3 Caol Isla, Islay

[NR 429 701]–[NR 429 710]

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3.1 Introduction

The coastal rock platform and low cliffs north of the Caol Isla Distillery, on the east coast of the Isle of Islay (Figure 2.1), provide excellent exposures of rocks belonging to the uppermost part of the Port Askaig Tillite Formation and the lower part of the overlying Bonahaven Dolomite Formation, interpreted by some as a cap carbonate. The gently dipping metasedimentary rocks are on the east limb of the F1 Islay Anticline. The Dalradian rocks in this part of Islay show little evidence of deformation, and have been affected by only low-grade (greenschist-facies) metamorphism.

The main Dalradian lithological units on Islay such as the 'Dolomitic Group' at Caol Isla were recognized by the Geological Survey (Wilkinson, 1907), but were not placed into their correct stratigraphical sequence until the work of Bailey (1917). In one of the first studies to use sedimentary 'way-up' structures in metamorphic rocks in the British Isles, Allison (1933) confirmed Bailey's interpretation that the 'Dolomitic Group' lies stratigraphically between the older, Port Askaig Tillite, and the Jura Quartzite above. Spencer and Spencer (1972) later combined groups 3–5 of Wilkinson (1907) to erect the Bonahaven Dolomite Formation, which is made up of four members and has a maximum total thickness of some 350 m (Fairchild, 1991, fig. 14). Wilkinson (1907) included a cross-section, and the rocks were mapped in detail by Spencer (1971). An excellent field guide is provided by Fairchild (1991).

The GCR site encompasses the best-exposed section through members 1 and 2 of the Bonahaven Dolomite Formation, the main focus being on the five units that make up Member 1. Members 3 and 4 of this formation are much better exposed on the north coast of Islay and are the subject of the *Rubha a'Mhail* GCR site report. The rocks at Caol Isla preserve a great variety of sedimentary structures characteristic of a tidal-dominated shelf environment (Klein, 1970; Kessler and Gollop, 1988). Of particular note are sand-filled cracks in alternating sandstone–mudstone sequences that give rise to well-organized polygonal patterns on bedding surfaces. These patterns reach over 10 cm in diameter, and have been variously interpreted as 'sun-cracks' indicative of subaerial exposure and drying out of mud layers; synaeresis structures formed at the water–sediment interface; or sections through dykelets resulting from dewatering of the sediment pile during burial. Considerable interest in these rocks was aroused briefly by the report by Brasier and McIlroy (1998) of fossil faecal pellets, of a type produced by the earliest organisms to have developed a gut capable of expelling such material. This identification has been subsequently retracted (Brasier and Shields, 2000).

3.2 Description

The rocks in the section at Caol Isla dip at 22–28° to the north, are right-way-up, and are unaffected by any major faults. The succession starts at the top of the Con Tom Member of the Port Askaig Tillite Formation (Member 5 of Spencer, 1971), and includes members 1–3 of the Bonahaven Dolomite Formation (Figure 2.7). There is a transitional contact between the Port Askaig Tillite and the Bonahaven Dolomite. In the vicinity of Caol Isla, Member 1 is seen only on the coastal section due to a local erosion surface having developed at this level farther inland, towards the inferred edge of the original sedimentary basin (Fairchild, 1991). This member is divided into 5 units, for which sedimentary logs were presented by Fairchild (1991, fig. 17).

Before describing the rocks from this site it is necessary first to clear up confusion over the previous stratigraphical nomenclature. Bailey (1917) introduced the term 'Lower Fine-grained Quartzite' to describe a thick quartzite, which occurs between the Port Askaig Tillite and the 'Dolomitic Group', to distinguish it from the Jura Quartzite (his 'Upper

Fine-grained Quartzite'), which lies above the 'Dolomitic Group'. Klein (1970) misused this term (Spencer, 1971; Klein, 1971) to include part of the 'Dolomitic Group', and both Kessler and Gollop (1988) and Tanner (1998a) perpetuated this misuse for historical reasons. The correct reading of the stratigraphy of this section (as followed here) is that the Con Tom Member of the Port Askaig Tillite (Bailey's 'Lower Fine-grained Quartzite') is succeeded by Member 1 of the Bonahaven Dolomite Formation. Most of the rocks described by Klein (1970), and all of those studied by Kessler and Gollop (1988), and Tanner (1998a), occur within the Bonahaven Dolomite Formation.

