GRIBUN

OS Grid Reference: NM454328–NM451332

Introduction

It was the Gribun Chalk that caught the imagination when first recorded byJudd (1878). This startlingly white bed, close to the roadside in the Gribun ‘boulders' (Figures6.6 and 6.7), contrasts with the dark lavas of Tertiary age on the surrounding cliffs. Prior to Judd, the presence of Mesozoic rocks in this part of Scotland had been largely dismissed as irrelevant to Scottish geology. It is now recognized that the history of movement on the major tectonic structures of the Highlands, the Great Glen Fault and the Moine Thrust–Camasunary Fault (Figure 6.2), has also to consider the evidence provided by the Upper Cretaceous rocks, especially at Gribun and the local network of sections on Mull.

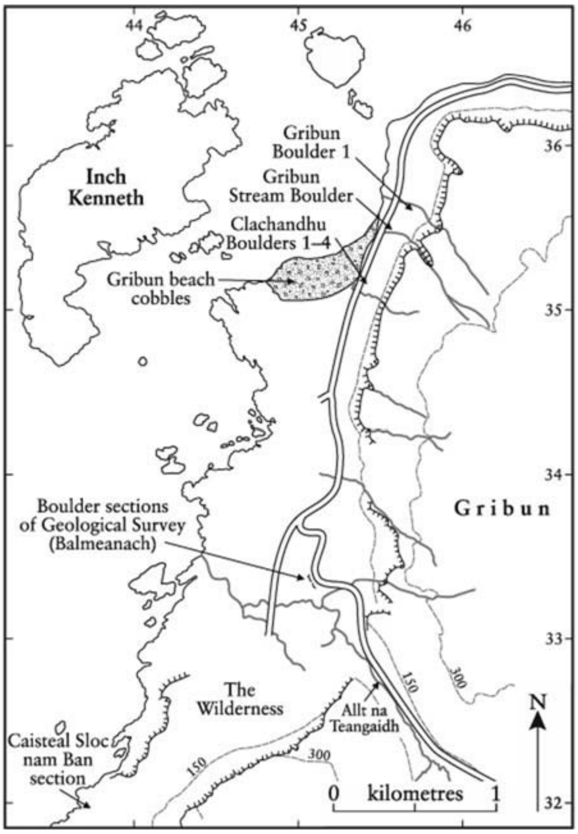

Figure 6.6: The Upper Cretaceous GCR sites at Gribun, Mull.

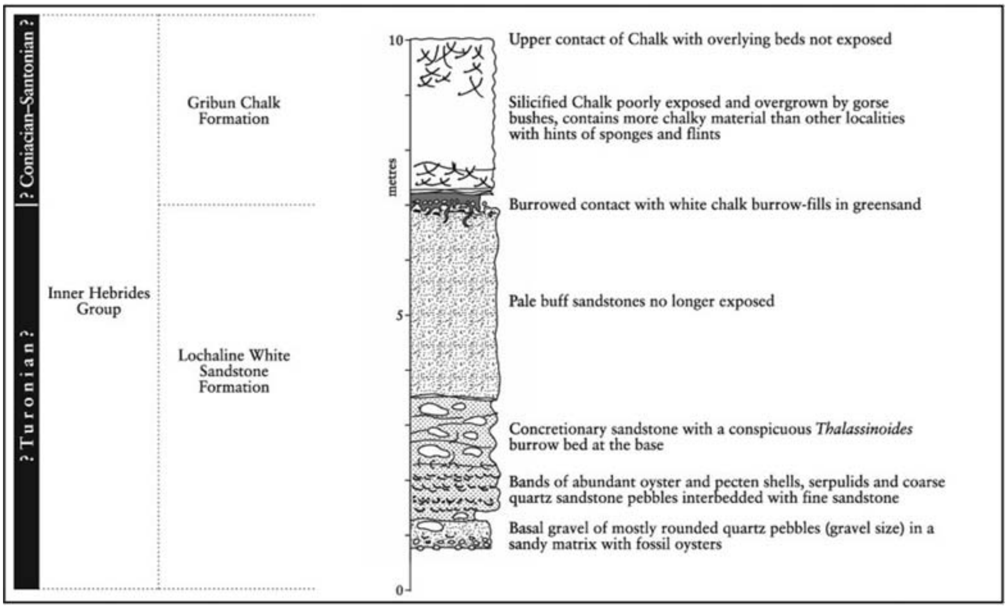

Figure 6.7: Gribun landslip section, (sometimes known as the 'Gribun Boulder'– Gribun Boulder 1, in the present volume).

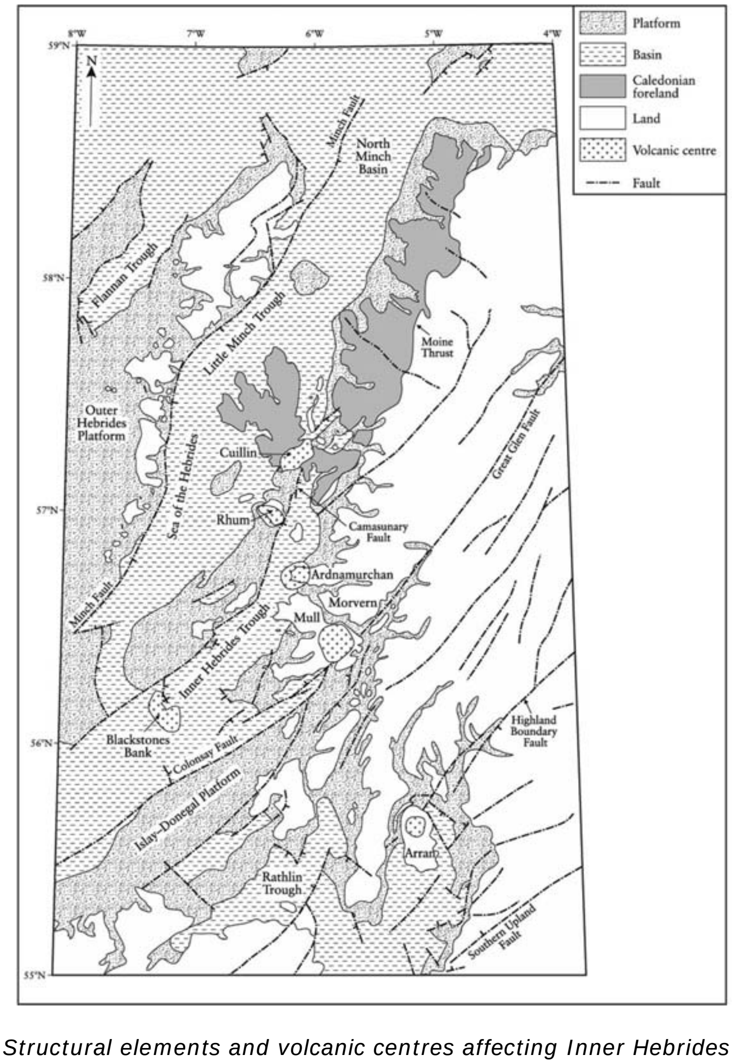

Figure 6.2: Structural elements and volcanic centres affecting Inner Hebrides Upper Cretaceous sedimentation.

Gribun is a relatively low-lying agricultural area of fields and pastures on Mesozoic sediments (mainly Triassic), with low sea cliffs and marine rock platforms to the west, contrasting with the vertical stark, black, Tertiary basalt cliffs forming the high ground to the east. Ancient landslips litter the base of the cliffs bringing down isolated remnants of the thin Cretaceous sediments, capped by basalts, to low levels adjacent to the road. The steep torrents flowing from the high plateau above sometimes bring down spreads of coarse debris (mostly boulder size) to cover some sections (fanglomerates). At other times the torrents erode into older fans revealing the underlying rock, providing generally small and incomplete sections. Some exposures recorded in earlier times, for example on the beach near Clachandhu, have remained buried for many years and have not been re-exposed (1998–1999).

The entire Gribun area has been selected for the GCR. The site includes the whole Mesozoic section, which comprises thin remnants of parts of the Trias, Jurassic and Upper Cretaceous deposits resting on Moine Schists. No Lower Cretaceous rocks have been recorded. The Upper Cretaceous succession occurs in four main groups of exposures; Group I, about 10 m thick, is at the northern end of the site in landslipped ‘boulders' near Clachandhu (Figure6.6). Group II is again in landslipped (but rolled) boulders adjacent to, and below, the road at Balmeanach. Group III is the most complete section, about 18 m thick, at Allt na Teangaidh, forming the walls of a narrow defile cut by a stream beneath the lavas. Group IV exposures of ‘chalk' are present to the south, in The Wilderness, at Caisteal Sloc nam Ban (Figure6.6).

Description

Judd (1878) was the first to recognize Upper Cretaceous deposits in the western Highlands and to describe the succession at Gribun. He additionally identified a section on the island of Inch Kenneth (Figure 6.6; Figure 6.15c, p. 450) where he thought Upper Greensand rested directly on his ‘ *Poikilitic Series* ' or Trias (1878, p. 732) and considered that the lower part, forming a conglomerate of quartzitic pebbles, was derived directly from underlying gneisses (Moine Schist). The upper part of the Upper Greensand comprised ‘ …ordinary glauconitic sands' with abundant exogyrine oysters, serpulids and sponges characteristic of these beds that he regarded, on the basis of sections at Carsaig (Figure 6.1), as equivalent to the English Lower Chalk. Judd also recognized that the ‘Scottish Chalk' was largely siliceous and ‘ … crushed out from beneath the overwhelming masses of basaltic lava that cover all the secondary (i.e. Mesozoic) strata… '. Judd had thin sections of the siliceous chalk made and analysed by Professor T. Rupert Jones (in Judd, 1878, p. 739), who identified foraminifera (sample No. 4, poorly preserved *Globigerina*), inoceramid prisms and sponges. In particular, Judd emphasized the ‘pseudomorphism' of the original calcareous chalk by silica. He was aware of Sorby's work, which had shown the extremely fine-grained, coccolithic nature of chalk (see Chapter 1). On the basis of an overview of the Scottish Chalk at many localities (seeBeinn Iadain GCR site report, this volume), Judd equated this part of the succession with the Upper Chalk of England, particularly because of the presence of inoceramid prisms (‘similar to beds around London at Charlton near Woolwich in the *Inoceramus*-zones', 1878, p. 739).

