Cadha Carnach, Isle of Raasay, Highland

[NG 582 392]–[NG 585 412]

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Introduction

The Cardha Carnach GCR site contains one of the best-documented and finest exposures through the Pliensbachian to basal Toarcian Scalpay Sandstone Formation. The site has also furnished important data on higher parts of the Lower Jurassic succession; the Lower Toarcian Portree Shale and Raasay Ironstone formations, and the uppermost Toarcian Dun Caan Shale Member of the Bearreraig Sandstone Formation. The 300 m-high cliff Druim an Aonaich, towards the north in the GCR site, extends as an almost linear north–south feature from Dun Caan to Screapadal and dominates the east coast of the Isle of Raasay (Figure 8.8). It is one of the most spectacular British Jurassic exposures. It appears unrelated to any tectonic structures but has been interpreted as a product of glacial erosion (Chesher *et al.*, 1983). This also caused oversteepening of the slopes east of Dun Caan, leading to instability and the formation of the large Hallaig rotational landslip (see Hallaig Shore GCR site report). The southern part of Cadha Carnach, at the southern end of the GCR site, consists of later smaller landslipped blocks mainly of Middle Jurassic sandstones.

The southern part of Druim an Aonaich, north of Cadha Carnach, shows a clear tripartite division. The main vertical part of the cliff comprises the (latest Toarcian to Upper Bajocian) Bearreraig Sandstone Formation. Below there is a distinct sloping ledge developed on the Dun Caan Shale Member (Aalensis Zone), the Raasay Ironstone Formation (Serpentinum Zone) and the Portree Shale Formation (also Serpentinum Zone). These are exposed only occasionally, being largely obscured by fallen blocks and scree from the massive units above, but a trench was excavated by the [British] Geological Survey, during the mapping of Raasay, to document the 'Upper Lias' succession. The steep slope below these units is formed by the Scalpay Sandstone Formation (here Davoei Zone to Tenuicostatum Zone). Although partly covered by vegetation, stream gullies expose a complete succession down to the foreshore.

Above the main cliff a ledge marks the position of the Garantiana Clay Member and the Cullaidh Shale Formation, both exposed at Cadha Carnach. To the west, gentler scarps and slopes are underlain by the various units of the Great Estuarine Group, cut by sills and capped by Palaeocene plateau basalts forming, within the GCR site, the summit of Dun Caan. On the western slopes of Dun Caan fragments of presumed Cenomanian greensand indicate the presence of a thin Upper Cretaceous sequence between the Jurassic and Palaeocene successions.

Useful sections through the Lower Jurassic succession can be seen at various points, notably towards the northern end of Druim an Aonaich (south of Screapadal) and towards the southern end. This southern section forms the Lower Jurassic part of the Cadha Carnach GCR site, named after the break in the cliff immediately east of Dun Caan. The Cadha Carnach GCR site was designated as a Lower Jurassic site largely because of the section through the (Pliensbachian to basal Toarcian) Scalpay Sandstone Formation, described by Howarth (1956, 1958) and Phelps (1985). However, important data can also be obtained (Lee, 1920) about the Portree Shale and Raasay Ironstone formations (both Lower Toarcian) and the (topmost Toarcian) Dun Caan Shale Member of the Bearreraig Sandstone Formation.

The eastern boundary of the Cadha Carnach GCR site lies between the in-situ strata of Druim an Aonaich and the Hallaig landslip. The western boundary is the top of the cliff with a westwards extension at the southern end to include Dun Caan. The GCR site extends north to the edge of another landslip, which forms a shallow recess in the cliff and has buried the Lower Jurassic succession beneath large fallen blocks of the Bearreraig Sandstone Formation. Access to the site is difficult, involving a long walk (*c.* 7 km) from the end of the road at North Fearns.

Description

Structurally the area is simple, comprising part of a large westerly tilted fault-block bounded to the west by the Screapadal Fault (see Morton and Hudson, 1995). Within the GCR site the strike of the beds is almost north–south, with dips between 13° and 21° to just north of west. The only fault within the site is an arcuate structure near the southern boundary, south of Cadha Carnach. Major dolerite and granophyre sills have been intruded into the Middle Jurassic sediments. The small granophyre sills represent the north-eastern edges of a large granophyre sheet which covers much of southern Raasay, while the dolerite sills are part of the extensive suite of sills which are prominent features in Trotternish, Isle of Skye. Minor dolerite dykes are confined to Cadha Carnach itself.