3.2.1 Member 1. (Carraig Artair Member, BGS, 1997)

Unit 1 (Figure 2.7) consists of metamudstones and appears to be conformable with the underlying Port Askaig Tillite. Exceptionally, a slaty cleavage cut by a crenulation cleavage affects the metamudstone by the shelter at Carraig Artair [NR 4292 7020] and even more unexpectedly, for a sequence of rocks which appear to be so little deformed and of very low metamorphic grade, metamorphic biotite is developed (Fairchild, 1985, fig. 3e).

Unit 2 consists of up to 18 m of flaser-bedded and rippled metasandstones.

Unit 3 is highly significant in that the cross-bedded metasandstones that make up this unit include a metaconglomerate at the base (at [NR 4294 7029]), which contains 'exotic' granitic clasts similar to those found throughout the upper part of the Port Askaig Tillite. This metaconglomerate is the youngest bed in the Bonahaven Dolomitic Formation to preserve glacially transported material, albeit reworked by current action, and this occurrence provides a link between this formation and the underlying Port Askaig Tillite.

Unit 4, comprising interbedded metasandstones, metasiltstones, and metamudstones, is well exposed in a small cliff and rocky promontory at Leac Thiolastaraidh [NR 4297 7037], 370 m north of the pier at Caol Isla Distillery, and its sedimentary structures and lithofacies have been closely studied by a number of workers. Klein (1970, figs 2–4) illustrated cross-lamination, flaser bedding, and two intersecting sets of ripple marks from this locality. Kessler and Gollop (1988) visited the cliff face at Leac Thiolastaraidh and published a measured 14 m section, from which they recorded the possible presence of desiccated algal mats at a number of levels; channels (including 'gutter casts') containing cross-bedded strata; possible hummocky and swaley cross-stratification; ripples; and cross-sets with irregularly-spaced foreset laminae of tidal origin (the 'tidal bundles' of Boersma, 1969).

'Sun-cracks' were first reported from these rocks (together with ripple marks) by Thomson (1877). They occur as sand-filled cracks in alternating sandstone–mudstone sequences and form polygonal patterns on bedding surfaces (Figure 2.8)a. The polygons commonly form orthogonal patterns (in which the majority of the cracks meet at right angles) and vary from centimetre-scale to larger structures over 20 cm across. Within the larger structures, a basic framework of cracks over 1 cm wide divide the surface into crude polygonal shapes, within which sets of thinner cracks define a second-order pattern. Tanner (1998a) analysed their 3-D morphology in detail, based on slabbed and sectioned material, and found that many of the cracks could be traced through a number of different beds.

These rocks also contain possible fossil remains; Fairchild (1977) recorded the presence of numerous phengite spherules, 50–150 mm across, which he considered to be possible glauconitized microfossils, from a metamudstone at the top of Member 1 in an equivalent section farther north at Bonahaven (not exposed in the Caol Islay section).

Unit 5 consists of a poorly exposed, honeycomb-weathered, dolomitic metasandstone.

3.2.2 Member 2. (Giur Bheinn Member, BGS, 1997)

This member is a cross-bedded meta-quartz-arenite, some 30 m thick, exposed in a small cliff section at [NR 4293 7044] (Figure 2.7). It is of historical interest, for this horizon was named the 'Pipe Rock' by Peach (in Wilkinson, 1907) and, together with the other weakly deformed and metamorphosed mudstones, quartzites, and carbonate rocks on Islay, was inferred to be of Cambro-Ordovician age, and incorrectly correlated with the foreland sequence in the North-west Highlands.