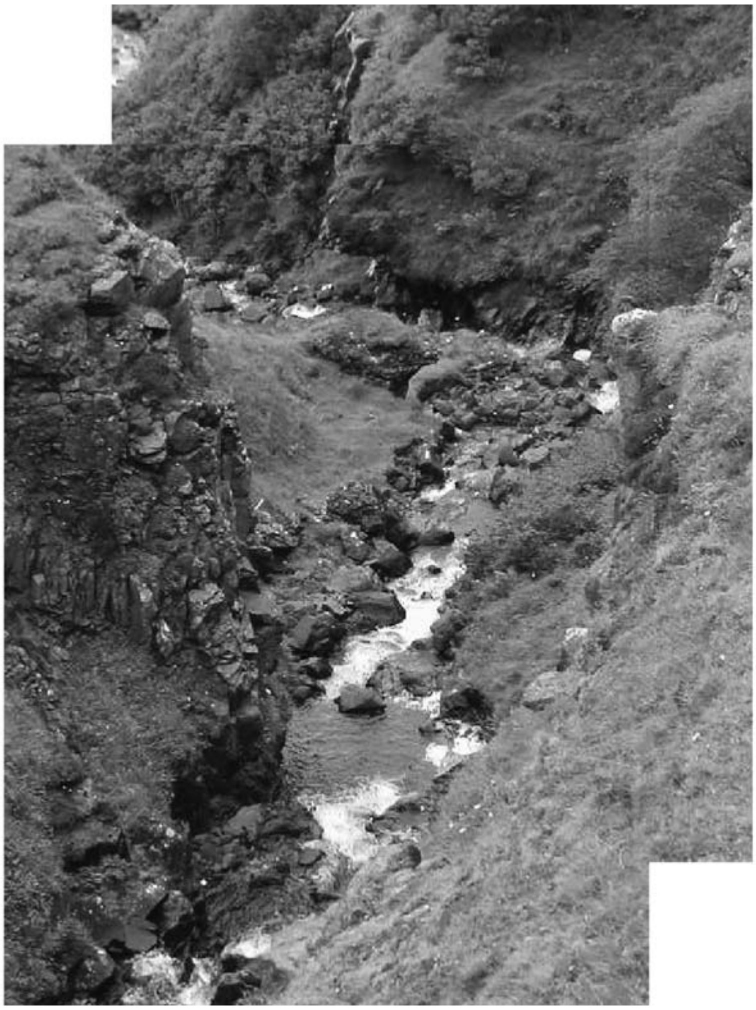

Figure 6.15: (a, b, c) Allt na Teangaidh, Gribun, Mull, looking north-west from the pass above the waterfalls to the Island of Inch Kenneth where a thick succession of Triassic sediments is present. (Photomosaics: R.N. Mortimore.)

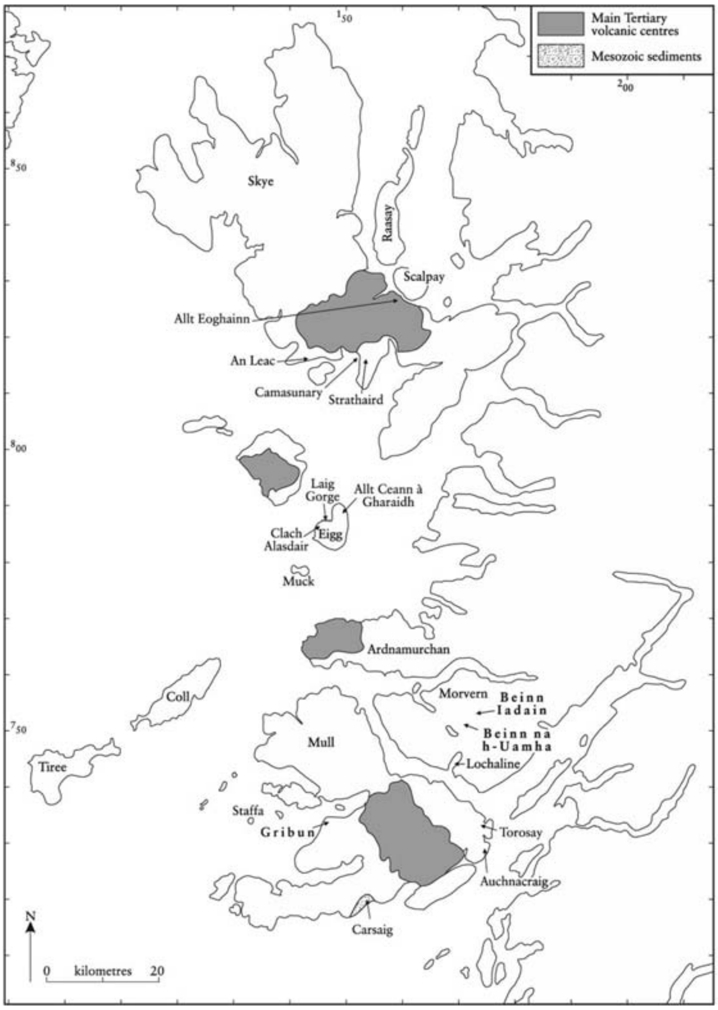

Figure 6.1: Main Upper Cretaceous localities in the Inner Hebrides Province; GCR sites are in bold type face.

The [British] Geological Survey (Bailey *et al.*, 1924; Lee and Bailey, 1925) could not agree with Judd on the occurrence of Upper Cretaceous strata on Inch Kenneth, re-interpreting these as Triassic in age, but recognized his Upper Greensand and Chalk at several places within the Gribun GCR site. Bailey *et al.* (1924, pp. 56–7) considered much of the Chalk to be *remanié* Cretaceous and possibly of Tertiary age.

The exposures of Upper Cretaceous strata at the Gribun GCR site illustrate lateral change in the succession typical of the entire Inner Hebrides outcrop. The sections form discontinuous small exposures, mostly disturbed by landslipping, over a distance of some 6 km north to south. It is uncertain whether all the rocks described are Cretaceous in age or whether some of the reworked silicified chalk and flint conglomerate, sandstones and mudstones are Early Tertiary (Palaeogene) in age. It is also uncertain whether the first lavas are latest Cretaceous or earliest Palaeogene in age. There is, at present, no adequate field evidence or dating to determine the ages of all the rocks. The first lava flow throughout the area is conspicuously columnar jointed and is considered to be the same as the Staffa flow forming Fingal's Cave, which can be seen on a clear day from Gribun.

Group I exposures: the Gribun Boulder 1 (NM 457 357)

The first Gribun section is in low cliffs east of the road on the south side of the first steep mountain stream south of 'The Bungalow' (Figures 6.6 and 6.7). The stream passes in a culvert under the road debouching in the centre of the beach. This so-called 'boulder' is in fact a series of landslip masses, broadly retaining stratigraphical integrity and comprises four small exposures within one outcrop. The exposures are all uphill, some 50 m east of the road and the dip of all the strata exposed in these landslip masses is consistent and about 10° – 20° to the east. The first exposure nearest the stream is hidden under a mass of gorse bushes but can be dug out to reveal the basal contact of the Gribun silicified chalk with the underlying glauconitic and slightly phosphatic greensand. The contact appears to be burrowed with white ‘chalk' occurring in lenses or millimetre diameter burrow-fills in the topmost greensand. It is a complex contact with some of the chalk appearing to be in the form of reworked fragments.

The upper beds of the Gribun Chalk Formation were overgrown at the time of writing and would require extensive excavation, but a mass of white ‘chalk' is still visible some 15 m south and 5 m higher towards the crest-line of the landslip masses. This second exposure does not show the top contact of the Gribun chalk with the red mudstones above; this contact is seen best in the Gribun Stream Boulder and the Clachandhu Boulders (see below). Nevertheless, real sponge and burrow-replacement flints do seem to be present in this Gribun chalk exposure. There are also hints of other shell fragments including ghosts of silicified inoceramid shells, echinoid spines, and sponges such as*Porosphaera*. Part of the difficulty with interpretation is the intense fracturing of the chalk by a joint set (10 joints per 100 mm, trending east) and the degree of alteration (silicification) of the whole mass. Some fragments ‘appear' to be quite chalky! There is a hint of a stratigraphy in the detailed structure (layers of dark black flaser marly wisps) and colour changes from dark grey to fawn to pale green upwards. Millet-seed sand grains fill the spaces between ‘silicified chalk' fragments and are particularly evident in the fawn coloured and uppermost parts of the succession.

Below this highest chalk exposure, but not in a continuous section, is the third exposure, a sandstone block of medium to fine ‘white' sands with oyster-shell debris bands and calcareous, weathered-out concretions. The fourth exposure or ‘boulder' is the lowest and is also a sandstone, again not in a continuously exposed section with the higher blocks. This lowest exposure contains a conspicuous basal pebble bed of rounded quartz pebbles in a sandy micaceous bed, also containing oyster-shell bands. It is assumed that the last three exposures, from the uppermost chalk to the basal pebble bed, represent a continuous outcrop, albeit only partially exposed, and that measurements across the dip therefore, give a true thickness for the total section (Figure 6.7).

These four exposures together comprise the ‘Gribun Boulder' section ofBraley (1990) and were measured during the 1998 field season and re-checked in 1999.

Group I exposures: the Gribun Stream Boulder (NM 456 355)

A more complete, well-washed Gribun Chalk Formation section, with overlying red mudstones, is present in a large ‘boulder' in the bed of the second mountain stream south of ‘The Bungalow' (Figures 6.6, 6.8–6.11). This stream also runs under the road in a culvert and debouches onto the beach, carrying numerous blocks of the eroded, silicified Gribun Chalk Formation, which are spread across the beach at this point. The section is some 50 m upstream from the culvert. During the winter of 1998–1999 the stream power was sufficient to expose (or re-expose) this section, which was covered by boulders in 1998. The strata in the ‘boulder' appears to dip in the same direction to the east at about the same angle as the other Group I exposures, suggesting that stratigraphical integrity has been retained.

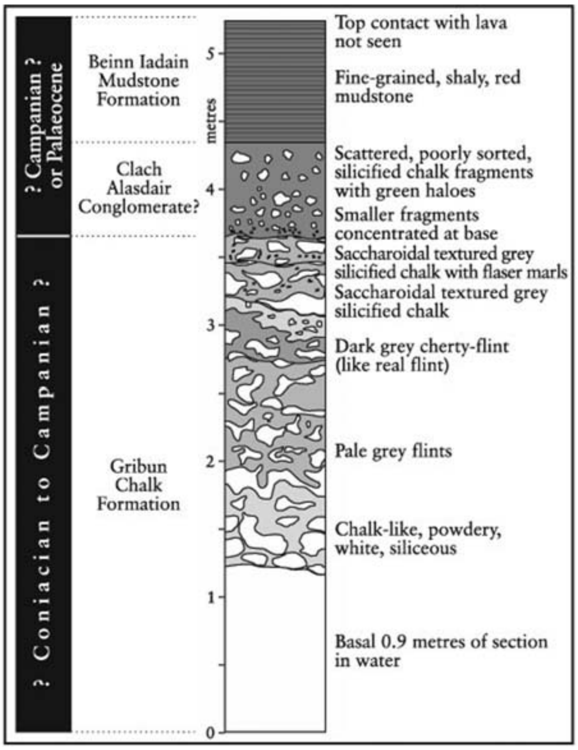

Figure 6.8: The stratigraphy of the Gribun Stream Boulder, which exposes beds stratigraphically above Gribun Boulder 1.