The Scalpay Sandstone Formation forms the steep slope in the lower part of the cliff and the foreshore but is accessible in steep parallel stream gullies [NG 585 404] which were described by Howarth (1956, section 7; marked as 'section' on Figure 8.9), Phelps (1985) and Hesselbo *et al.* (1998). The strata can be traced northwards along the shore and slope to almost the northern boundary of the GCR site [NG 586 411]. The base of the Scalpay Sandstone Formation is below sea level within the site, but crops out on the foreshore farther north [NG 5864 4249].

Exposures of the Portree Shale and Raasay Ironstone formations are more limited along the narrow steep ledge above the Scalpay Sandstone Formation, but have been recorded at several locations [NG 5848 4026], [NG 5851 4054] and [NG 5853 4091]. During the [British] Geological Survey mapping of Raasay, R. Tait excavated a trench (at [NG 5847 4022]; marked as 'trench' on Figure. 8.9) through the Dun Caan Shale Member (Bearreraig Sandstone Formation), the Raasay Ironstone Formation and the Portree Shale Formation, which yielded important information about the succession (Buckman in Lee, 1920) which has not been superseded.

The succession in the Scalpay Sandstone Formation of the Cadha Carnach area was first described in the [British] Geological Survey memoir (Lee, 1920). A more detailed description of the section was given by Howarth (1956) and this has served as the basis for more recent accounts (Phelps, 1985; Hesselbo *et al.,* 1998). The succession reproduced here (Figure 8.10) is based mainly on Howarth's descriptions, with additional data from Phelps (1985), Hesselbo *et al.* (1998) and other sources. The base of the formation lies below sea level and the lowest strata exposed on the foreshore are silty shales or muddy siltstones and thin sandstones (beds i to v of Howarth, 1956). These were included in the Scalpay Sandstone Formation by Howarth but represent part of a transitional series between the Scalpay Sandstone and Pabay Shale formations (see also discussion in Hesselbo *et al.,* 1998). They may belong, at least in part, to the Ibex Zone (see below). These beds coarsen up into the overlying Davoei Zone sandstones of Howarth's beds vi and vii, which form the lower part of the cliff. Distinctive marker beds (beds 14–18 of Howarth, 1956), including fissile micaceous shales crowded with crushed bivalves, occur some 6 m above the base of the cliff at this section and are important for correlation with Howarth's other sections on Raasay (see also Hallaig Shore and Rubha na' Leac GCR site reports). Beds 14 to 25 of this section were used by Howarth (1956) as the basis for his composite section of the Scalpay Sandstone Formation on Raasay. Beds 19 and 20 form the first thick, massive, calcareous sandstones at the top of the Lower Pliensbachian succession. The overlying beds, Bed 21 up to Bed 25, mark a return to predominantly silty beds in the lower part of the Upper Pliensbachian sequence. Thin beds and lenses of fine-grained sandstone, scattered calcareous nodules and bands of nodules occur at several levels. Ammonites occur but are rarely abundant (see below) while Bed 23 is characterized by numerous large *Gryphaea gigantea.* Hesselbo *et al.* (1998) noted a sheeptrack developed at the level of the lower part of Bed 23, and this forms a useful identifiable feature on the hillside.

The more sandy upper part of the Scalpay Sandstone Formation forms a steeper slope, up to the ledge formed by the Toarcian shales. The lowest massive sandstone, Bed 26, is the exception. It is mottled by pervasive bioturbation and is softer and more poorly cemented, forming a recessed ledge and giving rise to distinctive honeycombe weathering. These features can be recognized in other sections on Raasay, notably south of Rubha na' Leac (see GCR site report). Beds 28 and 30 are more calcareous, with nodular bands of sandy limestone, and more fossiliferous with frequent *Gryphaea gigantea, Pseudopecten equivalvis,* ammonites and nests of brachiopods (especially rhynchonellids). Other beds contain more scattered calcareous doggers, and fossils are less common. The thick massive-weathering sandstone (Bed 36) that forms the main upper part of the Scalpay Sandstone Formation is thinner here than south of Rubha na' Leac. It is capped by thinner beds of ferruginous and calcareous, though usually decalcified, sandstone which appears to correlate with the higher of the two calcareous beds at Gualann na Leac (so here also numbered Bed 39).