3.2.3 Member 3. (Margadale Member, BGS, 1997)

In-situ dolomitic metasandstones belonging to this member are uncommon but there are many large tumbled blocks along the tide line. It was correlated with the 'Fucoid Beds' by Peach (in Wilkinson, 1907) and Peach and Horne (1930), but neither Bailey (1917) nor any subsequent workers (e.g. Fairchild, 1977) have been able to confirm the presence of 'small pipes', 'ordinary pipes' and 'trumpet pipes' in the 'Pipe Rock' (Peach and Horne, 1930), or 'worm-casts' in this member. These structures are artifacts associated with the patterns of filled cracks seen on bedding surfaces and in cross-section, in both metasandstones and metacarbonate rocks of the Bonahaven Formation. Some of these filled cracks have been strongly affected by bedding-normal compaction and the small buckle folds appear vermiform in cross-section.

3.3 Interpretation

In one of the first sedimentological studies of Dalradian rocks, Klein (1970) identified a wide range of sedimentary structures including cross-bedding, ripple marks, 'tidal bedding', and flaser bedding, in the section north of Caol Isla Distillery. He concluded that the sequence had been deposited in a tide-dominated, shallow water environment. Unfortunately, as pointed out by Spencer (1972), this study suffered from a lack of stratigraphical control and appears to encompass both the metasandstones immediately north of the distillery, which belong to the top of the Port Askaig Tillite, and members 1 and 2 of the Bonahaven Formation.

From their detailed study of part of Unit 4 in Member 1, Kessler and Gollop (1988) concluded that the depositional environment was transitional between that of a shallow shelf or shoreface and an intertidal setting. However recognition of the 'intertidal' setting relies in part upon their interpretation of the polygonal sets of sand and silt-filled cracks having formed by the subaerial desiccation of 'algal mats'. Thin sections of these rocks show micro-cross-laminated silty layers alternating with homogeneous, non-laminated muddy layers (Tanner, 1998a, fig. 9), with no suggestion of the mediation of desiccated microbial mats in the formation of the filled cracks. From a study of the complete section, Fairchild (1991) concluded that units 1 and 2 were deposited in a nearshore, wave-dominated situation, which became landward of a barrier island during the time that units 4 and 5 were laid down, followed by an eventual drowning of the barrier system (Member 2). Fairchild (1980a) also studied the origin of the dolomite in these rocks and concluded that it formed in two stages; penecontemporaneous with sedimentation, and during burial diagenesis.

Following Thomson (1877), most workers have interpreted the polygonal patterns seen on the bedding surfaces as 'sun cracks' (Knill, 1963) or mud cracks (Klein, 1970; Fairchild, 1991) which had formed as a result of desiccation during subaerial exposure, and had been infilled subsequently with sand. From a detailed study of the filled cracks, Tanner (1998a) concluded that they are sections through 3-D patterns of dykelets resulting from interstratal dewatering of the sediments, possibly soon after their deposition, with no evidence of subaerial exposure (Figure 2.8)b. However, it is not clear what caused the homogeneous, layer-parallel contraction in the mudstone layers. There are two possibilities: it could have been triggered by earth tremors associated with movements on the synsedimentary Bolsa Fault (Figure 2.1) (see the *Rubha a'Mhail* GCR site report) or a related structure (Tanner, 1998a), or simply be the result of uniform contraction of material held together by microbial slime, as the latter decayed. The second explanation is the less likely, for, apart from the lack of evidence for its presence, such algal growths usually develop in calcareous not muddy rocks.

The rocks show little evidence of having been deformed, apart from the sporadic development of a slaty cleavage (generally only visible in thin section), and the slight distortion of some of the polygonal patterns seen on the bedding surfaces. The local presence of metamorphic biotite is consistent with greenschist-facies regional metamorphism. It is of historical interest to note that, in an attempt to date this metamorphic event in these low-grade Dalradian rocks, Leggo *et al.* (1966) obtained a Rb-Sr isochron apparent age of 572 ± 20 Ma from samples of metasandstone collected from the small cliff at Leac Thiolastaraidh. The result remains enigmatic.

