Chapter 6 Inner Hebrides Group, north-west Scotland

Introduction

The Upper Cretaceous sediments of the northwest Highlands were made famous by Bailey's (1924) paper entitled *The Desert Shores of the Chalk Seas.* The climatic implications for the Late Cretaceous Epoch from this work have been widely debated ever since. Massive cliffs of black, basaltic, Palaeogene lavas irregularly overlie and obscure the Upper Cretaceous deposits, sometimes filling palaeovalleys that have cut deeply through the underlying Mesozoic sediments. These palaeovalleys were presumably cut at the end of the Cretaceous Period following tectonic faulting, uplift and erosion prior to the volcanic outpourings. Consequently the outcrop of Upper Cretaceous sediments is not continuous and this is seen particularly well at the Gribun GCR site on the Isle of Mull, where only small pockets of sediment are preserved, often in landslipped blocks, along the strike. Even where relatively continuous outcrops are present, such as the sea cliffs at Auchnacraig and Carsaig on Mull and the Beinn. Iadain GCR site in Morvern, each exposure shows significant differences in preserved stratigraphy both within the Upper Cretaceous succession and as a result of pre-lava erosion. Many of the exposures are ephemeral stream sections high up slopes beneath the basalts in waterfalls, which can be torrents following rain.

Because the Upper Cretaceous deposits are so thin, there is little significant impact on geomorphology. The sandy deposits of Mull and Morvern overlie Triassic and Jurassic sediments of various ages but where, for example, shales occur beneath the sands, spring lines and saturated ground (bog) are often present. The limestones on Skye provide a different habitat, affecting the flora, which can be picked out as lighter green grassland patches amongst the generally darker green bracken and heather.

Tectonic setting and sedimentary history

The sedimentary succession comprises the Inner Hebrides Group (Braley, 1990; Lowden *et al.,* 1992) and forms part of a Mesozoic Inner Hebrides Basin or Province (Figure 6.1) and (Figure 6.2). The term 'Province' is preferred since it is uncertain whether an Upper Cretaceous basin really existed and whether or not inversion took place in the late Lower Cretaceous Epoch resulting in erosion of former sediments. The exposures are found locally beneath Palaeocene lavas on the islands of Skye, Eigg, Staffa and Mull and on the mainland in Morvern and Ardnamurchan. In the north-west Highlands large-scale geological structures, such as the Great Glen Fault and the Moine Thrust, have very long histories of movement affecting sedimentation over the last 400 Ma. The Great Glen Fault is adjacent to, and partly passes through, the Late Cretaceous deposits on Mull and Morvern (Figure 6.2). The Moine Thrust Zone, with the basal Kishorn Thrust, lies to the east of the Skye Upper Cretaceous deposits, but a further major geological structure, the Camasunary Fault, separates the Strathaird outcrops from those on Soay Sound. The Allt Strollamus exposure near Broadford, Skye, and the Coire Riabhach section, Beinn Iadain, Morvern are fault-controlled slices. Smaller-scale faults are numerous, and cross the outcrop of Upper Cretaceous sediments.

Because of the small, discontinuous exposures, it is not possible at this stage, to provide a comprehensive account of the influence of these structures on sedimentation. The evidence, however, for rapid lateral changes in stratigraphy, reworking, debris flows and local preservation windows, suggests that tectonic movements had a marked impact on the Late Cretaceous and Early Palaeogene history of the region.

Stratigraphy

The Inner Hebrides Group is a highly reduced succession, some 2–20 m thick for the inferred Cenomanian to Maastrichtian strata, compared with 110 m in Northern Ireland and 500 m in Norfolk. The succession comprises beds of greensand, white sand, limestones and chalk (in part and, in some places, reworked debris flows), overlain in places by lignite and/or mudstones. Prior to the data published in the present account, the limited fossil records indicated the presence of Cenomanian and, more tenuously, Turonian, Santonian and Campanian sediments. It is remarkable that any sediment remains, and much of it presents evidence of reworking, casting doubt on its age. All of the exposures are very difficult to access and interpret, and most indicate that the sediments have suffered a degree of thermal metamorphism, often calcining or burning important fossil evidence.

