4 Rubha a' Mhail, Islay

[NR 377 781]–[NR 426 793]

P.W.G. Tanner

Published in: The Dalradian rocks of the south-west Grampian Highlands of Scotland. PGA 124 (1–2) 2013 https://doi.org/10.1016/j.pgeola.2012.07.008. Also on NORA

4.1 Introduction

This rocky, isolated stretch of coastline at the northern tip of Islay (Figure 2.1), with its raised beaches, sea cliffs and caves, presents a number of magnificent sections through members 3 and 4 of the Bonahaven Dolomite Formation. The stratigraphical succession is a continuation of that seen at the *Caol Isla* GCR site, in which the lower two members of the Bonahaven Dolomite are best preserved. Although the outcrop of Member 3 is displaced a number of times by faulting, marker horizons in the sequence can be correlated for up to 3 km along strike. An abrupt change in thickness of this member in the west of the section is interpreted as being the result of movement on an important syndepositional listric discontinuity, the Bolsa Fault. At the top of the sequence there is a transitional contact between Member 4 and the younger Jura Quartzite Formation.

This GCR site is renowned for its outstanding 3-dimensional exposures and natural sections through both isolated, rounded stromatolite bodies (bioherms), and stratiform, continuous stromatolite beds (biostromes). Stromatolites are algal bodies that originated as thin, slimy surface films, called microbial mats, which trapped fine-grained carbonate sediment as they grew and progressively accreted into symmetrical masses or layers up to several metres across. The algal filaments are no longer preserved, but evidence of microbial growth is preserved by numerous, parallel, millimetre-scale laminations, now largely of dolomite. This laminar texture can be seen clearly where erosion has exposed the interior of these ball-like and sheet-like structures.

The locality lies astride the complex hinge-zone of the F1 Islay Anticline (Bailey, 1917), and the rocks are more highly strained than at the *Caol Isla* GCR site, with the development of large open folds, a penetrative cleavage oblique to bedding, and an evident distortion of angular relationships between sediment-filled cracks and the bedding planes (Borradaile and Johnson, 1973). The rocks belong to the greenschist facies, with the local development of phlogopite in metacarbonate rocks suggesting that temperatures of around 400°C were reached during the regional metamorphism (Fairchild, 1980c).

This part of Islay appears not to have been visited by the early geological travellers in the Western Isles such as MacCulloch and Thomson, and the earliest work was carried out by the Geological Survey (Wilkinson, 1907; Bailey, 1917) and Green (1924). Allison (1933) confirmed Bailey's (1917) stratigraphical sequence by the use of way-up structures, and published the first detailed sketch map of part of the site. Spencer (1972) established the current informal subdivision of the Bonahaven Dolomite into 4 units and prepared a detailed map of the whole section. However, it is Fairchild to whom we largely owe our current understanding of these rocks. With rare perseverance he has investigated in minute detail the stratigraphy, structure, petrography, chemistry, and other aspects of the formation (Fairchild, 1977, 1980a, 1980b, 1980c, 1985, 1989), and the description of the rocks given here relies heavily on his field guide to the section (Fairchild, 1991).

4.2 Description

The eastern end of the GCR site around Rhuvaal Lighthouse (1 km east of the east end of the section shown in (Figure 2.9)) is in the Jura Quartzite, but the main interest lies in the folded and faulted outcrops of members 3 and 4 of the Bonahaven Dolomite Formation. The Dalradian rocks are cut by numerous NW-trending dolerite dykes of Palaeogene age, which act as convenient waymarks in the section.

Member 3 is up to 200 m thick and forms two main outcrops west of Bagh an Da Dhoruis (Figure 2.9). The base is seen at only one locality, immediately west of the Bolsa Fault at [NR 385 780]. The member consists almost entirely of fine-grained dolomitic rocks, with abundant sedimentary structures, which may be divided into three facies (Fairchild, 1980b):

1. rocks consisting of one-centimetre-scale alternations of dolomitic metasandstone and metamudstone;
2. cross-stratified dolomitic metasandstones (to 3 m thick) and lesser pure metadolostone interbeds; and
3. stromatolitic beds, of which ten continuous stromatolitic units (biostromes) are recognized.

