideration of the exposures in such a way that the earlier parts of the story receive first attention.

Desert and associated deposits

Gribun (Sheet 43)

The Gribun sections are the only ones in Mull which show the chalk as a deposit and not merely *remanié.* There are four exposures all told, and in three of them the chalk is only seen in land-slips; but this does not prevent their use as indications of the nature of the geology of the district. In all four exposures, the chalk is silicified to a hard white rock, preserving a curiously chalky aspect, and very occasionally showing fossils to the naked eye.

Two of the landslip-exposures occur just north of the straggling village of Gribun near the ruins marked Clachandhu on the one-inch Map. One is in broken-up landslip-material between the two first streams shown north of Clachandhu. The other is a coherent landslip serving as the low coastal cliff of a raised-beach along which runs the road, just where it passes the most northerly cottage of Gribun. This latter exposure is particularly serviceable in reading the post-elevation history of the chalk, One can examine the silicified chalk in detail. It is 6 ft. thick and rests on a fine white sandstone,<ref>This white Upper Cretaceous sandstone, seen here and at Allt na Teangaidh, is of finer texture than the Tertiary sandstone of the district. Examined with a lens it shows much less rounding of its constituent grains, except in the case of its very few larger grains which at once attract attention for their smooth more or less spherical, or ovoid, form. It is pointed out in the companion Memoir that this sandstone has probably resulted through desert sand blowing into the Upper Cretaceous sea. It is therefore open to anyone to suggest that the Tertiary sands described in the text are merely *remanié* of Cretaceous desert sand, coarser in texture than that exposed at Gribun, though comparable with what is met with in Morven. On the other hand, as already pointed out, such an interpretation leaves the Tertiary silicification-phenomena unexplained. Apropos of the possible derivation of the round grains of the Tertiary of Gribun, it is well to emphasize the fact that the grains of the local Triassic, Rhaetic, and Liassic sandstones show no conspicuous rounding at all.</ref>10 ft., and this in turn on fossilifererous greensand. On close examination it is seen that the silicified chalk is traversed in all directions by sand, often completely cemented by a cherty matrix of smoother fracture than that replacing the chalk itself. The majority of the sand-grains are angular or subangular, but a considerable proportion are thoroughly well-rounded. A slice (S22090) [NM 4550 3539], cut across chalk and sandstone, shows much of the chalk represented by clear cryptocrystalline silica, but with white opaque patches. The matrix of the quartz-grains is white and opaque resembling the material of these patches. The hardness of this material is taken as proving its siliceous composition. Rounded quartz-grains of 0.4 mm. diameter are well represented in the sandstone.

The next exposure occurs in Allt na Teangaidh above Balmeanach Farm, and has the advantage of furnishing a complete section between the silicified chalk and the basalt-lavas. The chalk is 12 ft. thick, and shows the same type of phenomena as just described. It is overlain by 3 ft. of sandstone followed by 12 ft. of dark red-brown mudstone, that as usual forms the floor for the basalt-lavas. A slice (S20807) [NM 4544 3258] of the sandstone overlying the chalk shows a number of beautifully rounded quartz-grains about 0.2 or 0.3 mm. in diameter. These are distributed at random among numerous angular grains of distinctly smaller dimensions. Much of the slide has a white opaque matrix recalling the siliceous cement mentioned above in (S22090) [NM 4550 3539]. More locally, quartzite has been developed through the addition of quartz to the original elastic grains. The line between added and original quartz can sometimes be clearly traced by dirt. There is a little mica, albite, and zircon.

The last exposure of silicified chalk is four miles south-west of Allt na Teangaidh. Here several big blocks of the chalk lie at the base of the landslip that forms the southern part of The Wilderness, exposed on the coastal cliff on the south side of Aird na h-Iolaire. In one of these blocks, the silicified chalk has dark red mudstone penetrating its cavities.

Between Allt na Teangaidh and the Wilderness there is another very interesting exposure of part of the basal Tertiary sediments. It is afforded by a little waterfall some yards above a gorge, that reaches the sea close to a rock known as Caisteal Sloc nam Ban. The waterfall shows Triassic pebbly sandstone overlain by 5 ft. of greenish thin-bedded (? Rhaetic) sandstone with films of black shale near the base, and these in turn by 2–6 ft. of *remanié* chalk (silicified), and 2 ft. of white sandstone. Above the sandstone there is a gap which may well hide the basal mudstone. The *remanié* chalk has a matrix of sand, and the quartz-grains of this matrix, as well as those of the overlying sandstone, show wind-rounding masked to some extent by growth of secondary facets. Some of the quartz figured originally as small pebbles rather than grains, and in this case partial facets are particularly conspicuous under a lens. The fragments of chalk have not suffered deformation during silicification. A slice from the overlying sandstone (S20803) [NM 4522 3640] shows many well rounded quartz-grains, in places enclosed in a matrix of cryptocrystalline silica, but elsewhere with outgrowths of quartz; this added quartz is in some cases easy, and in others difficult, to distinguish from the original grains. A few patches of cryptocrystalline silica suggest pseudomorphs after small fragments of chalk.