Apart from an unpublished PhD Thesis by Braley (1990) and some observations by Rawson *et al.* (1978), very little significant work has been done since the observations of Judd (1878) and the original [British] Geological Survey memoirs for the area (Bailey *et al.,* 1924; Bailey, 1924; Lee and Bailey, 1925). As part of this review, all of the key sections on Mull, Morvern, Eigg and Skye have been revisited and remeasured, and it is the evidence from these sections that is used in this account, supplemented with observations from previous work, some of it unpublished.

A key part of the succession includes 5 m of limestones near Allt Strollamus on Skye with apparently Turonian foraminifera (Richey *et al.,* 1961; Braley, 1990) and *Inoceramus,* which may prove crucial to dating the group. A similar limestone may be present at Strathaird, Skye, in Laig Gorge on Eigg, and in the Torosay Quarry section on Mull. Also on Mull, there is a wide variety of sections, ranging from extremely condensed exposures showing reworked material (probable debris flows), to expanded successions with a common stratigraphy, at least in the lower part, comprising Cenomanian greensands. On Eigg, the Cretaceous succession is partly represented by the Clach Alasdair Conglomerate ((Figure 6.3)a), which may be equivalent to the conglomerate at Torosay and Auchnacraig (Figure 6.4) and (Figure 6.5), and partly by the thicker sandstones and limestones of Laig Gorge. Other records in the region include remnant blocks of chalk in a volcanic vent on Arran; chalk blocks elsewhere on Arran contain abundant belemnites. Extensive areas of Cretaceous deposits have been mapped on the mainland at Ardnamurchan and Morvern where there is a key section at Beinn Iadain apparently containing Late Cretaceous fossils (e.g. Judd, 1878) and a lignite bed of uncertain age.

Much of the dating of the succession remains controversial, as diagnostic fossils have not yet been obtained from all of the different lithologies. Even the date of the onset of vulcanism at the top of the section is open to question and may be partly Late Cretaceous in age (Kent *et al.,* 1998; Jolley *et al.,* 1998). There are also lignites that are of uncertain age because many of the pollen spores have been burnt-out by the heat from overlying lavas. Only the basal part of the succession, which largely comprises Shelly glauconitic sands, can confidently be dated as broadly Cenomanian in age. There are some similarities in fossil occurrences and lithologies with equivalent sediments in Northern Ireland where the metamorphism is of lower grade and different character. Hence Northern Ireland provides key evidence for unlocking the Hebridean succession.

Despite these uncertainties, the succession, and especially the GCR sites, provide evidence for regional events that are poorly understood at present, such as possible thermal doming prior to volcanic eruption or reactivation of faults during the Late Cretaceous Epoch. The Gribun and Beinn Iadain GCR sites are used as the reference sections against which the other sections in the Inner Hebrides Province are compared and contrasted.