When measured in July 1999 (Figures 6.8 and 6.9), the basal beds of chalk were underwater but some 4.0 m of Chalk and 1.0 m of red mudstones were recorded. As hinted at in the Gribun Boulder 1 description above, a stratigraphy within the Chalk is evident, based on changes in colour and fine structure. Again the intense, easterly striking joint set (10 per 100 mm) and the alteration/diagenesis make interpretation difficult. The basal beds exposed, ¢. 0.50 m thick) were very 'chalk-like', being white and powdery. These grade upwards into pale grey, cherty chalk (0.75 m), then dark grey cherty chalk (0.4 m, like real flints), overlain by a 0.25 m thick bed of fawn coloured, saccharoidal cherty chalk. The saccharoidal structure is imparted by millet-seed quartz sand grains between the more cherty chalk with sponge flints, and the whole layer is silicified. This is overlain by a 0.20 m thick unit of silicified chalk with wavy interlacing dark marly wisps (griotte or flaser texture) with hints of fossil fragments in the marly wisps. The flaser layer grades up into a conglomerate of reworked silicified chalk fragments (size ranges from 130 × 50 mm to 10 × 5 mm and sand-size). Although poorly sorted, there is a crude reverse grading with the largest fragments forming a 100 mm-thick layer on top of the bed. There is then a 0.25-m thick layer of more scattered fragments (some rounded, some angular) in a sandy matrix, the whole turned red and very hard. Many of the fragments have green haloes. The uppermost exposure comprises 0.6 m of fine micaceous, shaly, red mudstone.

Figure 6.9: The Gribun Stream Boulder illustrating the stratigraphy of the Chalk and its contact with the overlying sandstones, conglomerate and mudstones. Note, on figure (b) the mudstone is altered, hard (red) and shaly; the sandstone is altered, hard and red, with flint/chalk conglomerate; the greensands have partly turned red forming a flaser structure in the topmost chalk; the cherty chalk is fawn-coloured with saccharoidal

silicified, millet-seed sand-fills around the chalk; the dark grey flinty chalk looks like typical flint. (Photos: R.N. Mortimore.)

Many small boulders and pebbles of the Gribun Stream Boulder section are found lower down the stream bed and on the beach. These have been studied in detail because the clean fragments yield fossils and rock textures not easily studied elsewhere. The stratigraphy of the silicified chalk fragments is easily reconstructed once the stratigraphical colour changes in the main boulder have been determined. The list of fossils from these loose blocks is significant and includes the sea urchin *Salenia*, many long echinoid spines, well-preserved sponges including the globular calcareous sponge *Porosphaera*, inoceramid bivalve fragments and brachiopods. The total assemblage is indicative of a Late Cretaceous (post-Turonian), probably Santonian, age. Most of the fossils were found as silicified fragments in the dark flinty layer and the pale fawn saccharoidal layer. The textures in the silicified chalk illustrated typical burrow-replacement flint formation, especially in the darker beds, which included the trace fossil *Zoophycos*, suggesting that this succession was once a typical chalk-like deposit. Several boulders of the wispy, flaser-textured bed, in places stained deep red, confirm the presence of this texture. Other boulders include the change downwards to greensand at the base of the chalk.

Group I exposures: the Clachandhu Boulders

Some 200 m south of the Gribun Stream Boulder section is a holiday cottage (Clachandhu Cottage), behind and south of which, and only some 20 m east of the road, are three boulders of Gribun Chalk Formation (Figures 6.12 and 6.13), all with red mudstone on top of the Chalk. All of the Clachandhu Boulders show the same intense jointing seen in the Gribun Boulder 1 exposures and the Stream Boulder sections in the silicified chalk. The internal stratigraphy of the chalk in these boulders is also similar.

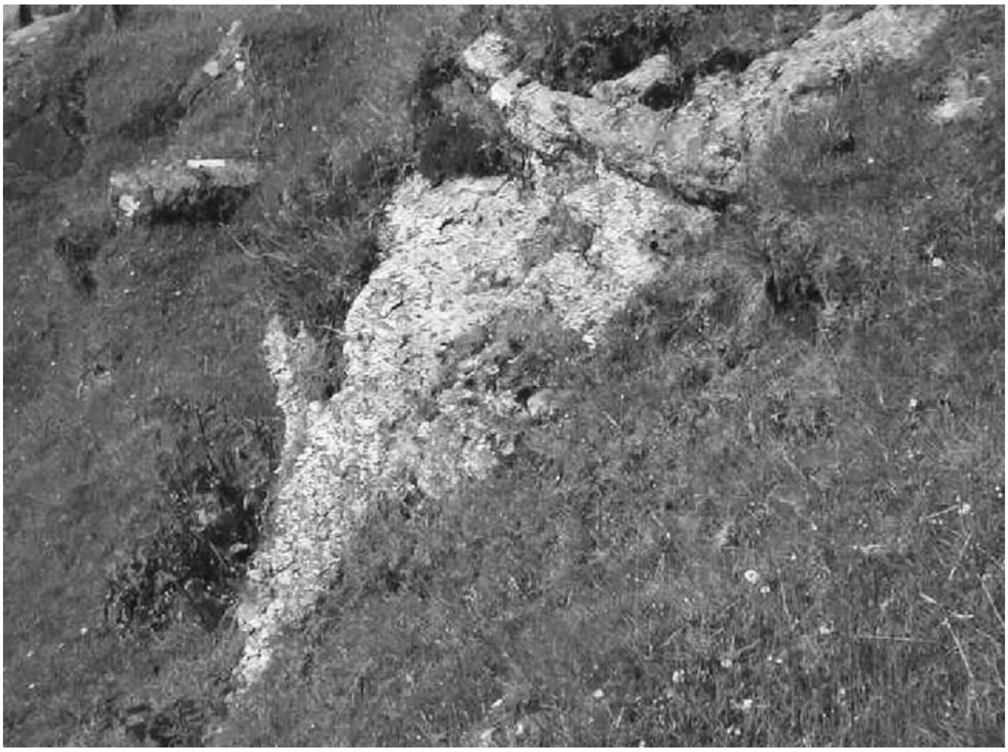

Figure 6.12: Group I exposures. (a) Northern end of Gribun Boulder 1 (arrowed). (b–f) The Clachandhu Boulders, behind Clachandhu Cottage, at the northern end of Gribun, Mull; (b) Clachandhu Cottage, with the Clachandhu Boulders behind; (c) The First (northernmost) Boulder (Clachandhu Boulder 1), immediately behind cottage; (d) the Second (central) Boulder (Clachandhu Boulder 2) showing the Chalk–red shale contact; (e, f) The Third (most southerly) Boulder (Clachandhu Boulder 3), adjacent to fence showing the contact between greensands and silicified chalk. (Photos: R.N. Mortimore.)

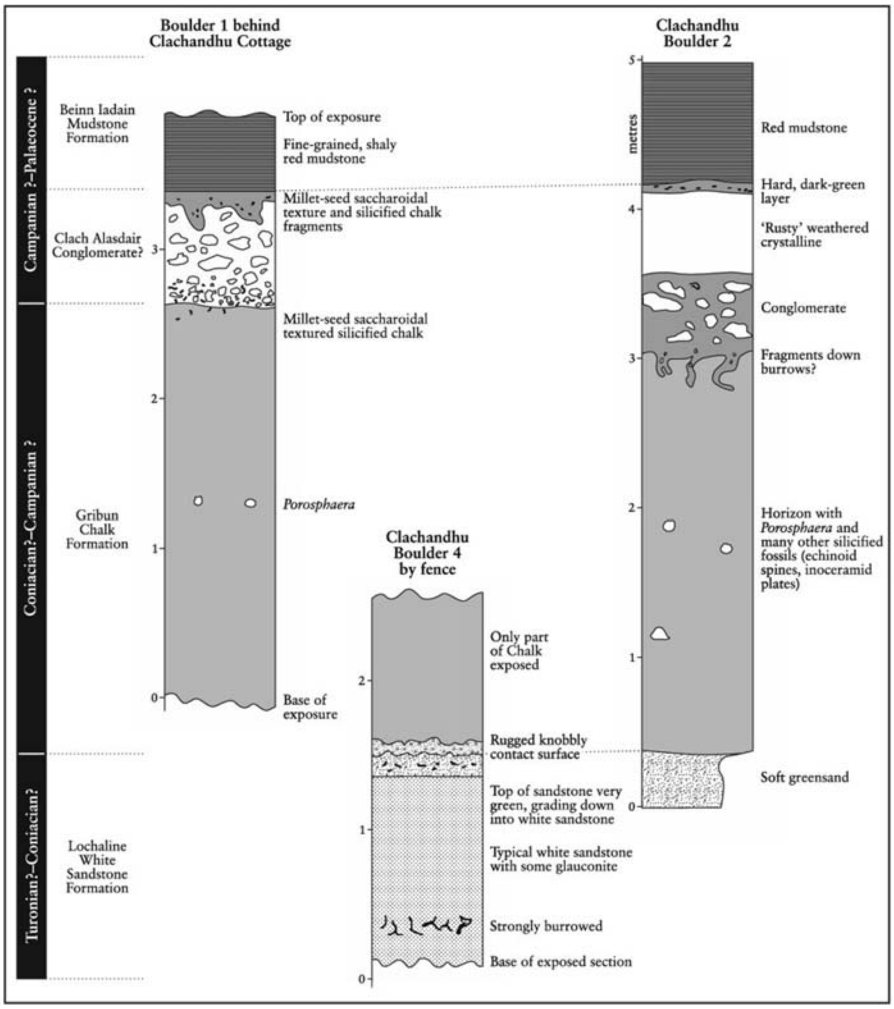

Figure 6.13: The stratigraphy of the Clachandhu Boulders at Gribun, Mull. Details of the beds are not as clear as in the Gribun Stream Boulder.

First Boulder behind Clachandhu Cottage (NM 4550 3533): This lichen-covered boulder (Clachandhu Boulder 1) exposes 1.05 m of silicified chalk in the lower part. Cavities in the middle of this section contain fossils, and a number of examples of the sponge *Porosphaera* are present as round, silicified balls. The 1.05 m of chalk is overlain by a 0.30 m unit of silicified chalk-conglomerate in a millet-seed, quartz-sand matrix. The matrix becomes a glauconitic greensand towards the top. Red, shaly mudstone (0.2 m preserved), rests on the greensand.