The two first lavas seen above the Tertiary sediments just described are somewhat columnar basalts. The higher of the two is a doleritic basalt extending for some distance along the cliff. It has a vesicular upper portion, which has weathered on top to a bright-red earth, but a little lower down shows cavities filled in with 'millet-seed' quartz-sand. It is suggested that in this case sand, fashioned in the desert: period, has travelled into position during the subsequent warm-temperate

climate that witnessed the outpouring of the lavas.

One last exposure of the Gribun district remains for comment. It lies between two faults shown on the one-inch Map at the Gribun School between Balnahard and Balmeanach. It is almost certain that the rocks concerned are altered Tries sandstone and conglomerate; but they have undergone a silicification which renders them extremely like the chalk and immediately associated Tertiary sandstone. It is therefore not improbable that they represent a local silicification of Trias sandstone and conglomerate performed during the Tertiary desert stage. The Triassic sediments, where unaltered in this neighbourhood, have a calcareous matrix.

The silicification has kept fairly constantly to one horizon—the uppermost few feet exposed. What intervenes between the zone of silicified rock and the Tertiary lavas is hidden. The junction with typical Triassic sediments below is, however, well-exposed. E.B.B.

Carsaig (Sheet 44)

It is in the Carsaig district that the Lower Tertiary sediments attain their greatest development, in thickness as well as in variety.

Some of the beds described here as Tertiary were considered by Prof. Judd to be Chalk, but detailed examination along the outcrop supports the view that the Carsaig Chalk is all *remanié* and should be ascribed to the base of the Tertiary. The observed masses of chalk do not form bedded layers, but are dispersed without order in a sandstone matrix.

The best exposure is in the stream above Feorlin Cottage, 50 yds. above the left affluent. Underlying the basalt-lavas is a purple mudstone, 3 ft. thick, which rests on a bed made up of chalk-fragments embedded in a black sandy matrix. This is underlain by a massive white pebbly sandstone with red staining, 20 ft. thick. Five feet from the top of this sandstone, is a lenticular bed, 2 ft. thick and some 80 ft. long, made up of white flints. The base of the section consists of Cenomanian glauconitic sandstone passing down to concretionary limestone. The lateral variation of these beds is rapid and considerable. In the affluent 50 yds. below the highest bed seen is a white sandstone. This is underlain by a 2 ft. layer of chalk-fragments resting on a 5 ft. sill, which caps the massive white sandstone referred to above.

The recognition in 1920 of what appears to be wind-rounding as a feature of the quartz-grains of the Tertiary sandstone of Gribun led to a re-examination of the white sandstone of the main stream above Feorlin Cottage. A pocket-lens shows beautiful rounding of many of the quartz-grains of the sandstone. Another point noticed was a white cherty halo surrounding included chalk-fragments and serving as matrix to adjacent sand-grains. From this latter phenomenon it is clear that silicification of the chalk occurred after the latter was embedded in the sand; and the fact that it proceeded without a flattening of the fragments shows that silica was precipitated to take the place of the lime removed. A slice (S20809) [NM 5339 2223] wat cut from a hand-specimen of sandstone enclosing chalk. Only silicified sandstone is shown with quartz-grains bound together by cryptocrystalline silica. Perhaps half the grains show marked rounding, and oval sections are common measuring 0.3 mm. by 0.2 mm.

The amount of chalk-fragments dimishes eastwards from the stream above Feorlin Cottage: at the waterfall Eas Mheanain, 400 yds. to the east, there is no individual layer of chalk-debris, but angular fragments are irregularly scattered throughout the mass of the white pebbly sandstone. Still farther east, at Eas na Dahhaich above Pennycross House, no chalk occurs in the white pebbly sandstone, which is here a little glauconitic. It merges downwards into glaueonitic sandstone with crushed lamellibranchs. Both the lamellibranchs and the glauconite are probably *remanié* Cenomanian.

The sandstone with chalk can be traced on the western side of the bay, as far as the waterfall at the Nuns' Pass Quarries, where it dies out.

In the gully above Aird Ghlas the following section shows a type of sedimentation different from that on the east side of the bay:

	Ft.
Basalt-lava	—

Soft shaly sandstone with fragments of flints	1
Greenish sandstone with flints and lumps of chalk	2
Purple mudstone	1
Greenish sandstone with a few lumps of chalk and flints	5
Gap	1
Cenomanian	—

From some inaccessible place a little south-west of this point, large fragments of' chalk up to a foot across have fallen on to the shore. There is no difficulty in believing they may come from *remanié* masses in the Tertiary as farther east.

The intercalated mudstone in the Aird Ghlas section is not of appreciable horizontal extent. The sandstone is apparently always greenish on this side of the bay, instead of white as on the other side. The rock to which the term chalk is applied here has much the appearance of chalk, but is silicified and consequently very hard. Notes on its microstructure, by the late Rupert Jones, are appended to Prof. Judd's Memoir.<ref>Prof. Judd's Memoir.<ref>J. W. Judd, Secondary Rocks of Scotland, *Quart. Journ. Geol. Soc., vol.* xxxiv, 1878, p. 739.</ref>

G.W.L.