There is a sharp lithological boundary between the top of the Scalpay Sandstone Formation and the shales of the Portree Shale Formation. The shales are dark-grey to black, fine grained with very small mica flakes in the lower part. Towards the top the mica flakes become larger and scattered ooliths appear so that, In the southern part of the Cadha Carnach GCR site at least (see below), there is an upward transition into the Raasay Ironstone Formation. Howarth (1956) recorded shales with *Dactylioceras* spp. from the top of his section 7 [NG 5850 4041] but did not cite a thickness. In the trench dug by Tait [NG 5847 4022] 3.96 m (13 ft) of the Portree Shale Formation is recorded. This compares with 2.74 m at Rubha na' Leac [NG 5983 3794] and 2.5 m at the opencast mine [NG 5718 3689] (Morton and Hudson, 1995). The ammonites are discussed below.

The succeeding Raasay Ironstone Formation also is rarely exposed along the ledge at the foot of the high cliff. Data obtained by the [British] Geological Survey (Lee, 1920, and original Geological Survey fieldslip) is available for three localities:

1. In Tait's trench [NG 5847 4022] the Raasay Ironstone Formation was recorded (Lee, 1920) as about 0.91 m (3 ft) thick, with a belemnite-rich layer at the top (*Dactylioteuthis*) and ammonites, discussed below. Lee (1920) noted that the ironstone was much thinner than in southern Raasay and that the chamositic oolite there had passed laterally at this locality into a ferruginous limestone with carbonate ooliths (largely siderite) and only minor traces of chamosite.
2. Approximately 300 m to the north [NG 5851 4054] the thickness of the ironstone is reduced to 0.15 m (6 in.).
3. Near the northern end of the GCR site [NG 5853 4091] the Raasay Ironstone Formation is absent.

There is no evidence as to whether the northward thinning (from 2.4 m at the main opencast mine [NG 5690 3645] and 2.74 m at Rubha na' Leac [NG 5983 3794]) and disappearance of the Raasay Ironstone Formation is due to lateral change or to erosion before deposition of the Bearreraig Sandstone Formation (see Morton, 1989 for discussion).

The Raasay Ironstone Formation is succeeded by the Dun Caan Shale Member. The latter was proposed by S.S. Buckman, on account of the conspicuous feature these shales make below Dun Caan, and subsequently accepted by the [British] Geological Survey (Lee, 1920). Natural exposures of this part of the succession are rare and occur in small disconnected patches. Hence Tait's trench section (at [NG 5847 4022]) through about 23 m (75 ft) of strata, exposing the complete thickness of the shales, represents virtually the only source of information about the Dun Caan Shale Member (Lee, 1920) and must be considered its type section. Supplementary information was also obtained from another locality 'a few hundred yards further north, at Drium an Aonaich' (Lee, 1920). The shales are dark-grey to black and usually highly micaceous with occasional calcareous nodules and slight upward-coarsening. Ammonites, preserved flattened, are the most common fossils, with belemnites and occasional layers crowded with small bivalves (*Pseudomytiloides, Bositra*). The thickness was given by Lee (1920, p. 66, but cf. p. 42!) as 23 m (75 ft), but the top 1.2 m (4 ft) includes thin limestone beds. By comparison with the Beinn na Leac section (see Morton and Hudson, 1995) the latter would be excluded from the Dun Caan Shale Member and included in the Beinn na Leac Sandstone Member. Therefore the true thickness of the Dun Caan Shale Member is 21.8 m (71 ft) (see Morton, 1965; Morton and Hudson, 1995 for comparison with other localities).

Interpretation

Within the Cardha Carnach GCR site a virtually complete succession can be seen from near the base of the Scalpay Sandstone Formation to near the top of the Bearreraig Sandstone Formation. However, the section is steep and parts are almost inaccessible (the southern end of the vertical cliff of the Bearreraig Sandstone Formation can be climbed by a steep gully on the northern corner of Cadha Carnach). Natural exposures of the Toarcian succession are rare, but the rocks can be exposed with a little effort and have been documented in the past (Lee, 1920).