Stromatolites showing columnar and domal forms are seen at [NR 410 788]; outstanding exposures showing clusters of ellipsoidal and bun-shaped stromatolites of different sizes are found at [NR 407 789] (Figure 2.10)a; and a number of large bioherms, several metres across, are seen at [NR 387 782] (Figure 2.10)b, where they lie in beds folded by F1 folds with axial planes dipping eastwards.

Special features of these rocks, which give a clue as to their environment of deposition, include shrinkage cracks, stromatolite flake breccias, and quartz-calcite nodules. They are accompanied by abundant cross-lamination, ripple marks on a variety of scales (up to 0.22 m in wavelength), graded bedding, and some striking examples of load structures (Fairchild, 1991). The shrinkage cracks are filled with fine-grained dolomitic material, and are seen as pale-coloured dykelets, up to 0.5 cm wide and 3 cm (exceptionally 40 cm) long, which in cross-section are seen to descend from the bases of beds (Spencer and Spencer, 1972; Borradaile and Johnson, 1973; Fairchild, 1980b). They are commonly ptygmatically folded, and form an irregular or incomplete polygonal pattern in plan view on the bedding surface. The shrinkage cracks can be seen at [NR 408 709] and are particularly well exposed at [NR 390 783], where they can be examined in three dimensions on small sea stacks scoured clean by the sea.

The stromatolite flake breccias are seen at [NR 387 782]. They are intriguing structures, which occur as randomly arranged aggregates of broken stromatolite laminae that occupy either shallow hollows on the surface of a bed or, less likely, partially eroded and then filled, desiccation cracks. The quartz-calcite nodules are clearly seen in cross-section on wave-scoured surfaces on an old sea stack near [NR 390 783] and are deformed within a near-vertical cleavage.

Member 4 is 40–62 m thick and consists of slaty metasiltstones and fine-grained metasandstones. The base is well exposed in Bagh an Da Dhoruis near [NR 410 788] (Figure 2.9), and the member includes a 10 m-thick massive metadolostone, exposed at [NR 400 784].

The Jura Quartzite forms a large outcrop at the east end of the GCR site on Rubha a'Mhail, and a transitional contact with the underlying Bonahaven Dolomite is seen in the cliffs at [NR 412 787]. The quartzite is repeated by folding in the middle of the section, between [NR 391 781] and [NR 399 783], and crops out within and west of the Bolsa Fault (Figure 2.9)b. It is a well-bedded, white-weathering, meta-quartz-arenite with some cross-bedding.

Stromatolites were first recognized by Wilkinson (in Peach and Horne, 1930), and were figured from the Rubha a'Mhail section at Bagh an Da Dhoruis by Anderson (1951, fig. 7), followed by Spencer and Spencer (1972). The biostromes form stratiform layers 0.1–4 m thick (generally 1–2 m), which consist of laminated yellow-brown dolomite with a characteristic 'elephant-skin' texture on the weathered surface. The laminae are 0.5–2 mm thick, and consist of alternating dark (finer grained) and lighter (coarser grained) dolomitic layers whose microstructure has been studied in detail by Fairchild (1980b). They generally form regular layers and rarely develop the columnar forms seen in some stromatolites. These horizons are accompanied by bioherms consisting of families of extraordinary-looking and beautifully exposed spheroidal to ellipsoidal stromatolite bodies, which can be examined in their position of growth on the bedding planes. These bodies are from 10 cm to several metres in diameter.

The major anticlinal closure seen in the eastern outcrop of Member 3 in this section plunges southwards and is accompanied by a number of minor folds (Figure 2.9)c. The latter are up to tens of metres in wavelength and, together with a steeply dipping slaty cleavage, are generally congruous to the major structure (Fairchild, 1977). The western limb of this fold has been affected by two major faults, which throw down to the east and cause a double repetition of members 3 and 4 (Figure 2.9)b. The complex fault-zone of one of these dislocations, the Bolsa Fault, can be examined at

[NR 386 780].

Borradaile and Johnson (1973) estimated the strain that has affected Member 3, by measuring the angular relationships between the penetrative cleavage, the filled dykelets and the bedding planes in these rocks. They assumed that, regardless of their origin, the dykelets would have formed initially at right angles to the bedding surfaces, and used the present angles made with bedding and cleavage to calculate the amount of strain at 5 localities within this GCR site. The measured strains indicate that the measured stratigraphical thickness is only 50–70 % of the original thickness.