Tobermory (Sheet 52)

In the road-section above the distillery at Tobermory, grey fossiliferous Liassic shales are followed immediately by one or two feet of red-brown Tertiary mudstone occurring at the base of the lavas. Some 70 yds. farther north, however, in a section at the back of the houses that stand below the cliff, three feet of olive-green sandstone interpose between the Liassic shales and the Tertiary mudstone. This sandstone has abundant rounded quartz-grains, some with secondary facets. White mica is also conspicuous.

A mile and a half south-east of the town, an exposure of soft white sandstone peen's beside a path that skirts the south-west side of the lake in the grounds of Aros House. The sandstone is largely composed of beautifully rounded quartz-grains with very subordinate white mica. There is no section connecting the exposure with those of neighbouring basalt-lavas, but the probability is that the sandstone is of Tertiary date, and that it lies at the base of the lavas and is bounded on the north-east by a fault. E.B.B., G.V.W.

Flint—conglomerate, etc., Eastern Mull

In the year 1909, when the basal flint-conglomerate of Eastern Mull was mapped, it was judged to consist of normal flint and silicified chalk, both occurring as water-worn pebbles. If this view is correct, it supplies clear proof that the period of silicification ante-dates the conglomerates.

Craignure district (Sheet 44)

No Tertiary sediments were noticed at the base of the lavas in the disturbed coast-sections near the entrance to the Sound of Mull, whether at Bàn Eileanan, Craignure Bay, or Duart Bay.

Inland, however, a good exposure of flint-conglomerate with abundant mudstone-matrix occurs above the road close to a deer-fence half a mile north-west of Torosay Castle. Three hundred yards farther south, the lavas are resting on a foot of flint-conglomerate and this upon a flinty bed, with grey limestone beneath, referable to the Upper Cretaceous.

some way south of this, a fault throws back the base of the lavas 600 yards to the west. A flint-conglomerate has been noted at intervals separating the lavas from the Lower Lias. Four hundred yards south-west of Upper Achnacroish Farm, the Tertiary basement-bed is 30 ft. thick, and consists of sandstone with only occasional flint-pebbles.

The Basal Mudstone

The most persistent Tertiary sediment of the Mull district is a muddy, often unbedded, rock of fine texture which breaks up into small irregular fragments. It is met with again and again at the actual base of the lavas, so that there can be little doubt as to its stratigraphical individuality. The bed is certainly absent in a few fully exposed undisturbed sections, but still its relative persistence is remarkable when taken in conjunction with the small thickness of the deposit which very rarely reaches 10 feet. As indicated already, the mudstone has probably in the main originated from lateritic weathering of basaltic ash. Sometimes a slight admixture with normal sediment can be detected. E.B.B., G.W.L.

The usual colour of the deposit is a purplish brown, or deep red, evidently determined among other things by an abundance of ferric oxide. Within the area included by the Limit of Pneumatolysis ((Plate 3)., p. 91), this red tint fails; and the mudstone as seen south of Craignure, and in the Port Donain Peninsula is dark, almost black. Taken in connexion with certain abnormal characters exhibited by the underlying Mesozoic sediments and overlying Tertiary lavas, the local colour in this case seems to be due to pneumatolytic change. At any rate, the analysis of a dark mudstone from the east coast (15, p. 34) shows 17.18 per cent. FeO as against 1.57 per cent. Fe_2O_3, which is probably very different from what would be found in the deep-red mudstone. G.W.L.

Another local variation of colour is one that may be ascribed to original conditions, rather than pneumatolysis. In the coastal sections of the Croggan Peninsula, the basal mudstone is very pale green or buff in colour, and is probably more aluminous, and correspondingly less ferruginous, in composition than usual. The occurrence has an additional interest, as it is suggested later on that a similar variety of mudstone is the source of the sapphire-bearing xenoliths described in Chapter 24. G.V.W.

Most of the exposures in Mull have been mentioned already, but a brief recapitulation is given below before proceeding to an account of the Loch Aline evidence:

Gribun (Sheet 43)

Two exposures have been described above. At Allt na Teangaidh 12 ft. of inudstone intervene between the desert Tertiary sand, below, and the basalt-lavas, above. At the south end of The Wilderness, the mudstone may be seen choking the cavities of a land-slipped block of silicified chalk.

An additional exposure occurs at the roadside in a great coherent landslip north-east of Balmeanach Farm. The locality is easy to find as it is situated at the sharp bend of the main road where it comes nearest to the farm-house.

Carsaig (Sheet 44)

Two exposures have been recorded above. In the stream above Feorlin Cottage, the basal mudstone, 3 ft. thick, occurs in its normal position immediately below the lavas. Underneath the mudstone itself, is the desert Tertiary sand.