Second Boulder behind and just south of Clachandhu Cottage (NM 4550 3531): The base of the Second Boulder (Clachandhu Boulder 2) is heavily undercut by weathering, possibly representing a softer chalky layer. Above this softer unit is 1.10 m of silicified chalk with *Porosphaera* in the middle part and other unidentified fossil fragments in the lower half. The top of the silicified chalk appears to contain a wispy, marly (flaser) layer, and to be burrowed, with debris and fragments from the overlying conglomerate filling the apparent burrows. The conglomerate is about 0.2 m thick, overlain by a rusty-weathered crystalline bed, 0.25 m thick, with a 0.03 m thick, hard greenish bed at the top, followed upwards by 0.30 m of red, shaly mudstone.

Third Boulder, just south of the Second Boulder, against the fence (NM 4550 3528): The Third Boulder (Clachandhu Boulder 3) exposes white sands, greensand and silicified Chalk. The top of the Chalk is covered by boulders of basalt. A thin bed of almost typical white sandstone forms the base of the exposure. A strongly burrowed surface is present 0.10 m above the base and the overlying 0.45 m of sandstone becomes a progressively more glauconitic greensand upwards. At the top of this sandstone is a thin layer of beautifully rounded quartz grains with some pebbles set in very green greensand. The contact with the overlying Chalk is not clear. In places it seems to be sharp, with no mixing of sediments, but when traced laterally and cleared of vegetation there is some evidence of mixing and possible burrowing. Black, thin marly wisps appear to be present at the base of the Chalk. The contact may be partly disturbed by the landslip effects. Only 0.5 m of Chalk is exposed above this contact.

Group II exposures: Balmeanach Boulders (NM 451 333)

A series of large air-weathered boulders are present downslope and to the west of the sharp bend in the road downhill from Balmeanach Cottage (cottage beside the road, Figures6.6 and 6.14). Unlike the Gribun Group I exposures, the Balmeanach Boulders are not in stratigraphical order, have rolled in all directions, and lack stratigraphical integrity. A crude stratigraphy can be reconstructed by recognizing the various lithological units identified within the Gribun Group I boulders and at Allt na Teangaidh.

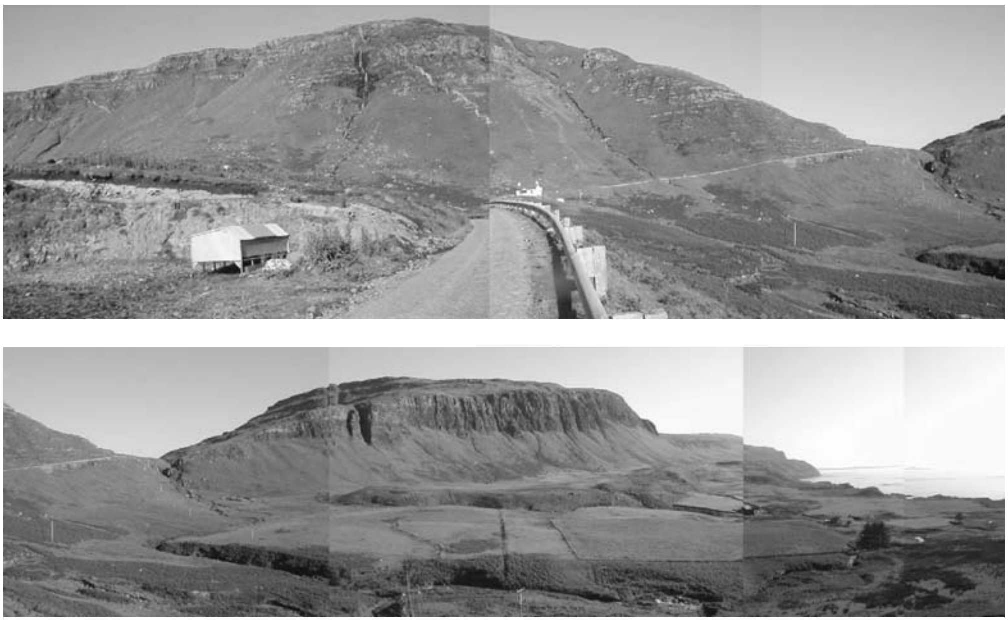

Figure 6.14: Panoramic view looking east over the southern end of Gribun and The Wilderness. The Mesozoic rocks form the flatter farmland in the foreground. Tertiary basaltic lavas form the high crags and plateaus and the Upper Cretaceous deposits are found in intermittent slivers beneath the basalts. (Photomosaic: R.N. Mortimore.)

The Balmeanach Boulders are important because of the quality of the weathered-out fossils, particularly the *Rhynchostreon* oysters and the serpulids in sandstones (Figure6.17b, p. 452) which include the calcareous nodular and conspicuous*Thalassinoides* trace fossil beds. No Chalk boulders are present but the evidence for the continuation of these sandstones beneath the Chalk in the wider Gribun area is useful.

Figure 6.17: Details from the Gribun sandstones. (a) Base of the Allt na Teangaidh section; greensands pass up into laminated beds and the calcareous nodular bed. (b) Abundant Rhynchostreon oyster horizon in a Balmeanach sandstone boulder. (Photos: R.N. Mortimore.)

Group III exposures: Allt na Teangaidh (NM 453 328)

The mountain stream called Allt na Teangaidh runs across the basalt lava plateau towards the north-west, parallel to the road. At the edge of the plateau it cuts a narrow defile through the basalts and underlying Cretaceous rocks (Figures 6.14 and 6.15), providing the most complete section of these sediments in Gribun (Figure 6.16). At the base is a pebble bed of rounded mostly quartzitic, gravel-sized pebbles set in greensand (Figure 6.17a). A soft bed of conspicuously dark green, glauconitic sand occurs above the pebbles at the base of the present exposure (1998) and contains abundant large shells of the oyster *Amphidonte*. More greensand below this bed was recorded by the [British] Geological Survey (Lee and Bailey, 1925, p. 121). The greensand is followed by a unit of sandstone, nearly 1.0 m thick, which contains conspicuous laminations, abundant oyster-shell beds and many serpulids. A conspicuous 1.0 m thick bed of concretionary sandstone with *Thalassinoides* (branching burrows) may form part of the underlying unit.

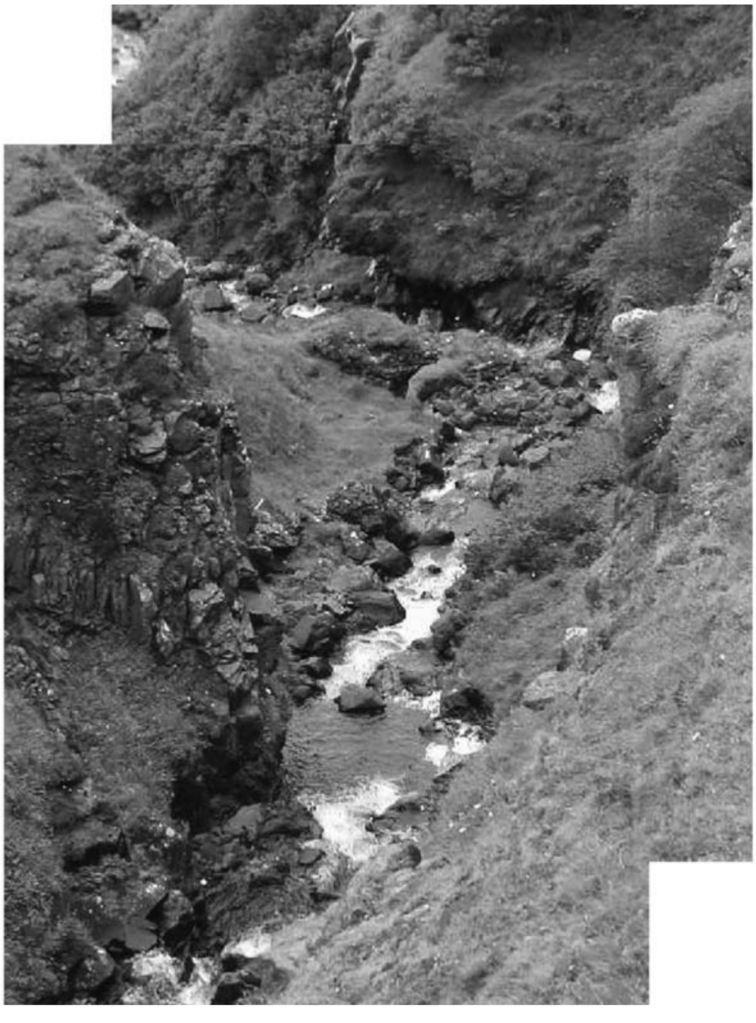

Figure 6.15: (a, b, c) Allt na Teangaidh, Gribun, Mull, looking north-west from the pass above the waterfalls to the Island of Inch Kenneth where a thick succession of Triassic sediments is present. (Photomosaics: R.N. Mortimore.)