A litho- and biostratigraphy for the Inner Hebrides Group

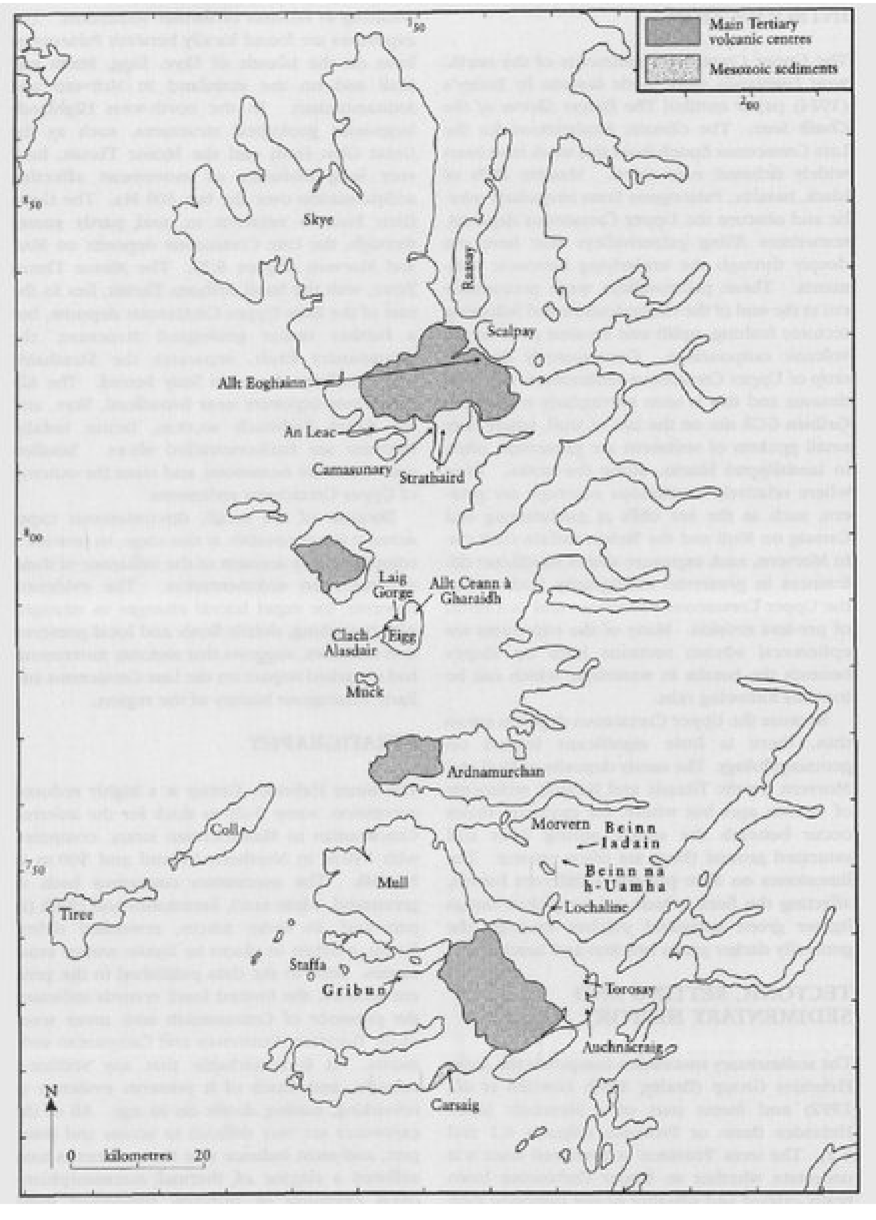
Judd (1878) proposed the first comprehensive lithostratigraphy for the Inner Hebrides Group. Subsequently, Braley (1990; in Lowden *et al.,* 1992) introduced a number of new units and arranged them in a different stratigraphical order. Braley's nomenclature was followed by the British Geological Survey in the Rhum Memoir (Emeleus, 1997). Because of the great uncertainty about the dates of many of the units, this stratigraphical succession and nomenclature has remained open to question. As a result of the present authors' current work, using the scanning electron microscope to identify and date the nannofossil assemblages, new dates for parts of the succession require a reassessment of the lithostratigraphy (Table 6.1). Critical to these new interpretations has been the dating of the greensands with phosphates at Gribun

Beinn Iadain (Morvern) and Clach Alasdair (Eigg), which indicate a Late Coniacian or Early Santonian age for these deposits, overlain by Early Campanian silicified pale chalks. Such an age for the phosphates was suggested by Reid (unpublished letters to Dr C.V. Jeans) who dated sponges from the Beinn ladain section collected by Jeans and Platten (Jeans, pers. comm.; Rawson *et al.,* 1978, p. 55). The presence of holococcoliths (*Lucianorhabdus* cf. *cayeuxii* Deflandre) in the greensands beneath the Clach Alasdair Conglomerate on Eigg indicates a similar age. Other sediments that must originally have been chalks at Torosay (Mull), Laig Gorge (Eigg), Strathaird (Skye) and Allt Strollamus (Skye) are now cemented dark blue-grey limestones containing abundant coccoliths. Some of these limestones contain nannofossil assemblages indicative of an Early Campanian age (e.g. the nannofossils *Prediscosphaera serrata* Noel and *Micula staurophora* (Gartner) Stradner)).