South of this, above Àird Ghlas, a 1-ft. mudstone for a short distance can be traced separated by 3 ft. of sandstone from the overlying lavas This section is unique in showing what appears to be the basal mudstone separated by other sediment from the lavas; but there is, of course, no difficulty in accounting for such a local peculiarity. Below the mudstone there are 5 or 6 ft. of Tertiary sandstone. G.W.L.

Nothing was seen of basal mudstone in the disturbed section of An Coileim south of Glenbyre Farm.

Croggan Peninsula (Sheet 44)

In the An Garradh section, at a point indicated on the one-inch Map, there are about 20 ft. of pale buff-coloured marl (S17398) [NM 6128 2027] above Middle Lias sandstone. This marl is regarded as an aluminous development of the basal mudstone. G.V.W.

Mudstone is definitely absent near the mouth of a small stream south-east of Beinn na Sreine, where the only Tertiary sediment is a very thin sandstone to be described at the foot of the page.

Farther north-east, at Port na Muice Duibhe, there is a section at the base of the lavas, much complicated by dykes and sills, but at the same time showing some 20 ft. of pale-green brittle shale or mudstone. This mudstone differs from the ordinary type in being distinctly bedded. It also at one point carries white concretions (S15867) [NM 6983 2422].

Port Donain Peninsula (Sheet 44)

Dark brittle mudstone is met with as the only Tertiary sediment at the base of the lavas south of Port nam Marbh.

North of Port na Tairbeirt, the coast-sections, as already noted, show a foot or two of similar mudstone above flint-conglomerate.

Craignure District (Sheet 44)

The only known occurrence of mudstone, iu the comparatively few available exposures of this district, occurs above the road at the deer-fence half a mile north-west of Torosay Castle. The rock has been referred to above as flint-conglomerate with abundant mudstone-matrix. E.B.B.

Tobermory (Sheet 52)

The list of Mull exposures is completed by recalling those at Tobermory, where, in the town, as already mentioned, one or two feet of mudstone is locally the only Tertiary sediment at the base of the lavas, while elsewhere it is accompanied by three feet of underlying sandstone with round wind-worn grains. G.V.W.

Loch Aline, Morven (Sheet 44)

The basal mudstone occurs in several sections on the two sides of Loch Aline, The following exposures may be enumerated: shore, north of pier on west side of Caolas na h-Airde; cliff, north of Achadh Forsa, 6 ft. thick; left bank of burn that flows into Rannoch River above Achranich, near Fountainhead; waterfalls from Allt Leacach southwards, 5 ft. thick; shore, west of Am Mìodar, over 4 ft. thick; faulted inlier in Allt na Samlmachain.

The mudstone in these sections always lies at the base of the lavas and is probably the only Tertiary sediment represented. It is often underlain by a white sandstone with some rounded quartz-grains, but this is regarded as of Upper Cretaceous age.

The mudstone is of normal character, muddy, unbedded, and breaking into small irregular fragments. Its predominant colour is purplish brown, sometimes red. No pebbles are present, and elastic elements are represented by small grains of quartz visible with the aid of a lens. At one or two places, namely near the Fountainhead above the pier south of Achranich, it contains small masses of impure coal or charred vegetable remains, which led to search for coal, as testified by two shallow day-levels. The same mudstone crops out on the left bank of Allt na Socaich. The valley here is sometimes called the Coal Olen from the fact that lignite was once obtained from it at a spot long since completely hidden by scree-materials. From analogy with the sequence at Beinn Iadain, farther north, Prof. Judd inferred that the lignite belonged to a sandstone-series overlying the chalk; but such a series is not known to be represented in the immediate vicinity of the Coal Glen, while on the other hand the mudstone near by contains small quantities of a coaly matter approaching lignite, so that it seems more probable that the lignite of the Coal Glen was obtained from the mudstone. G.W.L.

Ardnamurchan (Sheet 52)

Although Ardnamurchan falls outside the scope of the present memoir, it is proper perhaps to note that a basal mudstone comparable in type and thickness with that of the Mull and Loch Aline district has been found in several exposures.

Port Donain Peninsula (Sheet 44)

Round the Loch Don Anticline, no basement Tertiary sediments are to be seen. On the east coast, however, there is a capital section of them on the shore half a mile east of Auchnacraig Farm. The Cenomanian is overlain by a sandstone containing water-rounded white flints, up to a foot in diameter, along with numerous broken lamellibranchs, in both cases *remanié* of the Cretaceous. This bed is lenticular, varying in thickness up to 6 or 7 ft. South of a well-marked gully the sequence is a little different. The flints form a distinct conglomerate-band, 2 ft. thick, above a Cenomanian sandstone with *Exogyra* in place. The conglomerate has a sandstone-matrix. At both localities, the flint-conglomerate horizon is overlain by a foot or two of dark mudstone which is represented by Analysis XV. (p. 34). This mudstone occasionally contains fragments of flint and black shale, the former being numerous in the lower 8 inches as seen south of the gully. The top is decidedly sandy and gritty at this point, while it becomes shaly north of the gully. No plant-remains were noticed. A very small patch of flint-conglomerate occurs at Port Donain, but none is seen farther south.