Dating of the Scalpay Sandstone Formation in the Cadha Carnach section conies largely from the work of Howarth (1956, 1958), with some supplementary information about the lowermost part from Phelps (1985). The lowest beds (i and ii) have been placed in the Maculatum Subzone, but comparison with the Hallaig Shore GCR site suggests that they may be Ibex Zone. *Androgynoceras maculatum* and *Arieticeras* sp. in Bed v indicate the Maculatum Subzone, and *Aegoceras capricornus* in Bed 19 indicates the Capricornus Subzone, but the position of the subzonal boundary is uncertain. From

beds 21 to 26, Howarth (1956) recorded a good succession of amaltheid faunas, summarized on (Figure 8.10), indicating the presence of the Stokesi (Bed 21), Subnodosus (beds 22–24) and Gibbosus (beds 25–26) subzones. The age of Bed 27 is uncertain, though probably also Gibbosus Subzone since the lower part of Bed 28 contains early *Pleuroceras* (*P. transiens*) as well as *Amaltheus* from the lowermost Spinatum Zone (Apyrenum Subzone). The upper part of Bed 28 and beds 29–30 also yield Apyrenum Subzone *Pleuroceras,* but ammonites are rare in the overlying beds with only occasional *Pleuroceras spinatum* (Hawskerense Subzone) in the massive sandstone of Bed 36, which is thinner here than at Gualann na Leac (see Rubha na' Leac GCR site report). The lower calcareous bed (Bed 37) has not been recognized here.

The [British] Geological Survey (Lee, 1920) recorded specimens of *Dactylioceras,* indicating the Tenuicostatum Zone, from the top 1.8 m (6 ft) of the Scalpay Sandstone Formation. These records have been confirmed from elsewhere on Raasay, but the preservation is too poor for specific identification, so that subzonal attribution is not possible. The abruptness of the facies change to the overlying Portree Shale Formation suggests a hiatus representing part of the Tenuicostatum Zone, but this cannot be confirmed from the ammonite evidence.

Fewer details of facies and depositional environment are available than for the other Raasay GCR sites, but in general they appear similar. The Scalpay Sandstone Formation varies in grain size from silty shales to fine-grained sandstones. Three coarsening-up cycles can be identified here, as at Gualann na Leac, and are represented by beds i–20, beds 21–29, and beds 30–36. Both early- and late-diagenetic calcareous nodules and doggers occur. Fossils are scattered except for some nodules which are crowded with various types, especially brachiopods (see Ager, 1956a), and some layers with *Gryphaea* or *Pseudopecten.* Extensive bioturbation is evident throughout, though identifiable trace fossils are rare.

The Cadha Carnach GCR site includes some of the few localities on Raasay that expose the Portree Shale Formation, their value being enhanced by information gained from the exposure in Tait's trench. The thickness recorded here, 3.96 m, is greater than the 3 m at Gualann na Leac (see Rubha na' Leac GCR site report) or the 2.5 m at the opencast ironstone workings (Morton and Hudson, 1995), but is significantly less than on the Trotternish Peninsula of Skye (see Prince Charles' Cave to Holm GCR site report). At all these localities there is an abrupt facies change from sandstones to dark-grey shales, which become slightly coarser and more micaceous upwards. Towards the top, scattered chamositic ooliths are present, indicating an upward transition to the Raasay Ironstone Formation. No benthic fossils have been recorded, only ammonites and belemnites, suggesting deposition in an anoxic environment during an episode of sea-level rise. This correlates with the Exaratum Subzone global sea-level event identified by Jenkyns (1988; see Morton, 1989).

Buckman (in Lee, 1920) identified species of *Dactylioceras, Harpoceras* and *Peronoceras* in the material from Tait's trench, assigning the Portree Shale Formation to the Serpentinum Zone, with both the Falciferum and Exaratum subzones present. More recently these age assignments have been corrected on the basis of new collections made by Andrew B. Smith (of the Natural History Museum, London) at Bearreraig Bay and identified by Howarth (1992). This material suggests that only the Exaratum Subzone and possibly part of the Tenuicostatum Zone are represented in the Portree Shale Formation.