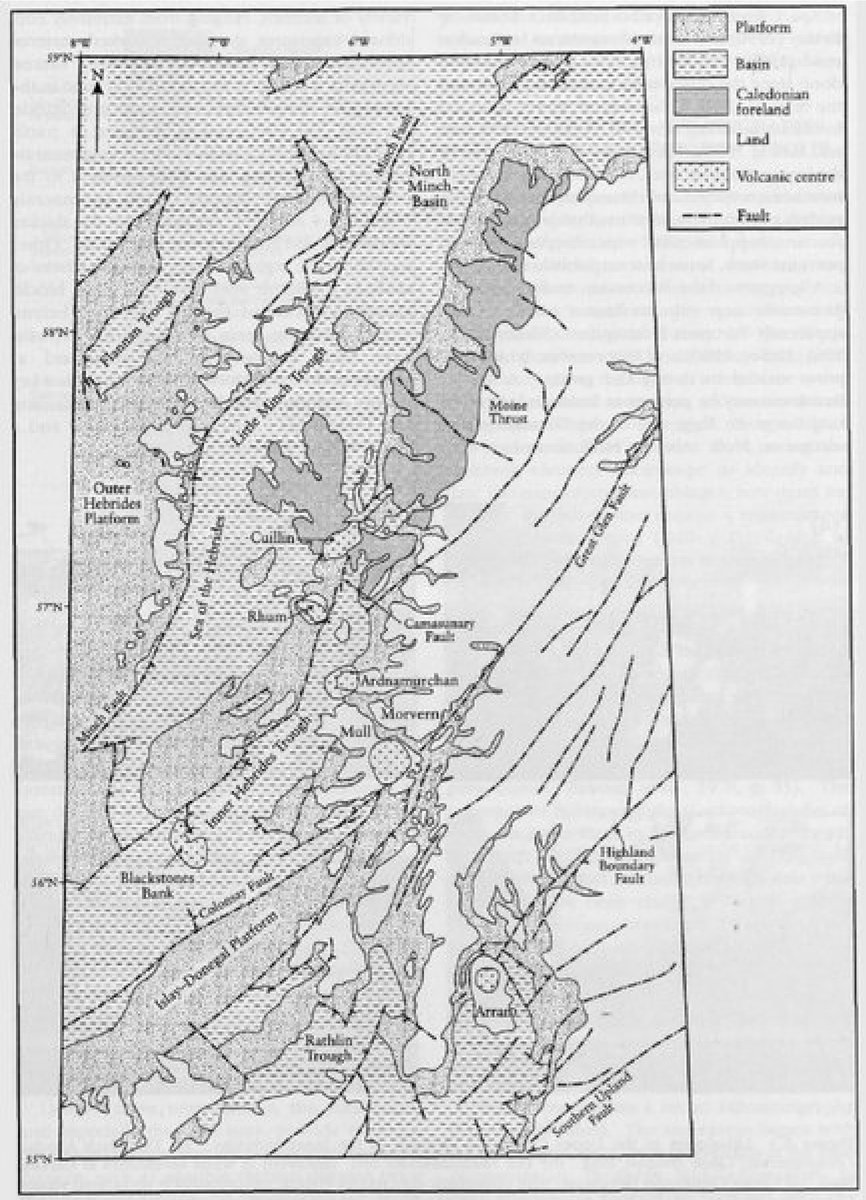
From these studies a broad lithostratigraphy can be established. The succession begins with oyster (*Amphidonte*)-rich greensands at the base (Cenomanian, probably Mid-Cenomanian, in age) passing up through sandstones with the trace fossil *Thalassinoides,* and calcareous concretions, immediately followed by oyster (*Rhynchostreon*)-rich beds with a special form of serpulid (the septagonal *Hepteris*) which, elsewhere in Europe, is typical of the shallow water sediments that equate with Jefferies' Bed 4 of the Plenus Marls Member. These serpulid and *Rhynchostreon* oyster-rich sands are overlain by the Lochaline White Sandstone Formation (probably Turonian–Coniacian in age) and then a greensand at the top with phosphates of latest Coniacian or Early Santonian age. Silicified chalks and limestones of Late Santonian–Early Campanian age follow and are in turn overlain by another phase of greensands containing reworked chalk and flint conglomerate. The final part of the succession contains mudstones, shales and lignites and possibly (as on Eigg), reworked earlier lava flows.

The GCR sites contain much of the evidence for this succession but lack the limestones rich in coccoliths. The localities with limestones on Eigg and Skye can be linked to the GCR sites to provide a more complete picture of the Inner Hebrides Group.