Other basal sediments

The preceding accounts of the Tertiary sediments beneath the lavas can be completed by two further notes:

Croggan Peninsula (Sheet 44)

The only Tertiary sediment at the mouth of the small stream that enters the sea south-east of Beinn na Sròine is a very thin sandstone containing numerous fragments of lava-form rocks (S15854) [NM 6804 2270], (S15855) [NM 6804 2270], (S15856) [NM 6804 2270], (S15857) [NM 6804 2270], (S15858) [NM 6804 2270], and a few of sandstone, in a matrix often rich in quartz-grains. The rock-fragments are occasionally water-rounded, and a small proportion of the sand grains seem wind-rounded.

The lava-enclosures are too weathered for accurate determination, but several of them look like trachyte. E.B.B.

Inninmore, Morven (Sheet 44)

A path leads to Inninmore Cottage at the angle of the bay of that name. A mile west of the cottage, and 170 yds. west of a prominent fault, this path takes a sharp bend. Just at this point, there is a small exposure of a greenish micaceous sandstone immediately overlying Triassic cornstone, and overlain by a sill. The relations of the sandstone to the underlying Trias are by no means clear; in fact, the sandstone was taken to be part of the Trias until search for fossils led to the unexpected find of a fossil leaf, This is not well-preserved, or specifically determinable, yet it is an undoubted Dicotyledon stated by Mr. Clement Reid to resemble oak in its primary venation. The position of the sandstone is below the basalts; but its age relative to that of the Loch Aline mudstone cannot be ascertained, the mudstone being absent here. G.W.L.

Leaf-beds and associated gravels of Ardtun (Sheet 43)

The famous Leaf-Beds of Ardtun are included in a belt of sediment outcropping, as shown on the one-inch Map, for about a mile close to the coast of the Ardtun Peninsula between Loch na Lathaich and Loch Scridain. The Duke of Argyll distinguished three leaf-beds in the sequence: a top leaf-bed, styled by him the 'first'; a mid or 'second'; a bottom or 'third.' Their positions are indicated in the descriptions given below. The whole series was mapped for the Geological Survey by Mr. Bosworth, but the detailed researches of Mr. Starkie Gardner<ref>J. S. Starkie Gardner, On the Leaf-Beds and Gravels of Ardtun, Carsaig, etc., in Mull, Quart. Journ. Geol. Soc., vol. xliii., 1887, p. 270.</ref> so fully cover the subject, that the following account of field-relations is drawn mainly from his descriptions. For further information the reader should refer to the original paper which is illustrated by six text-figures.

Mr. Tait has made a large collection of plants for the Geological Survey from the leaf-beds. He also obtained a few beetle and molluscan remains. The plants and beetles are discussed in the following chapter. The molluscs have been found by Dr. Lee "not sufficiently well preserved to permit identification yet it seems that they include a *Cyrena,* beside gasteropods." They occurred actually in a leaf-bed.

The best exposure is in a ravine indicated by a note on the one-inch Map. Gardner measured the section when cleared by quarrying; and it still remains in satisfactory condition. His measurements for the east side of the ravine are:

	Ft.	In.
Rudely columnar basalt cut by intrusive sheet	—	—
Sandstone, more or less fissile	8	0
Indurated gravel	7	0
Hard bed, with *Onoclea*	1	0
Black Leaf-Bed (Mid Leaf-Bed)	2	4
Indurated gravelly sand	2	0
Carbonaceous rubble	1	0
Amorphous basalt	—	—

The columnar basalt on top is the lower part of a lava; the amorphous basalt at bottom is the upper part of another lava, which downwards becomes columnar. The position of the Duke's top leaf-bed is at the top of the sedimentary sequence, but the 8-foot sandstone exposed in Gardner's excavation did not prove fossiliferous, and was separated from the overlying basalt merely by a parting of carbonaceous rubble. The bottom leaf-bed was not found on this side of the ravine; but on the west side it is 1 foot thick, a pale buff or cream-coloured laminated sandstone resting on the amorphous basalt.

Westwards the sediments thin somewhat, and as seen in a fine section in another ravine 120 yards from the main locality, are only 14 feet thick.

Eastwards they thicken for a space, and 80 yards from the ravine taken as our starting point, they provided Starkie Gardner with the following measurements:

	Ft.	in.
Columnar basalt	2	0
Position of Top Leaf-Bed (grassed over)	25–40	0
Gravel	2	6
Black Mid Leaf-Bed	7	0
Gravel, about	2	0
Grey clay, with faint leaf-impressions	0	6
Fine limestone, with rare but beautiful leaves	0	3
Clay, with layer upon layer of beautiful leaves	1	0
Clunch with rootlets	0	7
Amorphous basalt, becoming columnar at base	—	—