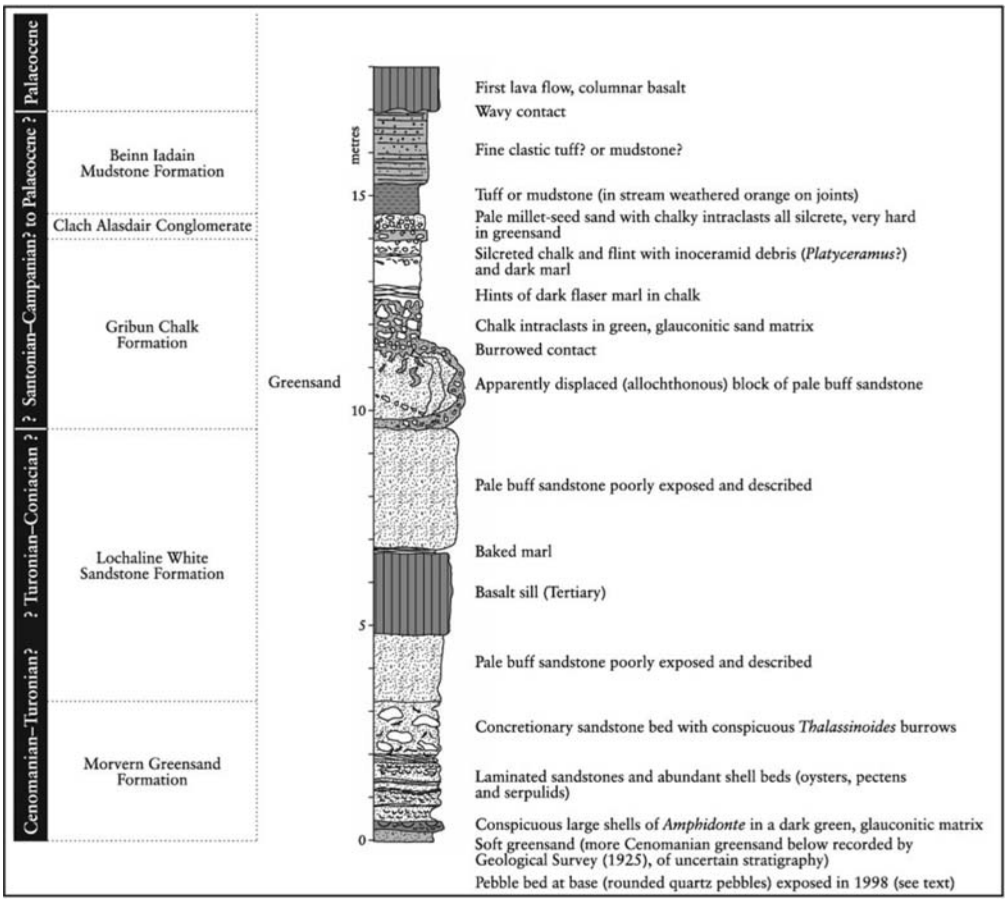

Figure 6.16: The Gribun Group III exposures, Allt na Teangaidh stream bed, Mull.

Above the concretionary bed is a massive unit of pale buff sandstone, intruded by a sill, which forms steep walls where the stream has cut through this narrow, partly overhanging section of the defile. The exposure is covered in grass and water-weeds. The field relations of the next unit up are obscured by the stream bed but a block of the pale buff sandstone appears to be surrounded by glauconitic greensand and the greensand appears to fill burrows into the buff sandstone. Angular 'flint' fragments in the greensand also surround the block. The greensand passes up through a chalk-flint intraclast bed with greensand surrounding the clasts, into a more continuous bed of 'fragmented' siliceous chalk nearly 2 m thick. Many sedimentary structures are present in the sandy, glauconitic fills between the angular 'chalk' fragments. Within the more coherent part of the 'chalk' are other possible sedimentary structures including flaser-like wispy marly layers (partially stylolitic) and a concentration of 'flinty' fragments containing inoceramid bivalve shell debris.

A thin greensand unit (about 0.2 m thick) overlies the chalk and is partly piped down into the top of it. This layer also contains 'flint' intraclasts and these continue upwards into a bed of pale sandstone (millet-seed sands?). The final complex unit beneath the lavas contains two beds (Figure 6.16), the first in the stream bed is a dark purple unit of fine mudstone(?) with orange-stained joints, and this is overlain by a paler purple bed, possibly a mudstone or a volcanic tuff.

Group IV exposures: Caisteal Sloc nam Ban (NM 431 312)

A long walk from Balmeanach Farm south through The Wilderness (Figure6.14), past McKinnon's Cave, leads to a stream section with several waterfalls. The best route is to keep to high ground and not follow the cliff top. Just south of McKinnon's Cave is a fine section in Triassic rocks where several streams join before forming a spectacular waterfall over the sea cliff. Equally spectacular sills and dykes are present, cutting through the sediments. This location is best identified by the two huge gullies or clefts in the basalt cliffs, forming the backwall to The Wilderness, down which the streams tumble from the plateau above. There are no Cretaceous or Palaeogene deposits here and the Caisteal Sloc nam Ban section is about one kilometre farther south.

In contrast, the Caisteal Sloc nam Ban section comprises only one stream emanating from the plateau above. Below the point where the stream falls over the lowest of the basalt lavas there is a wet, weed- and algal-covered stream-bed section, partially buried by boulders, revealing a 2 m thick flint conglomerate of red and green coloured 'real' flint cobbles and pebbles set in a very hard, cemented matrix. This flint conglomerate is separated by some 20 m from the next exposure below (Figure 6.18) by the boulder-strewn stream-bed. The stream then crosses coarse- to medium-grained, cross-bedded white sandstone that also forms the lip of the next waterfall (Figure 6.18). In the undercut beneath the waterfall is a spectacular chalk conglomerate comprising lenticular lenses of chalk fragments with quartz pebbles, interbedded with coarse sand and gravel lenses (Figure 6.19). Beneath the chalk conglomerate is a 1.40–1.50 m thick greensand with thin wedge-shaped lenses of coarser white chalk fragments, underlain by two black shale seams. Below these shale seams are greenish-coloured Triassic coarse sandstones with lenses of white fragments that are derived from the Triassic cornstones.

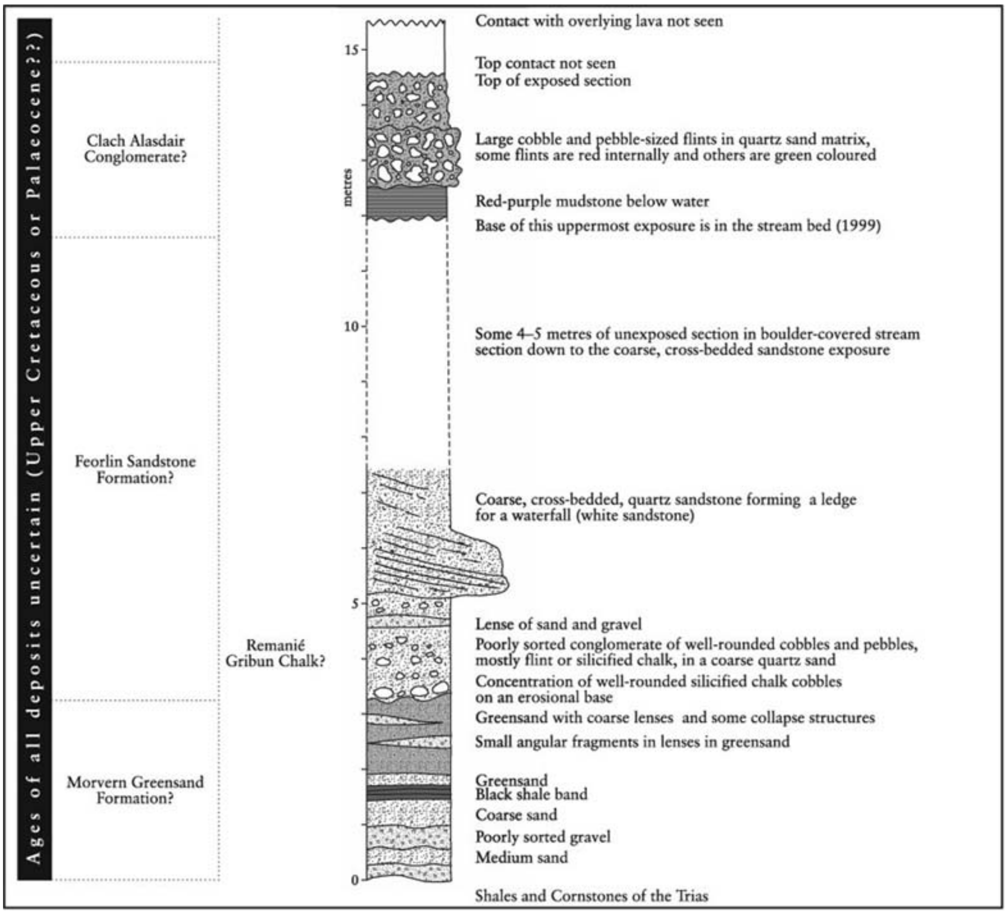

Figure 6.18: The Caisteal Sloc nam Ban section in The Wilderness, Mull. Section drawn as a weathered profile of the rock exposure, not as a sedimentological grain-size profile.

Figure 6.19: The most southerly Upper Cretaceous? or basal Palaeocene section in Gribun at Caisteal Sloc nam Ban, Mull, showing two conglomerates separated by a thick 'white', millet-seed sandstone unit. The lower conglomerate is a mixture of silicified chalk fragments and well-rounded quartz pebbles and cobbles, all poorly sorted, and containing sand/gravel lenses. The upper conglomerate is primarily composed of flints including red flints. (a, b, c) Upper section beneath Tertiary basalts, the poorly sorted flint conglomerates including red and green coloured flints. (d, e, f) Lower section with the waterfall on the white sandstone and the under-cut section in a silicified chalk quartz sand and gravel deposit, which thickens in a wedge from beyond the waterfall towards the geologist. Many Upper Cretaceous fossils are present in the reworked chalky material. (Photos: R.N. Mortimore.)

The whole of the conspicuous chalk conglomerate forms a lense half a metre thick on the south bank of the stream and two metres thick on the north side.

Biostratigraphy

There are no diagnostic macrofossils recorded from any of the Gribun sections but the large *Amphidonte* in the basal greensands at Allt na Teangaidh suggest a (Middle?) Cenomanian age for these lowest beds (see discussion below). Serpulids within the basal beds of the Lochaline White Sandstone Formation suggest a Late Cenomanian Plenus Marls Bed 4 age. Nannofossil evidence from the silicified chalks in the Gribun Stream Boulder suggests a possible Santonian–Early Campanian age for at least part of the Gribun Chalk Formation. This dating is supported by the record of the benthic foraminifera *Gavelinella thalmanni* (Brotzen) and *Stensioeinena exsculpta gracilis* Brotzen (Rawson *et al*., 1978 p. 56). These two species both have a late Santonian–Early Campanian range but their co-occurrence points more to an Early Campanian date (H. Bailey, pers. comm., 2001). On this evidence, the main mass of the Lochaline White Sandstone Formation would then be latest Cenomanian, Turonian or Coniacian in age.

It would not be possible to interpret the Gribun sections, fully or reliably, without comparing them with sections elsewhere on Mull and on the mainland in Morvern.

The Gribun sandstones

Parts of the Allt na Teangaidh and the Clachandhu Boulder sections can be correlated with sections at Carsaig on the south coast of Mull (Figure 6.27, p. 462, Figure 6.34, p. 471). Greensands at the base of the sections containing probably Cenomanian age *Amphidonte* are common to both areas. At Carsaig (Figure 6.20), a number of exposures (Figures 6.21–6.25) show great variation in thickness and structure of the greensands. In the big coastal cliff localities towards Malcolm's Point, rhythmically bedded marly layers interbedded with greensand bands, are packed full of shells and common unspecified ammonites. Oyster-shell debris layers in quartz-rich pale sandstones with abundant serpulids, including the conspicuous seven-sided serpulid, *Hepteris*, are also present in both areas, overlain by the concretionary sandstone with conspicuous *Thalassinoides* burrows. Fallen boulders near Rubh' a' Chromain contain spectacular weathered-out burrows (Figure 6.3). The overlying pale-buff sandstone forms a conspicuous feature in the cliffs at Carsaig (Figures 6.25 and 6.26a) and is similar in appearance to the Allt na Teangaidh exposure at Gribun. The age of this unit is uncertain.