4.3 Interpretation

Minor features having a direct bearing on the environmental setting of these rocks are discussed first. The precise origin of the sediment-filled cracks in the dolomitic metasandstone–metamudstone sequence is uncertain, but they must have formed by some form of contraction in the plane of the bedding, either by subaerial desiccation, interstratal dewatering, or synaeresis (Spencer and Spencer, 1972; Borradaile and Johnson, 1973; Fairchild, 1980b). The latter origin was favoured by all of these authors, but the actual mechanism by which this process takes place is not clear, and no unambiguous natural examples of synaeresis cracks have been reported (see Tanner, 1998a for discussion). The cracks closely resemble those from the Devonian rocks of Caithness, which were interpreted as synaeresis cracks by Donovan and Foster (1972), but as desiccation cracks by Astin and Rogers (1991).

The stromatolite flake breccias are very distinctive and are derived from the local breakdown or erosion of stromatolite bodies. This process does not involve subaerial exposure of the sediment surface, and the fragments could have been swept by currents into depressions or even into synaeresis cracks at the sediment–water interface. Fairchild (1985) considered the quartz-calcite nodules to be secondary after anhydrite, despite earlier doubts (Fairchild, 1980b).

Sedimentological analysis has shown that Member 3 was deposited in a shallow-water environment (Fairchild, 1980b, 1989). The layered facies represents a broad lagoonal environment, with local emergence that was affected by infrequent storms; the sandstone facies was deposited in lower intertidal sandflats; and the stromatolitic facies was mainly subtidal, with some intertidal development. Overall, the finely crystalline carbonate rocks, ooids, and pseudomorphs after (?)anhydrite, indicate semi-arid conditions and a warm climate. The petrography and carbonate chemistry of the dolomitic rocks were described by Fairchild (1980b, 1985). The dolomites are rich in Fe and Mn, and dolomitization occurred before burial and penecontemporaneous with sedimentation. Unfortunately the stromatolites are not suitable for taxonomic study, do not yield any useful chronostratigraphical information and could have grown in either warm or cold water conditions.

Five independent lines of evidence, including wave-ripple geometries and lateral facies relationships, indicate that Member 3 was derived from a landmass to the north-west (Fairchild, 1989). Current directions from cross-strata are weakly bimodal or show no preferred direction (Fairchild, 1980b).

Member 4 is also of shallow-water origin, with the thick metadolostone having been deposited in a supratidal-flat environment (Fairchild, 1991). It is succeeded, by the tidal-shelf Jura Quartzite.

The Islay Anticline was first recognized by Bailey (1917), who considered it to be a ‘secondary’ structure. Later workers (Roberts, 1974; Fairchild, 1977) concluded that it is a major primary (D1) structure but it has a number of anomalous features. For example, the structure of its closure at this GCR site, where it is best exposed, is not fully understood. Over most of Islay, the anticline plunges and closes to the north, but at this GCR site the closure plunges south, suggesting that the Bonahaven Dolomite Formation has been brought back to ground level by a plunge culmination in the major structure. However, there is an area (between [NR 398 787] and [NR 410 788] which has an ‘anomalous’ cleavage orientation (Fairchild, 1977), suggesting that there may be a cleavage that pre-dates the main cleavage associated with the Islay Anticline. These structural problems clearly warrant further investigation. Another interesting structural aspect of the area is that the Bolsa Fault is inferred, from an abrupt change in thickness of Member 3 across the fault-zone, to have been active during sedimentation (Fairchild, 1980c; Anderton, 1985).