The lower 4 feet or so may be grouped as the Bottom Leaf-Bed. Gardner describes the stratum at the base of the 1 foot clay as the most interesting of the whole series: "This consists for an inch or: two of layer upon layer of leaves in the most perfect preservation, and retaining almost the colour of the dead leaves themselves. One of the most striking, as well as most abundant, is *Ginkgo,* of large size and purple colour. Still more conspicuous is the large *Platanites hebridicus,* Forbes, one leaf exposed measuring full 15½ inches in length and 10½ inches in breadth. Many other kinds of leaves appeared to be almost equally fine, and the characteristic dicotyledonous trees of this locality possessed at that period relatively large foliage. In the same bed were coniferous branches like the living *Taxodium* (*Glyptostrobus*) *heterophyllum* and *Cephalotaxus.* Unfortuately every effort to remove and preserve these specimens has failed. There are rush-like stems, from 1 to 3 inches in diameter towards the base, but the beds are almost destitute of monocotyledons, and no trace of Ferns or even *Equiseta* has been seen in them. This lowest leaf-bed passes into a thin seam of coal in one direction, and rests upon 6 to 7 inches of whitish, clunchy, and concretionary clay, with rootlets, and with softer clay filling

in the rough surface of the underlying basalt."

Eastwards the sediments thin, but there is no ground for Mr. Gardner's statement that they fail altogether.

A few words may now be said regarding the contents of the gravels and sands. The sands abound in quartz-grains with only a comparatively small proportion of rounded individuals. The most noteworthy pebbles of the gravels, or conglomerates, are water-worn chalk-flints (first recorded by the Duke of Argyll) and porphyritic lavas. The former seem to the writer to resemble genuine flints rather than the silicified chalk of Gribun, etc.; but Professor Cole<ref>G. A. J. Cole, Note on the Gravel of Ardtun, Quart. Journ. Geol. Soc., vol. xliii., 1887, p. 276.</ref> thinks that the latter type may be well represented. He, in fact, suggests that silicification may have occurred after inclusion in the gravels; but it is fairly certain that these well-worn pebbles were hard at the time they were transported. The porphyritic lavas represented among the pebbles have long been recognized as distinct in type from the neighbouring basalt-flows. They have generally been assumed to be of Tertiary age, but this is by no means certain. The suggestion is here advanced that they may be porphyritic augite-andesites, and allied types, of Lower Old Red Sandstone age (S20764) [NM 3803 2485], (S20765) [NM 3803 2485], (S20766) [NM 3803 2485], (S20768) [NM 3803 2485]–(S20769) [NM 3803 2485]. Another noteworthy type is of less common occurrence (S20767) [NM 3803 2485], but has been met with by Professor Cole as well as ourselves. It is an intrusive type consisting mostly of zoned alkali-felspars, often with perthitic interiors; the ground is microgranophyric with subordinate quartz; the ferromagnesians are mainly decomposed, but include a little pale biotite. The rock has been styled a sadinophyre or sanidine-felsite by Professor Cole. As in the case of the lava-pebbles it does not seem safe to assume that it is of Tertiary age, although it vaguely recalls certain abnormal Tertiary intrusions.

The whole deposit, gravels, sands, and leaf-beds, may well be interpreted as a fluvio-lacustrine series, with a root-bed locally developed at the base.

E.B.B.

Sediments of Malcolm's Point (Sheets 36 and 44)

Mr. Starkie Gardner has described what he very reasonably regards as a reappearance of the Ardtun sediments on the south coast of Mull at Malcolm's Point west of Carsaig. The point falls within Sheet 36 of the one-inch Map, and has been dealt with by Dr. Harker in the Geological Memoir on that Sheet. It is also engraved on the margin of Sheet 44. Dr. Harker's account is reproduced below:

"The stratified deposits rise from sea-level at Carsaig Arches and may be followed continuously in the lower part of the cliff to Malcolm's Point and some half a mile beyond. Their position is thus very near the base of the basalt succession. Near the Arches they are only a few feet thick, consisting of bedded basaltic tuff with sandy material. The deposit rests on basaltic lava, and is covered by a dolerite sill. Followed past Malcolm's Point, the bedded group thickens, and there is more non-volcanic material mingled with the basaltic debris. At about 500 yards beyond the Point the thickness is some 12 feet, and there are isolated rolled pebbles of flint, which become more numerous, until the deposit may be described as a conglomerate. The last good section, near the limit of the map [i.e. Sheet 36], shows 15 feet of conglomerate, composed of rolled flint pebbles up to 4 or 6 inches in diameter, and passing up into a bedded basaltic tuff, surmounted by the same dolerite sill. Below the conglomerate is about 30 feet of amygdaloidal basalt."

Near Carsaig Arches, Mr. Gardner noted 2 feet of impure sand, with indistinct vegetable-markings at the base of the deposit at one place, and finer material with a thin band of lignite at another.

What may well be a continuation of the same outcrop is seen farther east at the foot of the cliff a third of a mile south-west of the Nuns' Pass (Sheet 44). The section reads as follows:

	Ft.
Lava	—
Sill	2
Sandstone	3

Sill	8
Highly vesicular basalt, probably lava	—

The sandstone is black and pebbly and to some extent made of basalt-fragments. A layer of flint-pebbles occurs near its base.