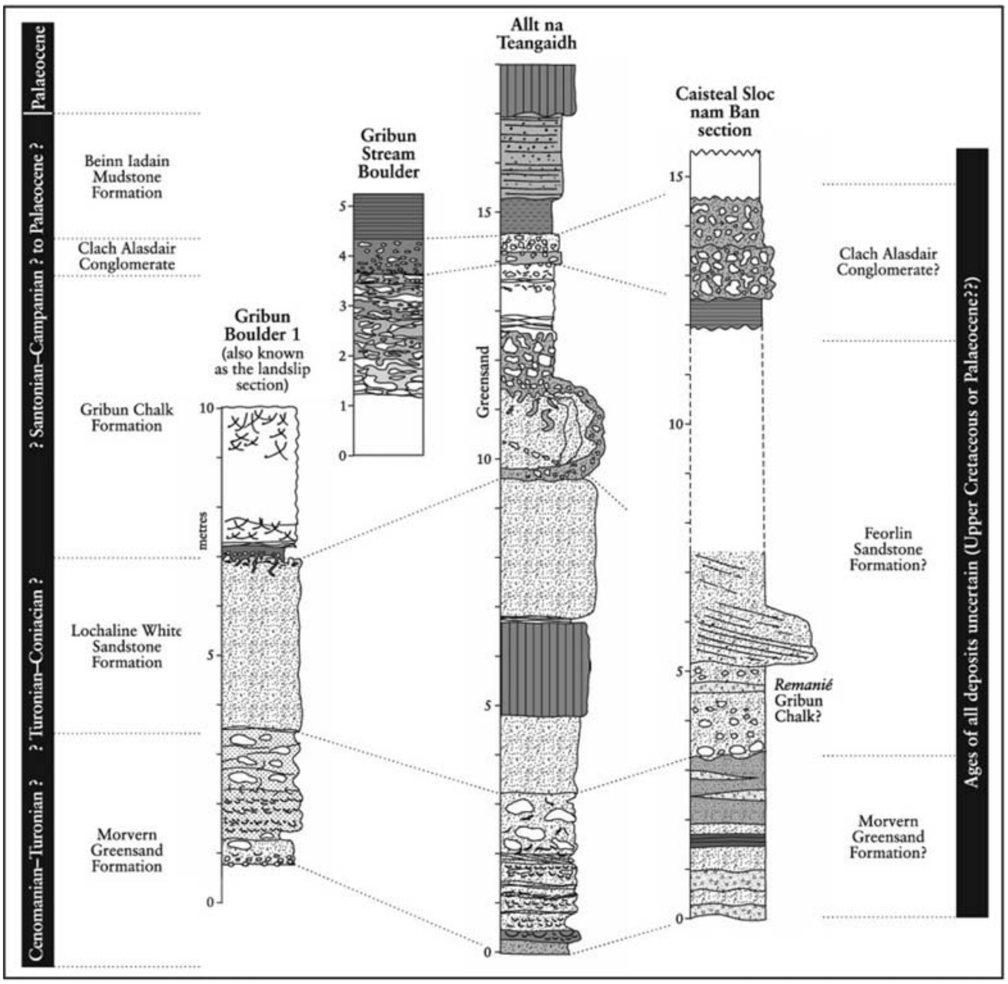

Figure 6.27: A possible correlation of the Gribun sections, Mull.

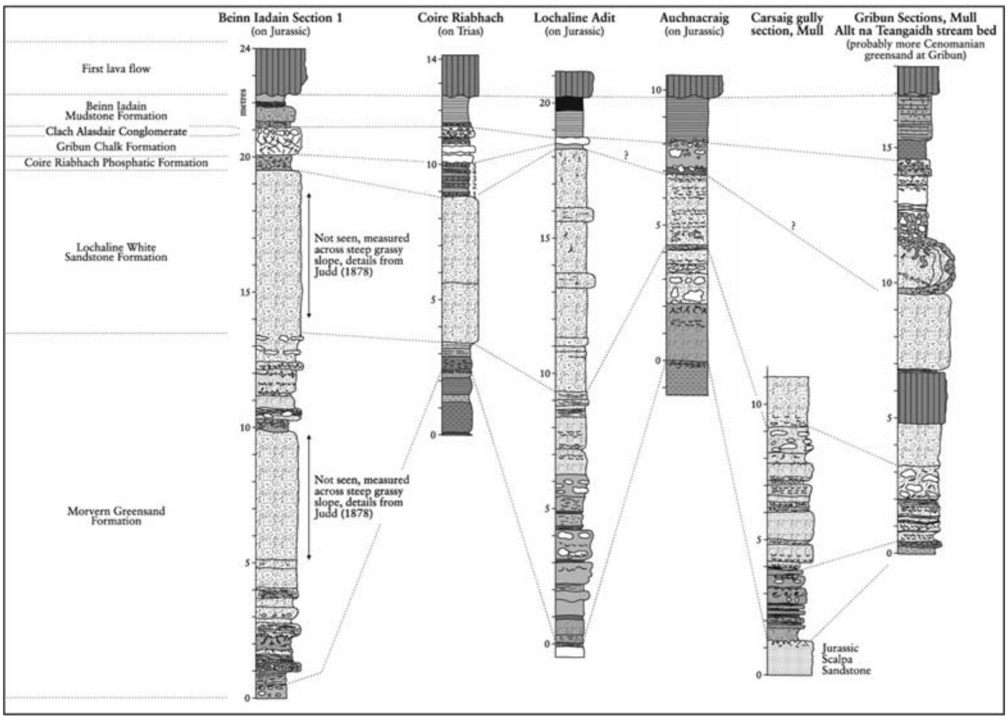

Figure 6.34: Correlation of the Upper Cretaceous GCR sites in the Inner Hebrides at Morvern, Argyll (Beinn Iadain and Lochaline) and at Auchnacraig, Carsaig, and Gribun, Mull. Note the restructuring of the lithostratigraphy of the Inner Hebrides Group.

Figure 6.20: Two views of the Carsaig sections. (a) Sections above Carsaig House include the waterfall (arrowed). (b) Upper Cretaceous sections (arrowed) north-west of Carsaig beneath basalts and above Jurassic sandstones and shales. (Photos: R.N. Mortimore.)

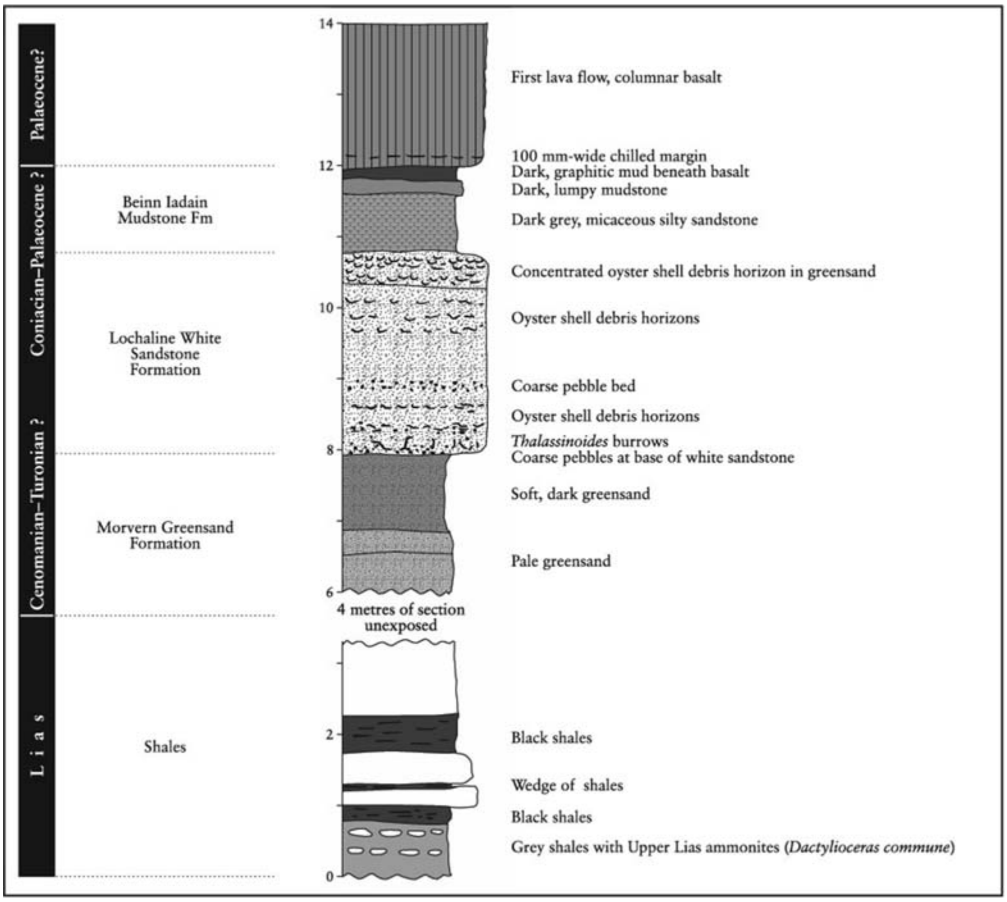

Figure 6.21: Upper Cretaceous sections at Carsaig, Mull. The far western gully section.

Figure 6.3: Lithologies in the Upper Cretaceous deposits of the Inner Hebrides. (a) The Clach Alasdair Conglomerate, Clach Alasdair, Eigg. (b) The Thalassinoides bed (arrowed) in white sandstones at Carsaig, Mull. (c) Upper Cretaceous Greensand with phosphatic concretions resting unconformably on Jurassic shales, Clach Alasdair, Eigg. (d) Upper Cretaceous Greensand with phosphatic concretions (arrowed), Clach Alasdair, Eigg. (Photos: R.N. Mortimore.)