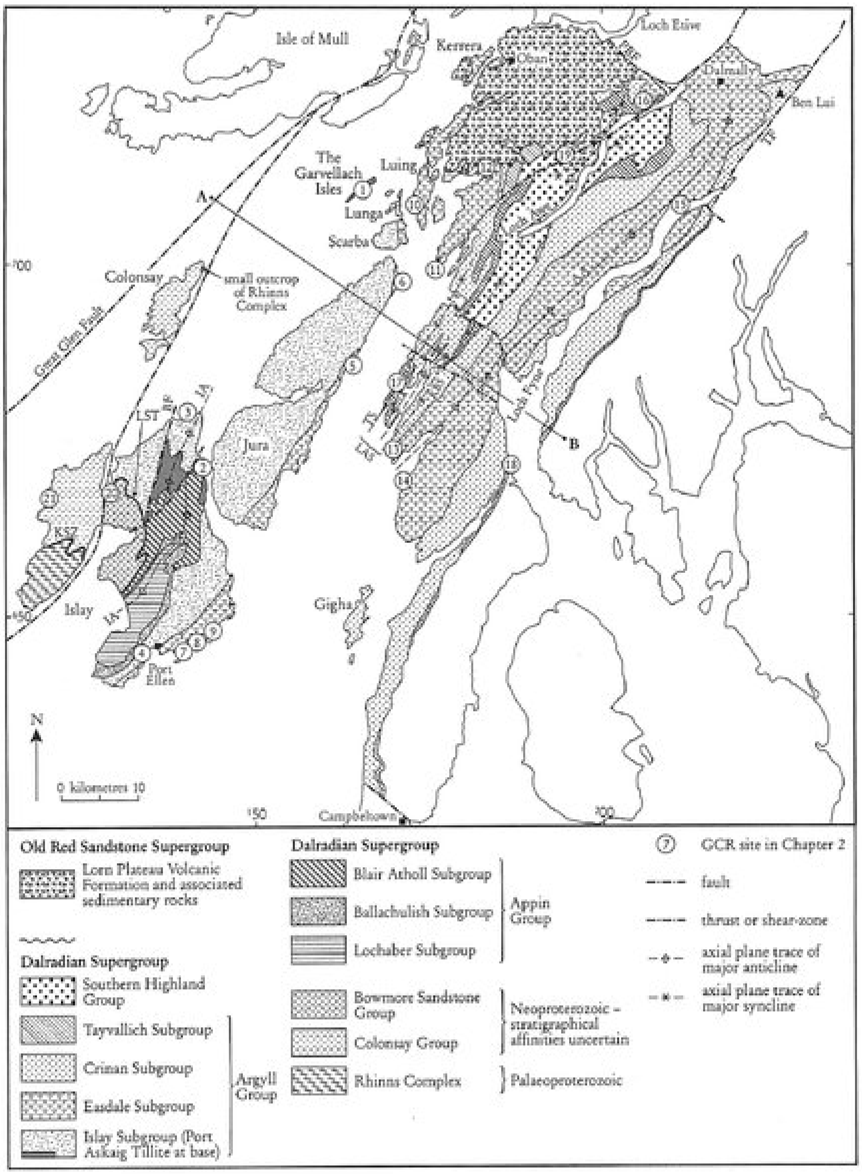
Late-Precambrian tillites are characterized by having a 'cap' of carbonate rocks, whose significance is the subject of current worldwide research interest, and Fairchild (1993) has suggested that the Bonahaven Dolomite is the 'cap carbonate' to the Port Askaig Tillite, though this has been disputed by others. The paradox presented by these carbonate rocks is that they are usually considered to have formed in a warm or temperate climate, so their presence could require a rapid, unexplained, change in climate immediately following the glacial event. Alternatively, deposition of carbonate rocks both before and after the glacial event could have taken place in cold water conditions. It is therefore important to determine the precise climatic conditions under which the cap carbonate was laid down.