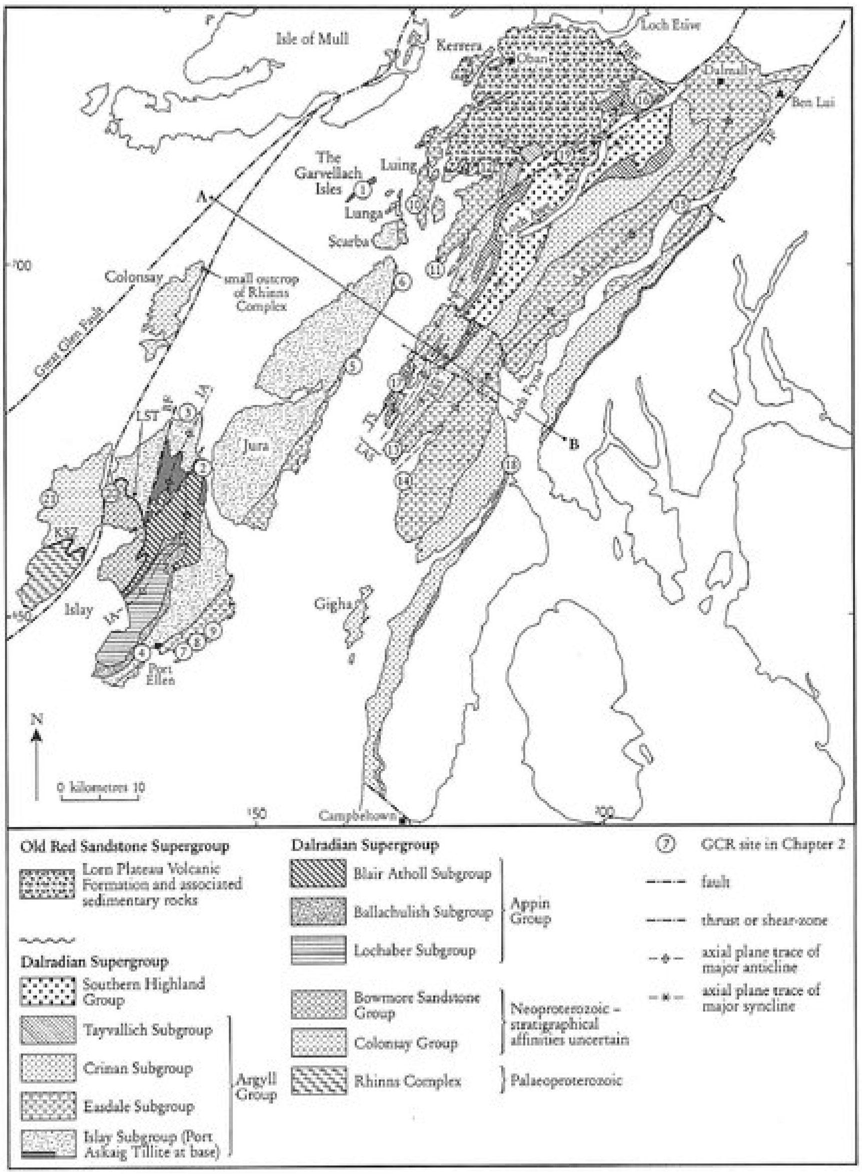
4.4 Conclusions

The Rubha a'Mhail GCR site is of international importance for the excellent state of preservation, in three dimensions, and in their position of growth, of fossil algal bodies (stromatolites). These are amongst the most primitive fossil forms to be preserved in the geological record, and pre-date the evolution of more advanced organisms, the metazoans, which used them as a food source. Stromatolites originated as a microbial slime, which coated the sea floor and, by trapping grains of sediment, enabled a variety of different forms to develop. At this locality, these range from continuous layers to a variety of intriguing spheroidal and elliptical bodies up to 3 m across. The range in morphological types, and excellent state of preservation of these stromatolites is unique in the Precambrian rocks of the British Isles, and they are of value for future study.