Sediments east of Carsaig (Sheet 44)

An addition to our knowledge of the Mull leaf-beds was made during the survey of the district. Fifty yards west of An Dùnan, about one mile east of Carsaig Bay, at the landward end of a little gully, there is exposed below high-water mark a lenticular bed composed of black shale, gritty sandstone, and a 3-inch coal seam, intercalated between basalts (see below). From the black shale, Mr. Tait obtained a small suite of plants rather badly preserved. They are discussed in the following chapter.

G.W.L.

Lignites of south-west Mull

A local association of very thin seams of lignite, or inferior coal, has been noticed above in connexion with the sediments described from Ardtun, Malcolm's Point, and east of Carsaig. Recurrences of the same type are rather characteristic of this south-west district of Mull, and have long attracted attention alike on account of the hopes of mineral wealth that they have given rise to and also because of their genuine scientific interest. As regards

their economic value, Sir Archibald Geikie has rightly said "they seem to be always lenticular patches"; moreover they are of inferior quality (Chapter 38).

Beinn an Aonidh, (Sheet 44)

The most important seam of lignite, or coal, occurs near the south coast of Mull, 40 ft. below a porphyritic lava, which serves as a convenient index in correlating the separate exposures. The coal is seen at the top of the cliff at Dearg Bhealach above Tràigh Cadh' an Easa', about 400 ft. above sea-level, and perhaps not very much more than this figure above the base of the lavas. The outcrop is shown on the 1-inch Map, and details will be given in Chapter 38 on Economics. At present it may be enough to mention that it can be traced as far inland as Airidh Mhic Cribhain, and that the same coal occurs on the western flank of Beinn an Aonidh, where in one place it is reported to have been 3 ft. in thickness. It is associated with carbonaceous shale, but is very irregular, and in addition often burnt by intrusions. Some graphitic sediment also occurs in one of the streams which drain the north-west slope of Beinn an Aonidh; but the mode of occurrence is doubtful, and the material obtained may have been xenolithic. E.M.A.

Carsaig (Sheet 44)

A coal-seam from this locality is referred to in the writings of Sir Archibald Geikie. It is exposed about 70 ft. up in the coastal cliff, below Sgùrr Mhòr immediately east of the important fault shown on the one-inch Map. The coal is here 18 inches thick, brownish-black in colour, dirty, soft, and friable. It is associated with several feet of sandy shale. An intrusion of columnar basalt cuts across the seam obliquely. The extent of the exposure is not more than 40 yds.; but about 200 yds. farther east, coal is seen on the raised-beach platform, unfortunately much broken by intrusions. Possibly the planty sediments mentioned above belong to the same horizon, but this point is not, as yet, definitely established.

G.V.W.

Shiaba (Sheet 43)

Another coal, sometimes worked for home-use by the Shiaba shepherd, is seen near the bottom of a waterfall called Eas Dubh, half a mile east of Shiaba Cottage near the southern margin of Sheet 43. It has for the most part a dull brown

colour, and seems of a parroty nature. In one place it is two feet thick but diminishes to 6 inches within a few yards. It dips steeply east and cannot be traced far.

Gowanbrae and Ardtun, Bunessan (Sheet 43)

In his description of the Ardtun leaf-beds, the Duke of Argyll refers to two outcrops of coal in the vicinity. One of these is shown on the one-inch Map at Gowanbrae. It was opened up in shallow pits, apparently on. the Duke's instructions, some time in the seventies. The trials must have proved unsatisfactory, as no attempt was made to carry the work further. Around the pits, which are still visible, there are pieces of dark shale With fragments of wood and traces of leaves, but no coal.

The other outcrop is clearly visible where shown on the one-inch Map close to the shore of Loch Scridain, south-east of Tòrr Mòr<ref>The Tòrr Mòr referred to is the small hill of that name between two and three miles north-east of Bunessan, and not, as has been erroneously stated, 5 miles east of Ardtun.</ref> The exposure was recently opened up, and from 6 inches to 1 ft. 2 in, of coal were seen resting on a reddish-brown clay containing recognizable fragments of basalt. Most of the seam was very inferior with no more than 6 inches of bright coal. A columnar basalt-lava serves as roof, and has its under surface apparently chilled, and also corrugated into subparallel waves.

C.T.O

Macculloch's Tree (Sheet 43)

A thin seam, or streak, of lignite occurs in places at the base of the lava which envelopes Macaulloch's well-known upright tree (p. 111).

A very few other instances of the same kind are mentioned in the literature of the subject, but were not located during the geological survey of the district.

E.B.B.

Other sedimentary intercalations

The Ardtun, Malcolm's Point, and Carsaig outcrops, described already, stand almost alone in supplying evidence of non-volcanic detritus having entered the district during the accumulation of the lavas. Three other cases are known; two of them from southwest Mull are sufficiently described elsewhere (pp. 56, 115); the third is represented by a minute outcrop of reddish yellow sandstone, from one to two feet thick, intercalated between basalt- flows on the north shore of the Sound of Mull, south-east of Loch Aline and a third of a mile west of the site of Ardtornish House (Sheet 44). It is quite barren of fossil-remains, and its position is low in the basalt-series, perhaps between the first and second flows.
G.W.L.