3.4 Conclusions

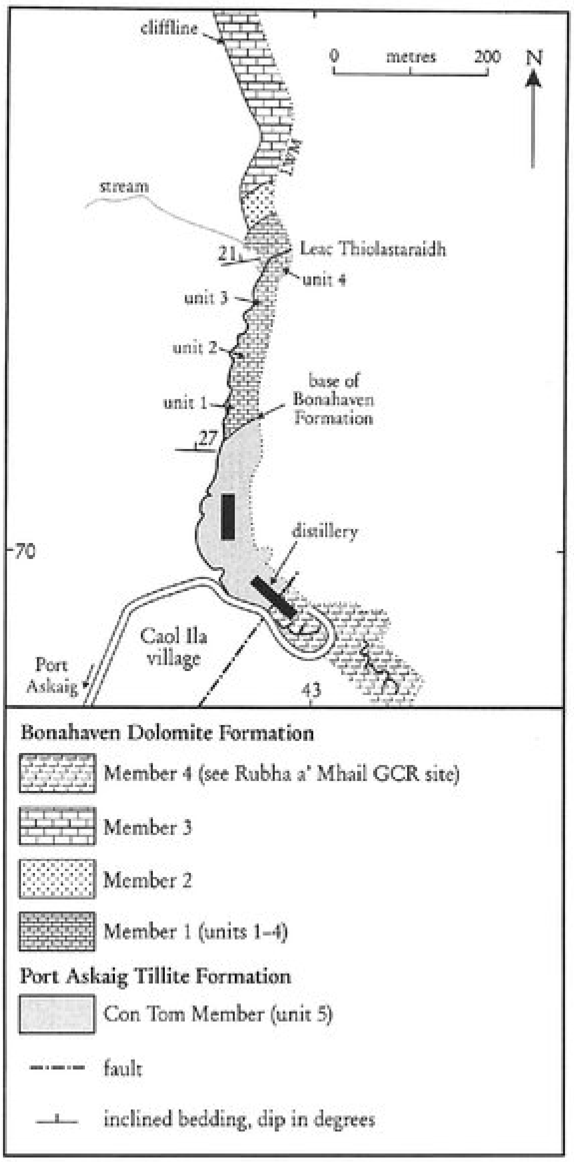
The *Caol Isla* GCR site is of international importance for determining the environment of deposition of the rocks immediately overlying a late-Precambrian glacial deposit, the Port Askaig Tillite. The sequence is crucial in this respect for it forms a transition between the tillite and its possible ‘cap carbonate’, the Bonahaven Dolomite Formation (the upper part of which is described in the *Rubha a’Mhail* GCR site report).

In addition, the well-exposed coastal section provides a representative section for the lower part of the Bonahaven Dolomite Formation of the Argyll Group, and enables a bed-by-bed study to be made of the sedimentary structures in this tide-dominated, shallow water sequence. Features of particular interest include sand-filled cracks, which form polygonal patterns on the bedding surfaces. Their 3-dimensional morphology suggests that they originated by loss of water from the sediments after burial, possibly triggered by movements on a fault that was active during development of the sedimentary basin (see the *Rubha a’Mhail* GCR site report). The site is made more valuable by the fact that the rocks are almost unaffected by tectonic strain, an unusual situation in the Dalradian.