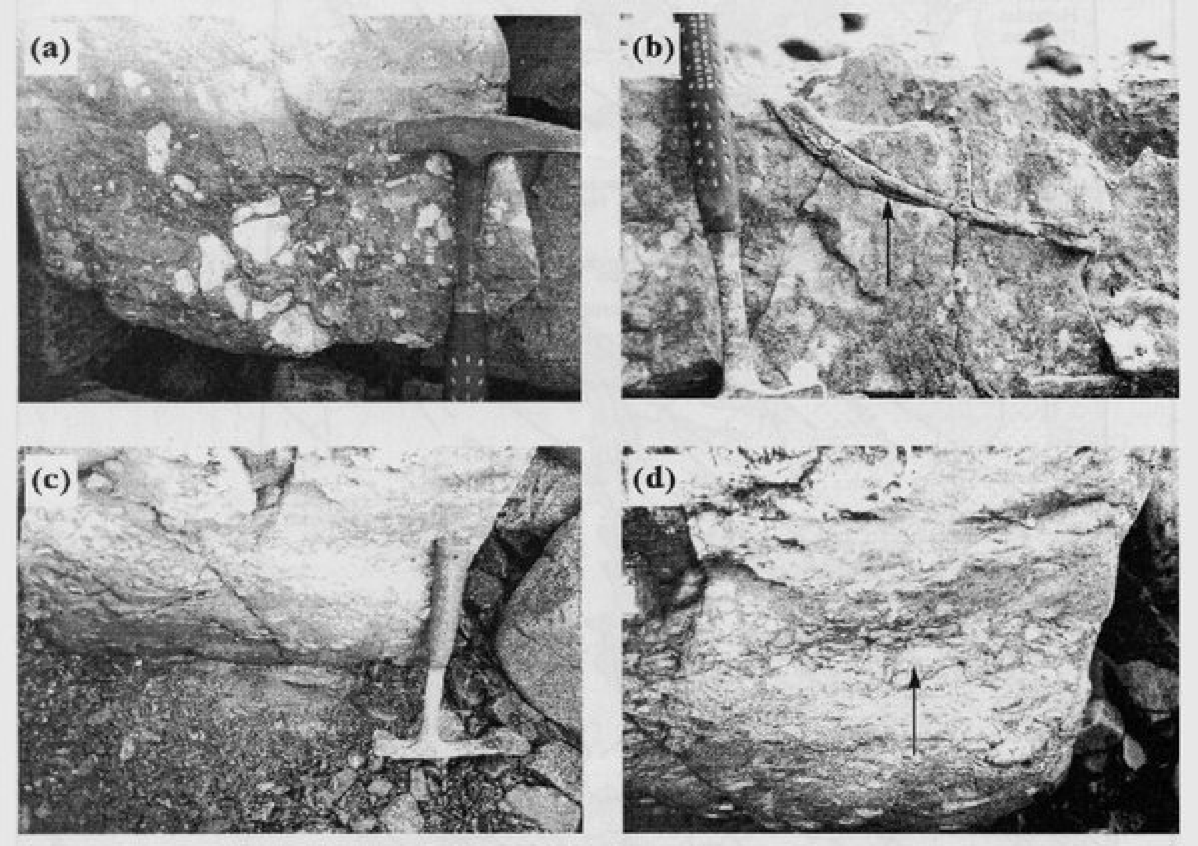
References



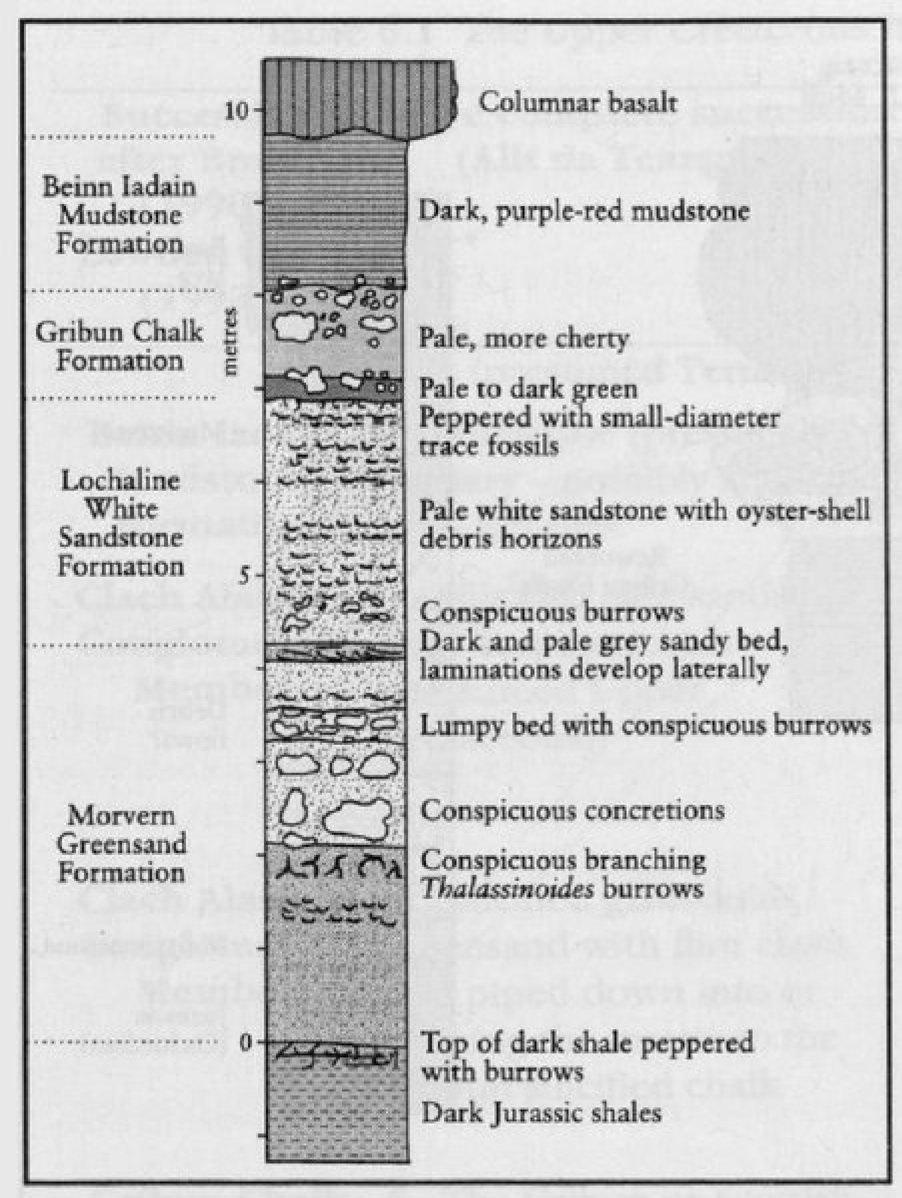
(Figure 6.1) Main Upper Cretaceous localities in the Inner Hebrides Province; GCR sites are in bold type face.