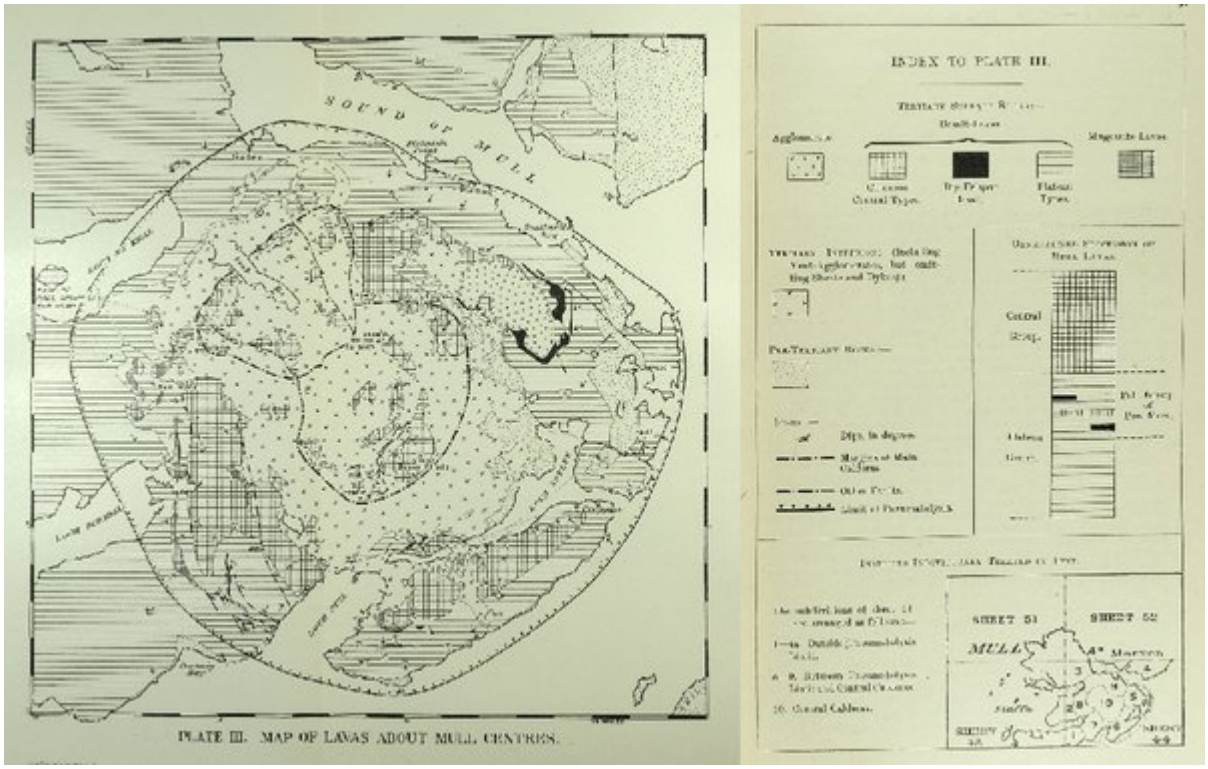
In the descriptions of the basalt-lavas which follow, reference will be constantly made to thin layers of red bole often met with between flows in the district outside the Limit of Pneumatolysis of (Plate 3), p. 91. Inside this limit, such red volcanic muds soon fail for one reason or another. Attention may be directed, however, to a good example of a sedimentary intercalation unusually high up in the sequence. It occurs a little above the Ben More mugearite-zone, about half a mile due south of Ben More summit (Sheet 44). It consists of 8 to 9 ft. of sediment, partly breccioidal, partly a carbonaceous shale with obscure plant-remains. Another sedimentary intercalation is known in the same general district exposed in a stream cast of Beinn nan Gobhar. it seems to overlie a bostonite shown on the one-inch Map, and its nature will be discussed more precisely in this connexion (Chapter 14). Its thickness is about 5 ft.

E.M.A.

Very little sediment accumulated in the south-east caldera of (Plate 3) (p. 91), although there is good reason to believe that it was often occupied by a lake during pauses in the accumulation of the Central Type of lavas (Chapter 5). There is,

however, an interesting exposure of volcanic sand and mud which may be referred with some confidence to this period. It occurs on the north-east face of Beinn Bheag, north of Beinn Talaidh, and is lettered i on the one-inch Map (Sheet 44). It is greatly cut by the Late Basic Cone-sheets of Chapter 28, but can be seen to be flatly bedded and to lie upon the chilled top of a small-felspar dolerite, which in character strongly recalls pillow-lavas well represented in the same general district. Much of the deposit consists of recognizable mineral-debris, felspar and augite, some of it remarkably fresh and of a character such as the pillow-lavas, or corresponding tuffs, might readily supply (S18653) [NM 6340 3561], (S18667) [NM 6292 3589].

E.B.B.



(Plate 3) Map showing the distribution of lava-types and the limit of pneumatolysis