Above the Portree Shale Formation the Cadha Carnach GCR site exposes only a thinner more marginal facies of the Raasay Ironstone Formation than that seen at the type section in southern Raasay. Furthermore, the formation disappears completely towards the northern edge of the GCR site, although whether this is due to lateral thinning/facies change or to subsequent erosion before deposition of the Dun Caan Shale Member is unclear. Ammonites collected from the Raasay Ironstone Formation in Tait's trench were identified by Buckman (in Lee, 1920) as *Hildoceras bifrons* d'Orbigny (*non* Bruguiere), *Dactylioceras cf. crassiusculosum* and, in the upper part, *Coeloceras dayi.* They were interpreted as indicating a Bifrons Zone, Commune Subzone, age but with the *Dactylioceras* possibly remanié, an age assignment accepted by Arkell (1933), Hallam (1967a) and Howarth (in Cope *et al.,* 1980a). However, material collected by Andrew Smith and identified by Howarth (1992) included *Harpoceras falciferum, Hildoceras laticosta* and *Dactylioceras toxopborum,* indicating the Falciferum Subzone, and *Cleviceras elegans* indicating the top of the underlying Exaratum Subzone. There is no evidence on Raasay of younger ammonites within the Raasay Ironstone Formation, which contrasts with the presence of Thouarsense Zone ammonites in Ardnamurchan (Howarth, 1992).

The Raasay Ironstone Formation at Cadha Carnach contains carbonate and siderite ooliths scattered in a fine-grained matrix. This contrasts with the more ferruginous, coarser-grained and sometimes cross-bedded ironstone seen at the main outcrops in southern Raasay (see also Rubha na' Leac GCR site report). Interpretation of the depth of the depositional environment of the Raasay Ironstone Formation regionally is controversial — above wave-base in places (with cross-bedding, stromatolites) or below wave-base in a deep-water environment. The latter seems more likely at Cadha Carnach. Deposition occurred during an interval of sediment starvation caused by sea-level rise (Hesselbo and Jenkyns, 1998) and/or tectonic stability (Morton, 1989). Supporting evidence includes the occurrence of a belemnite lag, with *Dactyloteuthis, at* the top of the ironstone.

Most of the fossils collected by Tait from the Dun Caan Shale Member were ammonites, which were submitted to S.S. Buckman (in Lee, 1920). Buckman's identifications were summarized in his table I (In Lee, 1920), together with the collector's detailed stratigraphy given in feet below a thin limestone bed crowded with ammonites (*Leioceras* 'spp.' which would now be classified as of the *L. comptum* group) belonging to the lower Aalenian Opalinum Zone. This work has never been superseded or independently verified, but is probably reliable because Buckman had recently monographed (1887–1907) the ammonites of this age in southern England and hence was very familiar with the faunas even though those from Raasay are crushed. Selected species are recorded in (Figure 8.10).

Within the Dun Caan Shale Member Buckman (in Lee, 1920) distinguished an upper Venustula Zone 4.9 m (16 ft) thick, and a lower Aalensis Zone proper 16.8 m (49 ft — should be 55 ft, corrected from table I) thick. In the appendix Buckman gave further details (table I and p. 67) and, comparing the Raasay succession with that in the Bridport Sand at Chideock, Dorset (Buckman, 1910), was able to identify three hemerae. Based on his identifications and comments on the faunas, the following characteristic morphological features can be recognized:

(iii) an upper Venustula Hemera (4.90 m) characterized by very finely ribbed ammonites in some of which 'bundling' of the ribs occurs, including *Pleydellia* (*Canavarina*)*venustula* and *Pleurolytoceras leckenbyi.*

(ii) A middle Digna Hemera (5.80 m) characterized by well-ribbed ammonites with clear separate ribs which curve onto the venter, including *Pleydellia* (*Canavarina*)*digna,* forms transitional from this to *P.* (*C.*) *steinmanni,* and *Pleurolytoceras leckenbyi.*

(i) A lower Cotteswoldia Hemera (11.00 m) characterized by ammonites with strong distant ribs which fade before the venter and also towards the aperture, including *Pleydellia* (*Cotteswoldia*) *subcandida, P.* (*C.*) *costulata, P. aalensis, P.* (*Walkericeras*) cf *burtonense, P. subcompta.*

These faunal subdivisions of the Aalensis Zone on Raasay appear to be comparable with the subzones recognized in Spain by Goy and Ureta (1991), as shown here in (Figure 8.10). The lowest *Pleydellia* appear to have been found less than 0.20 m above the Raasay Ironstone Formation, while belemnites of the *Megateuthis tripartitus* group occur immediately above the ironstone as well as higher. These confirm the occurrence of a major hiatus in the Toarcian succession of the Hebrides identified by Buckman (Morton, 1989). The top 1.2 m (4 ft) as described by Buckman contain the first *Leioceras* (*Cypholioceras*)*opaliniforme* (*sensu* Buckman) as well as *Pleydellia* (*Walkericeras*)*subglabrum.* They were placed in Buckman's Opaliniforme Hemera, now basal Aalenian Opalinum Zone. However, the shales at this level include some limestone beds which, in comparison with the Beinn na Leac section (see Morton and Hudson, 1995) would be included in the basal part of the Beinn na Leac Sandstone Member.