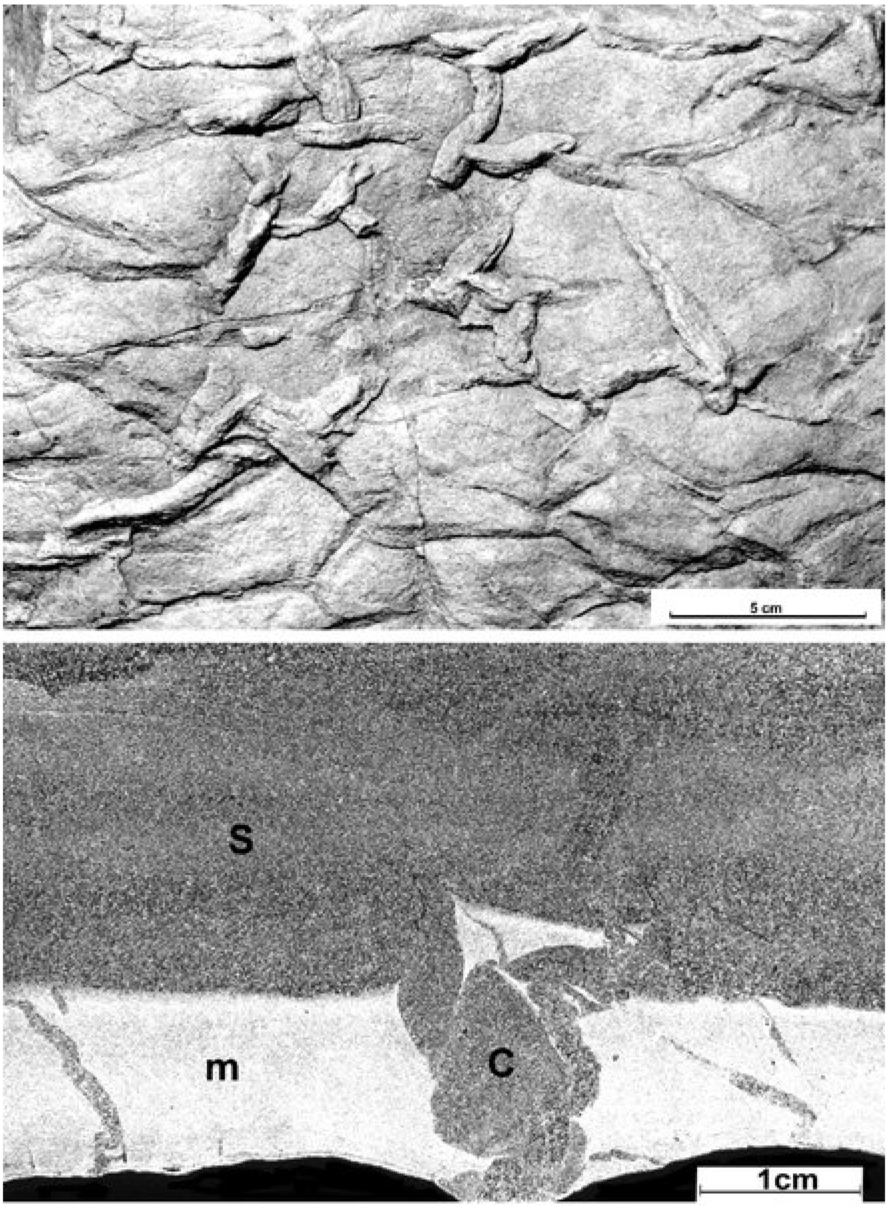
References



(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 2.7) Map of the shore section north of Caol Isla distillery, Isle of Islay. Adapted from Fairchild, (1991).



(Figure 2.8) (a) Casts of sand-filled dewatering cracks seen in relief on the base of a metasandstone bed from Leac Thiolastaraidh, north of Caol Isla, Isle of Islay [NR 4297 7037]. (b) Negative print taken from an acetate peel of a typical dewatering crack from Leac Thiolastaraidh. The illustration shows a sandstone bed (s) overlying a layer of mudrock (m), both units having been cut by the upward injection of a sand-filled dewatering crack. Following exposure to erosion at the Earth’s surface, the mudrock layer lying beneath the sandstone might be eroded away, leaving the sandstone infill (c) as a cast protruding from the base of the bed, as in (Figure 2.8)a. (Photos: P.W.G. Tanner.)