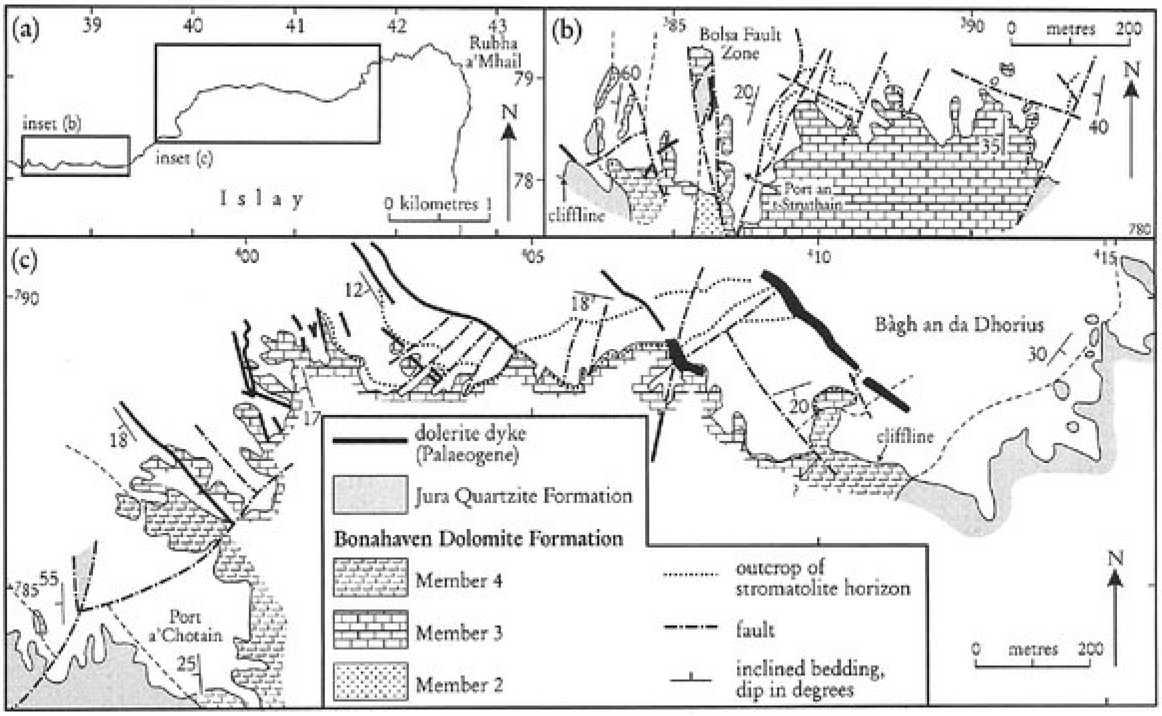
Sedimentary structures at this GCR site show that the stromatolites grew within a sequence of rocks that was deposited in a shallow-water, subtidal to intertidal environment. Due to the low degree of metamorphism and deformation, the mode of formation of these organisms, and their relationship to bedding and other sedimentary structures can be examined in detail. Some problematical small-scale structures found only at this site could shed more light on the environment in which the stromatolites thrived. These include possible desiccation cracks and pseudomorphs after anhydrite (calcium sulphate, normally formed by the evaporation of seawater and hence indicating a warm climate).

The dolomitic rocks described from here and the *Caol Isla* GCR site overlie the Port Askaig Tillite, and this site has provided a type section for a detailed comparison with dolostones associated with other late-Precambrian tillites, in particular those in East Greenland (Fairchild, 1989).