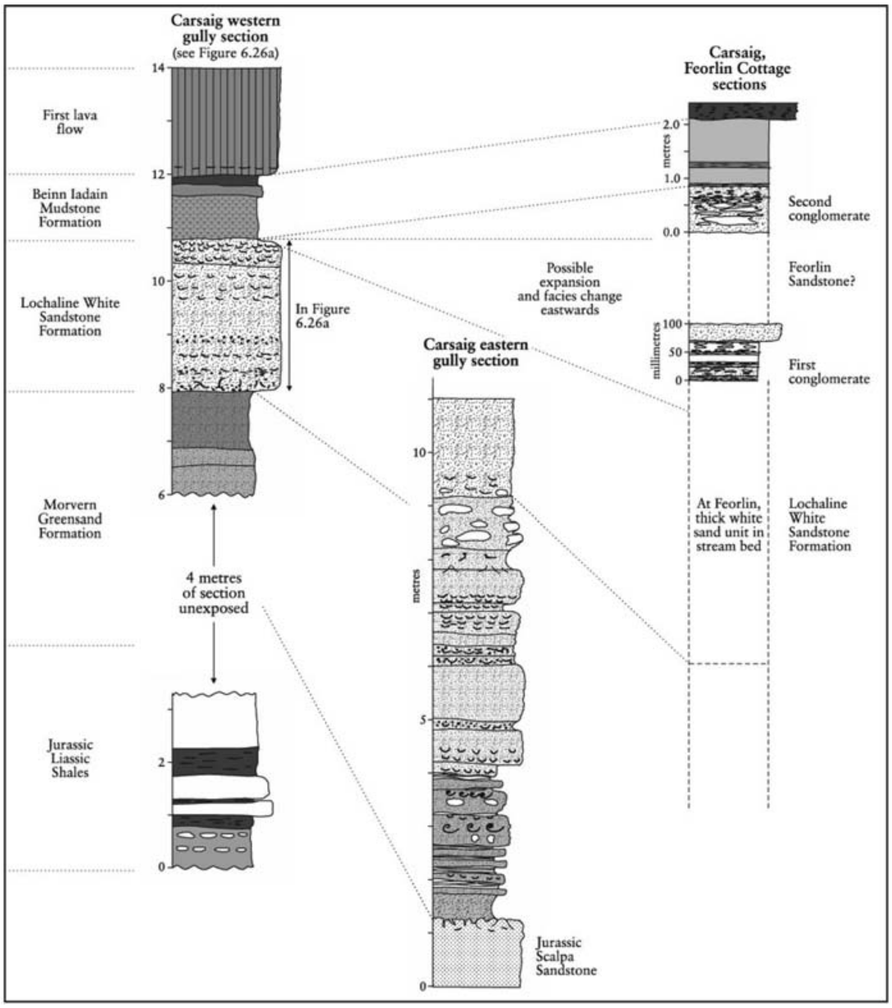

Figure 6.25: Possible correlation of the Upper Cretaceous sections at Carsaig, Mull.

Figure 6.26: Three Carsaig exposures. (a) North-west of Carsaig, abundant oyster-shell beds (OSB) at the top, and base of, the sandstone are arrowed (see also Figure 6.25, western gully section). (b) Above Carsaig House, showing an abundant oyster-shell bed (OSB) at the top of the sandstone, and a concretionary bed (CB) at the base of the sandstone. (c) Feorlin Cottage upper stream section. An upper band of chalk/flint separating two sandstone units is arrowed. (Photos: R.N. Mortimore.)

The Gribun Chalk Formation

The Caisteal Sloc nam Ban section is crucial in interpreting the Gribun Chalk Formation. This most southerly exposure in the Gribun shows the silicified chalk as a complex of intraclasts set in a sandy (in places, greensand) matrix, resting on greensands that in turn rest on the Rhaetian succession. Bailey *et al*. (1924), described this exposure as *remanié* Cretaceous and it appears to be a reworked 'mélange' of material (Figure 6.19). Traced northwards, the Chalk appears to be a more competent unit at Allt na Teangaidh, with possible internal sedimentary structures and inoceramid shell beds, but sands and greensands still occur as piped-down, or let-down, cavity-filling laminations between the silicified blocks. In the Clachandhu Boulders the Chalk is still a fragmented mass of peculiar silicified fragments, but contains less sand, and could be interpreted as either in-situ chalk silicified in place (a possible silcrete) or as a reworked mélange with very little matrix (further discussed in the final interpretative section).

Bailey *et al*. (1924, pp. 55–6) gave a graphic description of the chalk of the Clachandhu Boulders section; ' ...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... '. This was a crucial locality for Bailey, providing evidence for him of in-situ silicification in desert conditions (a silcrete that he related to observations made on current silicification processes in the Kalahari Desert). This interpretation was supported by the presence of well-rounded quartz grains of 'millet-seed' sand, which he considered characteristic of desert conditions. The reworking of chalk as a 'flint-conglomerate' at many localities suggested to him that silicification had occurred in the Cretaceous Period. Bailey *et al*. (1924, pp. 56–7), interpreted many of the reworked flint conglomerates at other localities, such as Caisteal Sloc nam Ban and Auchnacraig (Loch Don) (Figures 6.1, 6.4 and 6.5), as *remanié* Cretaceous set in a matrix of Early Tertiary deposits. They considered silicification of these conglomerates on top of the Chalk at Carsaig and Loch Don to have resulted from continuing desert, silcrete-forming, conditions in Early Tertiary times. These are challenging ideas that need to be considered alongside the causes of reworking and the presence of mudstones and lignites in the beds above the Chalk (see below).

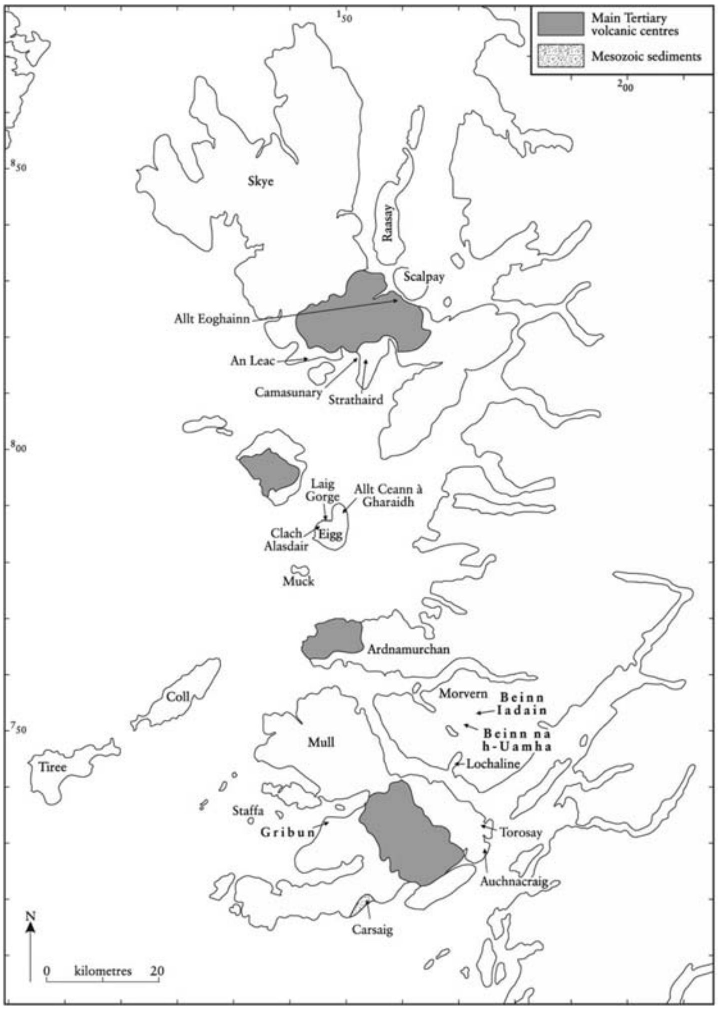

Figure 6.1: Main Upper Cretaceous localities in the Inner Hebrides Province; GCR sites are in bold type face.

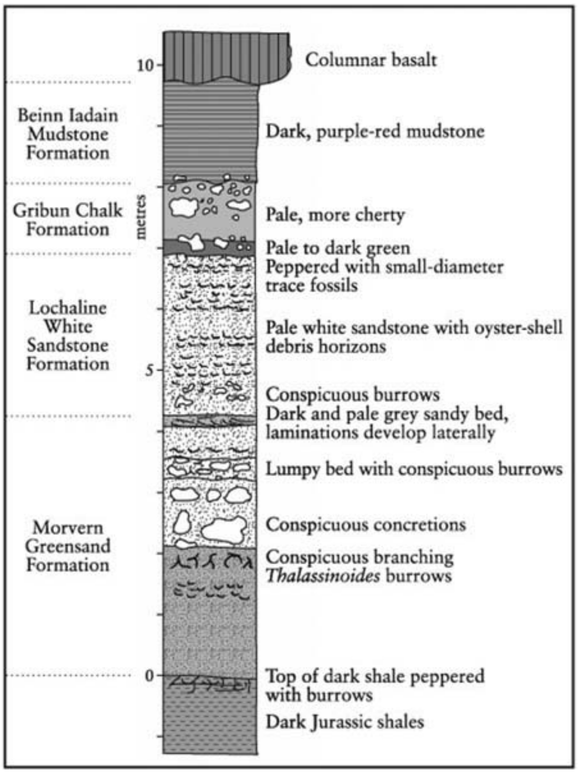

Figure 6.4: The Auchnacraig Section 1, Mull (see also Figure 6.5).

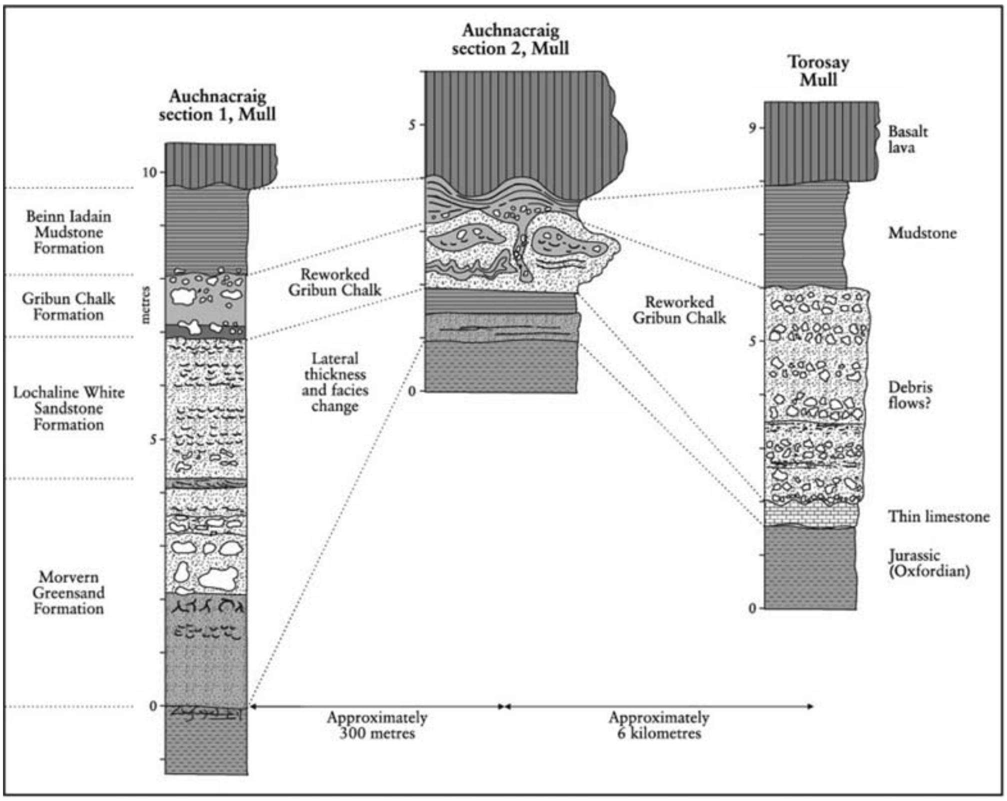

Figure 6.5: Lateral variation in the Upper Cretaceous stratigraphy on Mull illustrated by the Auchnacraig sections and the nearby Torosay section. These sections are near the Great Glen Fault. See also Figure 6.4 for notes on the beds.