The lithology of the Dun Caan Shale Member is apparently uniform except for slight upwards coarsening and occasional shelly layers which suggest episodes of relative sediment starvation. It marks a return to deposition in a strongly subsiding basin, which at Cadha Carnach possibly lay below wave-base in a dysaerobic environment. This follows a long interval of stability which resulted in the Toarcian hiatus (see Morton, 1989).

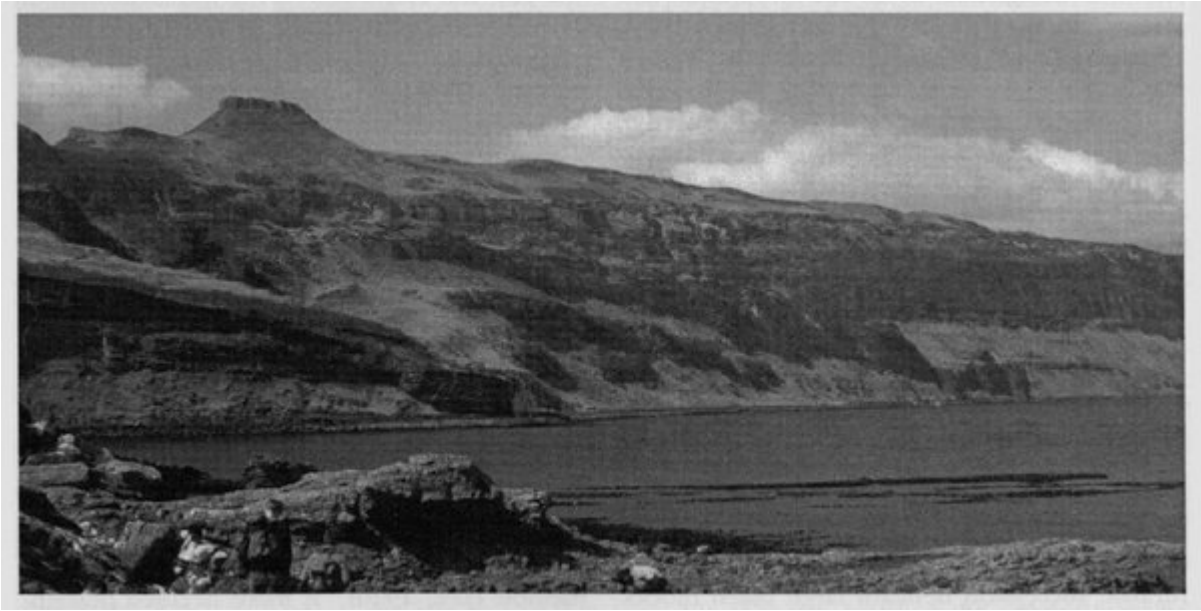
Conclusions

The Cadha Carnach GCR site makes available steep, but largely accessible, Lower and Middle Jurassic sections (excluding parts of the vertical cliff of the Bearreraig Sandstone Formation). The section in the Scalpay Sandstone