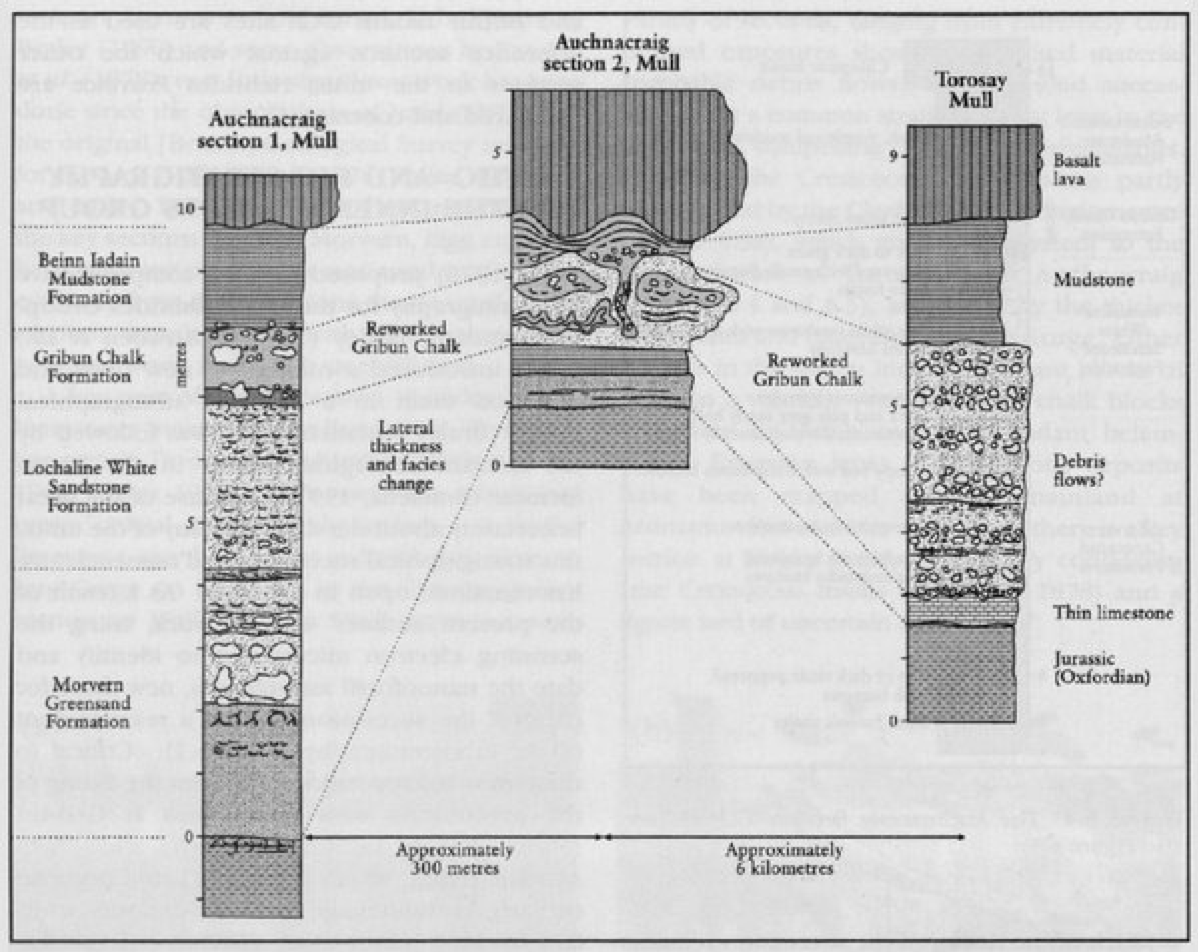
(Figure 6.2) Structural elements and volcanic centres affecting Inner Hebrides Upper Cretaceous sedimentation.



(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 6.4) 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.

Succession after Braley (1990); Lowden *et al.* (1992);	More complete succession (Allt na Teangaidh)	Less complete succession (Torosay Track)	Variations Torosay Quarry	Variations Feorlin Cottage Carsaig
	Lava (presumed Tertiary)	Lava		Lava
Beinn Iadain Mudstone Formation	8. Mudstone (presumed Tertiary – possibly argillized ash); laterites	Mudstone	Top of section unknown	Mudstone with lignite
Clach Alasdair Conglomerate Member	7. Silicified pale sandstone with flint intraclasts (presumed Upper Cretaceous);	Flint conglomerate in sandy matrix showing evidence of debris flows	Flint conglomerate at the top	Flint conglomerate
Clach Alasdair Conglomerate Member	6. Silicified glauconitic greensand with flint clasts also piped down into or forming the matrix to the Gribun silicified chalk	Possible thin dark-grey limestone with planktonic foraminifera	Thick dark grey limestone in Torosay Quarry	Thick wedge of white sandstone on top of chalk conglomerate at Feorlin Cottage
Gribun Chalk Formation	5. The Gribun or Scottish Chalk, in places with hints of internal bedding, containing inoceramid shell debris bands, sponges etc. (the inoceramids are Cretaceous but may be reworked as silicified chalks into younger greensand; or the chalk may represent silcrete formation first in the Late Cretaceous, then the Tertiary?)	Resting on Rhaetic, Lias or Oxfordian	Resting on Oxfordian	Chalk conglomerate
	4. Glauconitic greensand with flint intraclasts			
Lochaline White Sandstone Formation	3. Pale buff sandstone (the White Sands)			Thick white sandstone
	2. Laminated and concretionary sandstone with oyster shell beds and *Thalassinoides* burrow bed			
Morvern Greensand Formation	1. Cenomanian greensand with marly units in expanded sections and containing Lower and/or Middle Cenomanian fossils. Basal pebble bed			
Unconformity	Upper Cretaceous resting on Lias or Oxfordian sediments			Base of section unknown

(Table 6.1) The Upper Cretaceous Inner Hebrides Group Succession in Mull.