The Gribun mudstones

The chalk at Gribun is succeeded by further thin sandstone units with silicified chalk intraclasts (angular), followed by a mudstone unit. The origin of this mudstone is controversial. It could represent a deeper-water clastic phase as a result of subsidence, or could be due to argillization of tephras following earliest volcanic activity in the area (Bailey *et al*., 1924, p. 59). Pre-eruption thermal doming may have developed local limestone (chalk) platforms and silicic conditions, followed by an eruption phase and subsidence. At present, there is too little evidence to support any particular theory.

The red and purple colours of the mudstone have led many to suggest that lateritic processes occurred before the eruption of the first lavas (Judd, 1878; Bailey *et al*., 1924; Lee and Bailey, 1925).

Lignite beds

At Carsaig there are lignite beds apparently interbedded with the earliest lava flows but also possibly beneath the lavas. These lignites locally form bright coals, seen as fallen blocks on the beach. The lignites are generally presumed to be Early Tertiary in age although there has been no satisfactory dating of these deposits and they could equally well be Late Cretaceous in age, as Judd (1878) hinted by inference from Maastrichtian lignite deposits in Germany. Bailey *et al*. (1924) considered all of the lignites to be of Tertiary age (based primarily on dating of the Ardtun Leaf Beds, south-west Mull) and used the presence of lignites to suggest that warm moist conditions predominated. Recent results from dating the Ardtun Leaf Beds and other lignites on Mull (Simpson, 1961; Bell and Jolley, 1997, 1998; Kerr and Kent, 1998) all indicate an Early Tertiary age for the top of the Lower Group of lavas, leaving open the possibility of an earlier age for the base of this group, including some of the sediments interbedded with the lavas.

Other localities on Mull

Gribun and Carsaig are the two main localities where relatively complete successions of the Late Cretaceous Inner Hebrides Group of sediments are preserved on Mull. Two other areas on Mull, Loch Don and Torosay, also contain remnant Late Cretaceous deposits (Figure 6.1). The so-called 'Loch Don sections' occur along the sea cliffs between Grass Point and Port Donain within the Auchnacraig Estate. There are several quite different successions in these exposures, most recently described by Skelhorn (1969). In the northern sections (Figure 6.5), the 'Flint Conglomerate' of the [British] Geological Survey (Bailey *et al*., 1924, p. 58; Lee and Bailey, 1925, p. 118) is incorporated in a sandy matrix, the whole bed resting on Lias without any intervening Cenomanian greensand or Lochaline White Sandstone Formation. Reworked oyster-shell debris is common and the bed contains contorted laminae and many other sedimentary structures. Above the conglomerate, the 'mudstone' is very dark, often difficult to distinguish from the overlying lava, and contains fragments of flint and black shale (Bailey *et al*., 1924). In the more southerly sections (Figures 6.4 and 6.5), Cenomanian greensands contain the typical *Amphidonte*, and the Early Cenomanian ammonite *Schoenbachia varians* (as *intermedia*) has also been recorded (Bailey *et al*., 1924; Richey *et al*., 1961).

In the southern sea-cliff exposure at Auchnacraig, 100 m south of Port na Tairbeirt (NM 742 294), there is an expanded succession (Figure 6.4), compared to the section north of this point. This expanded section brings in beds that show similarities with the Allt na Teangaidh and Carsaig exposures. The Late Cretaceous sediments rest unconformably on dark Jurassic shales. The first bed above the unconformity is sandstone with abundant oyster shells (probably the *Amphidonte* bed). Conspicuous branching *Thalassinoides* follow at the base of a 1.5 m thick calcareous concretionary limestone, very similar to the *Thalassinoides* and concretionary bed at Allt na Teangaidh and Carsaig cliffs. Oyster-shell beds in white sandstone are present almost up to the base of the chalk conglomerate. A thin greensand separates them and forms the matrix at the base of the chalk conglomerate. The chalk conglomerate is about 0.90 m thick, with the topmost clasts occurring in a second greensand matrix, very much the same as occurs at Gribun and Carsaig. A mudstone, consistently 1.70 m thick, is present from the conglomerate up to the base of the first lava flow.

Two sections near Torosay expose quite different successions. In old quarry workings (NM 7245 3521), a dark grey, crystalline limestone is exposed that, in the present account, is interpreted as altered chalk on the basis of numerous overgrown coccoliths. Braley (1990, p. 79) provided section details indicating that the Upper Cretaceous strata rest on Oxfordian limestone, and begins with a 2.1 m bed of dark grey, micritic limestone. This limestone is overlain by a flint conglomerate, 0.40 m thick, which grades upwards into a second bed of dark grey limestone containing sparse flint fragments. Thin sections of this limestone (some kindly supplied by Prof. R. Skelhorn) show many foraminifera of Late Cretaceous aspect, but they are taxonomically indeterminate. Braley (1990) correlated this bed with the apparently similar Strathaird Limestone on the Isle of Skye and in Laig Gorge, Eigg, which contained better-preserved foraminifera indicating a Turonian age. The Skye and Eigg examples were dominated by calcispheres and planktonic foraminifera including *Hedbergella praehelvetica* (Trujillo), a Lower and Middle Turonian species. The presence of flint conglomerate below and above the limestone was considered by Braley to be an important indication of the age of the conglomerates. The occurrence of inoceramid bivalve fragments in these limestone outcrops is curious and needs further investigation. Correlation of the Strathaird Limestone of Skye and Eigg with the Torosay Limestone on Mull (Braley, 1990) is an interesting possibility, but remains unproven. Calcareous nannofossils in these limestones indicate a possible Early Campanian age, especially in the Laig Gorge Limestone.

The Torosay Quarry section introduces many questions on the origin and dating of the Inner Hebrides Group. Torosay is the only area other than on Skye or Eigg where such limestone has been recorded and this occurrence is completely anomalous on Mull. Except for a 200 mm thick grey limestone bed on the Torosay track (see below), nearby sections on the Torosay track and Auchnacraig show markedly contrasting successions with no evidence of the dark grey limestone. An explanation for this extraordinary outcrop may include a local fault-controlled basin, or a tectonic slice brought in from elsewhere.

A second section in the Torosay area occurs on the track (NM 720 349) leading to the communications towers on Maol nan Uan. This section comprises a thin (200 mm thick) dark, grey-green sugary limestone at the base, resting on Jurassic mudstones full of belemnites. Above the limestone are 4 m of reworked silicified chalks (flint conglomerate) and some oyster-shell debris set in a sandy, silicified matrix. The first layer of reworked material is reverse graded and rests with an irregular contact on the limestone. The matrix is also silicified, containing patches of chalcedonic cement. There are six horizons of white, silicified, mostly angular clasts, generally poorly sorted, but possibly all reverse graded. It is probable that this reworked unit represents debris flows, an interpretation supported by the poor sorting and crude reverse grading. The uppermost unit between the flint conglomerates and the first lava flow is a dark purple mudstone, 2 m thick.

Fault control of sedimentation

Each locality on Mull shows significant differences in the Inner Hebrides succession. The most condensed, reworked deposits on the north side of Auchnacraig and on the Torosay track are close to the Great Glen Fault (Figure 6.2). There may also have been local troughs in which sediments such as the Torosay Limestone formed. Variation in thickness and lithology along the Carsaig cliff sections between Carsaig Bay and Malcolm's Point may also indicate local, fault control of sedimentation. Similarly, the variation in the thickness and composition of the sediments in the Gribun sections, notably the mélange in the most southerly, Caisteal Sloc nam Ban section, indicates rapid changes in this sedimentary environment, if indeed all the sections are Late Cretaceous in age.

Conclusions

Gribun, complemented by the local sections on Mull, together expose the eight main rock units comprising the Late Cretaceous(?) Inner Hebrides Group on Mull (Table 6.1). Apart from the Cenomanian greensands there is, as yet, very little evidence for dating the sediments or for including all of them in the Cretaceous and/or Tertiary systems. It was the strikingly white Gribun Chalk Formation (Judd, 1878) in contrast to the dominating dark rocks of the Tertiary lavas that first attracted attention. Now it is the environment of sedimentation that is of great interest, stimulated by Bailey's (1924) interpretation of desert shores of the chalk seas, represented, so he thought, by millet-seed sands and silcretes.

Missing from the Braley (1990) and Lowden *et al.* (1992) lithostratigraphical schemes are the greensands that form conspicuous thin beds at the base and top of the Chalk. The overall succession represents three phases of transgression, possibly onto unconformable surfaces, represented by, respectively, the Middle? Cenomanian *Amphidonte* greensands, the greensands beneath the Chalk (possibly Santonian) and the greensands at the top of the Chalk (of unknown age).

The absence of good dating and detailed sedimentological analyses makes interpretation of this group of rocks very difficult. There is increasing evidence, however, to support Bailey's concept of *remanié* Cretaceous at various places. The Caisteal Sloc nam Ban, Auchnacraig and Torosay track sections all contain evidence of reworking, possibly by debris flows. These could be either Late Cretaceous or Tertiary deposits and Bailey *et al*. (1924), and Lee and Bailey (1925) are not clear or consistent in their dating of these deposits. Because of these uncertainties, the stratigraphical relationships suggested by Braley (1990) and Lowden *et al*. (1992) (see Table 6.1) must remain in doubt; however, their stratigraphical terminology is useful and is, where possible, adopted in the present volume (e.g. Figure 6.27).

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