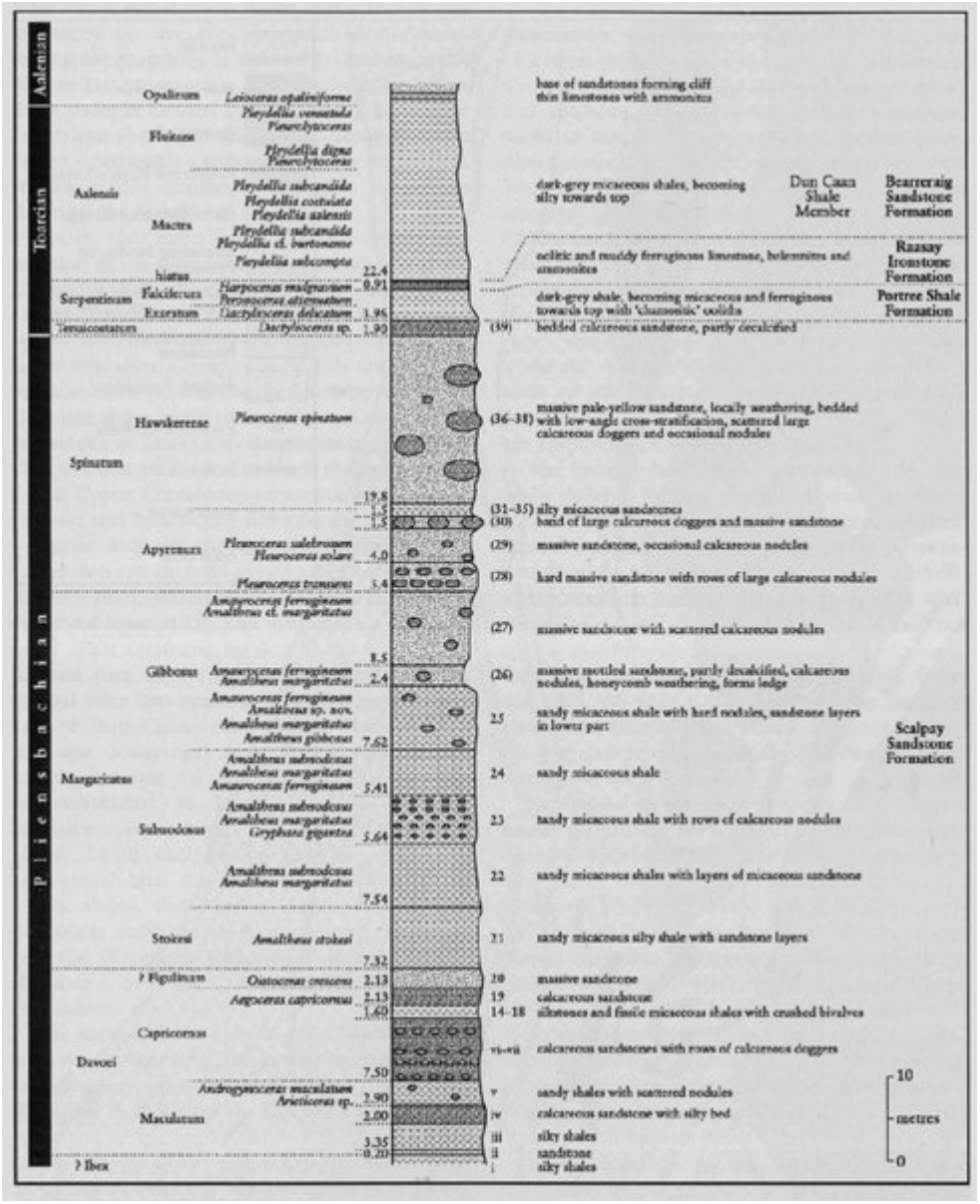
Formation complements those farther south on Raasay, in the Hallaig Shore and Rubha na' Leac GCR sites. It is particularly important for the succession of Upper Pliensbachian ammonite faunas in the Margaritatus and lower Spinatum zones.

The GCR site is also of importance for understanding the Toarcian history of the Hebrides, especially the section exposed by the [British] Geological Survey in the trench excavated by Tait. The ammonites found there enabled S.S. Buckman to identify a major hiatus representing much of the Toarcian Stage, since confirmed as including the Bifrons to Pseudoradiosa (excluding Aalensis) zones. The ammonites collected from the Dun Caan Shale Member in the trench, the type section of this lithostratigraphical unit, were also identified and reported by Buckman. This collection, which has not yet been replicated, provides important evidence about the detailed succession of ammonite faunal horizons in Britain. It has also enabled comparisons to be made with the Iberian subzonal scheme.

References



(Figure 8.8) View from Rubha na' Leac of the prominent peak of Dun Caan and the cliffs of Drum an Aonaich and Cadha Carnach. The main cliff is of Bearreraig Sandstone Formation above a slope developed on the Portree Shale and Raasay Ironstone formations, with the Scalpay Sandstone Formation forming the lower part of the cliff down to sea level. (Photo: N. Morton.)



(Figure 8.10) Succession from the Scalpay Sandstone Formation to the Dun Caan Shale Member north-east of Dun Caan, Isle of Raasay, based on Howarth (1956), Lee (1920) and Morton (unpublished). Bed numbers for the Scalpay Sandstone Formation are modified from those of Howarth, in brackets where this was based on other localities on Raasay.