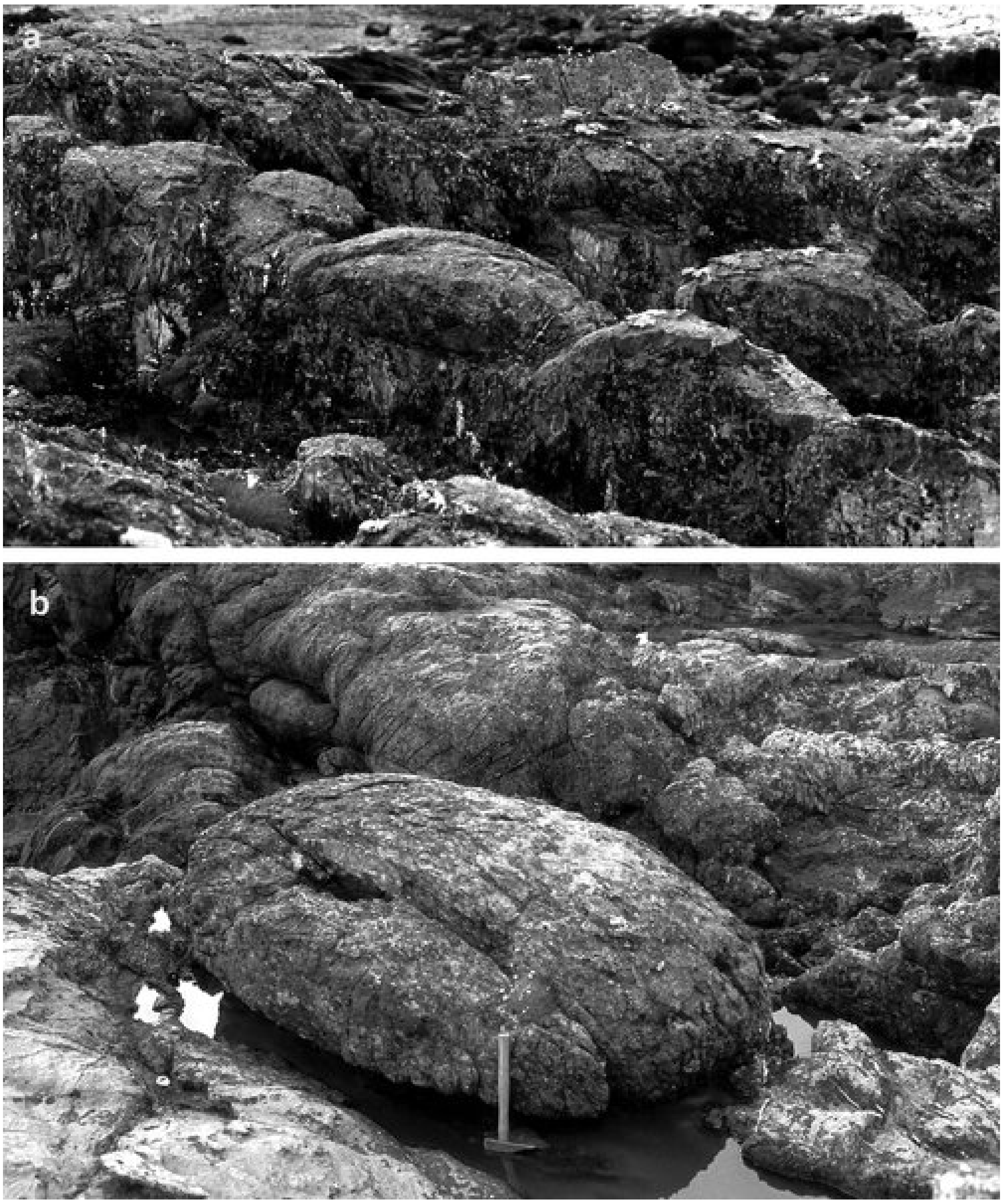
References



(Figure 2.1) Map of the South-west Grampian Highlands showing subgroups of the Dalradian Supergroup, the axial plane traces of major folds, the line of section A–B on (Figure 2.3) and the locations of the GCR sites included in this chapter. Only areas described in Chapter 2 are ornamented. GCR sites: 1 Garvellach Isles, 2 Caol Isla, Islay, 3 Rubha a'Mhail, Islay, 4 Kilnaughton Bay, Islay, 5 Lussa Bay, Jura, 6 Kinuachdrach, Jura, 7 Surnaig Farm, Islay, 8 Ardbeg, Islay, 9 Ardilistry Bay, Islay, 10 Black Mill Bay, Luing, 11 Craignish Point, 12 Fearnach Bay, 13 Kilmory Bay, 14 Port Cill Maluaig, 15 Strone Point, 16 Kilchrenan burn and shore, 17 West Tayvallich peninsula, 18 South Bay, Barmore Island, 19 Loch Avich, 20 Bun-an-Uillt, Islay, 21 Kilchiaran to Ardnave Point, Islay. Abbreviations: AA Ardrishaig Anticline, BF Bolsa Fault, IA Islay Anticline, KBS Kilmory Bay Syncline, KSZ Kilchiaran Shear-zone, LAS Loch Awe Syncline, LGF Loch Gruinart Fault, LST Loch Skerrols Thrust, PBF Pass of Brander Fault, TF Tyndrum Fault, TS Tayvallich Syncline.



(Figure 2.9) Map of the coastal section at the Rubha a'Mhail, Isle of Islay, after Fairchild, (1991). The outline map (a) shows the locations of detailed sections (b) and (c).



(Figure 2.10) Stromatolite bodies from Member 3 of the Bonahaven Dolomite Formation, north-east of Port a'Chotain, Rubha a'Mhail GCR site, Isle of Islay. (a) Domal stromatolite bioherms at Bagh an da Dhorius, [NR 410 788]. Hammer shaft (arrowed) is 47cm long. (b) Large bioherm at [NR 407 789]. Hammer shaft is 47 cm long. (Photos: P.W.G. Tanner.)