11 Black Mill Bay, Luing

[NM 733 087]–[NM 729 092]

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11.1 Introduction

Black Mill Bay is situated on the exposed west-facing coastline of the island of Luing in the Firth of Lorn, 4 km north of the southern tip of the island. The GCR site lies on the north shore of the bay and exposes the Easdale Slate Formation, which forms the upper part of the Easdale Subgroup (Figure 2.25). Here, the formation shows greater lithological diversity and structural complexity than is generally seen elsewhere in its outcrop, and includes a strongly deformed debris flow deposit (or debrite). The eastern margin of the site is marked by the Cobblers of Lorn, a prominent group of rounded, pale-coloured knolls of felsic igneous rock that provide a readily identifiable mark for mariners.

The geology of Black Mill Bay has previously attracted little attention, being mentioned only briefly by Peach *et al.* (1909) and summarized in a single paragraph of a field guide by Baldwin and Johnson (1977). The Easdale Slate Formation consists of black, pyrite-rich, slaty metamudstone with subordinate metasiltstone and metasandstone, in which there are a few beds of calcareous metasandstone, centimetre-thick black pebbly metasandstone, and dark grey, brown-weathering, pods and lenses of ferroan metadolostone. Sedimentary features include the debris flow, a (now cleaved) clastic sedimentary dyke and a few graded beds of metasandstone.

The original mudstone–sandstone sequence has been deformed twice, the second event all but obliterating local evidence of the steep to vertical first cleavage (S1). The second event (D2) resulted in the formation of mesoscopic folds of bedding and slaty cleavage, accompanied by a widespread, gently dipping, crenulation cleavage.

11.2 Description

At Black Mill Bay, the metasedimentary sequence consists of black slaty metamudstone, with pyrite cubes to 0.5 cm across, and includes several horizons of dark grey, brown-weathering metacarbonate rock of the type that has been reported elsewhere to be of ferruginous ‘metadolomite’ (Anderton, 1979). Large bodies of metadolostone give rise to characteristic whale-back forms. Many of these are arranged in sets, or linear arrays, of doubly-plunging early folds with a consistent sense of vergence; others appear to be strings of boudins, or even primary sedimentary concretions. Also present are calcareous metasandstones, metasiltstones, and beds of black metasandstone that show graded bedding. Although it is folded locally by pairs of tight to isoclinal folds, the succession youngs overall to the east, with most beds being right-way-up.

Of greatest interest in this section is the presence of a 4 m-thick debris flow deposit (debrite) at locality A (Figure 2.26), a and b [NM 7311 0875]. The rocks below the debrite consist of thin, commonly gritty, metasandstones (less than 50 cm thick), that contain clasts of carbonate material and young east on graded bedding (with grains up to 2 mm across at their base). These rocks are followed by brown laminated metasandstones and a black slaty metamudstone that contains thin beds of metacarbonate rock.

The base of the debrite is marked by three or four beds of black, gritty metasandstone containing carbonate clasts. They vary in thickness laterally from 5–25 cm, and form a 40–57 cm-thick unit that has a channel-fill geometry and an irregular, erosive contact with the underlying metacarbonate rock. Both rock types are cut by numerous quartz-carbonate veins. The metasandstone unit appears to have provided the sediment for a clastic dyke that penetrates into the overlying debrite for a distance of approximately 1.5 m. The overlying 130 cm of the debrite consists of finely banded, silty metamudstone, which carries the S1 spaced cleavage and contains a matrix-supported population of spindle-shaped sandstone clasts ranging in length from 1–20 cm. This mudstone-supported metaconglomerate is overlain by a 90 cm-thick unit of black slaty metamudstone containing a population of smaller, more widely dispersed clasts. The metamudstone occupies a gully and, in contrast to the units on either side, has a structure dominated by an intense flat-lying crenulation cleavage (Figure 2.26)c. It is succeeded by 186 cm of near-vertical, brown-weathering metasiltstone, which grades into metacarbonate rock in the top few tens of centimetres and is affected by a strongly developed pressure-solution cleavage dipping at over 80°. This unit contains matrix-supported sandstone clasts, which are generally larger and more abundant than in the metamudstone below. The top of the debrite is not seen clearly and is arbitrarily taken at the point where the last clast is seen, before the transition from metamudstone to metacarbonate rock takes place.

The F1 folds seen at the GCR site have steep to vertical axial planes and curvilinear hinges, are upward facing, and approach sheath-fold geometry in metamudstone. At the south end of the section, the S1 cleavage is near vertical and is the dominant planar fabric in metacarbonate rock and metasiltstone, where it is seen as a millimetre- to centimetre-spaced cleavage. The corresponding S1 slaty cleavage in metamudstone is associated with a steeply plunging stretching lineation and curvilinear bedding-cleavage intersection lineations. A good example of the magnitude of the D1 strain is seen in the debris flow deposit, where the clasts are elongated parallel to the L1 extension lineation and flattened in the plane of the spaced cleavage (Figure 2.26), a and b. The clasts have a maximum dimension (Y) in cross-section of 2–7 cm, and exceptionally up to 9 cm. They are up to 20 cm in length and plunge, on average, at 80° towards 197°.

In many places, the early structures are strongly modified by a near-horizontal to gently dipping crenulation cleavage (S2), which masks their geometry, and also locally by mesoscopic, recumbent F2 folds (Figure 2.26)d. For example, at location B, an isoclinal F1 fold, showing strong refraction of the early cleavage between beds and plunging at 40–50° to 001°, is cut by the intense near-horizontal S2 crenulation cleavage and is effectively disguised. The mean orientation of the S2 crenulation cleavage is dip 7° east, strike 339° (N=7), with the π-axis for slaty cleavage and bedding plunging at 7° to 010° (N=16) (inset on (Figure 2.25)). The local dominance of one cleavage over the other, depending on the rock type, is graphically displayed by the metasiltstone and metamudstone units in the debrite at locality A (Figure 2.25). This has resulted in a striking contrast between metacarbonate and metasiltstone beds displaying a steeply dipping to vertical, spaced S1 cleavage, and adjacent units of black metamudstone characterized by a horizontal crenulation cleavage that has all but destroyed the earlier slaty cleavage (Figure 2.26)c. The early spaced cleavage is axial planar (mean of fanned cleavage) to a south-plunging F1 anticline in the strongly cleaved metacarbonate bed immediately to the east of the debrite.

The debrite is crossed in part by a 15 cm-thick, folded, clastic dyke that has been affected by a steeply dipping S1 spaced cleavage continuous with that in the host rock. The fold plunges at 80–85°. The sides of the sandstone clasts in the debrite carry a horizontal set of corrugations that represent the intersection between S1 and the flat-lying crenulation cleavage (S2) (Figure 2.26)a.

Apart from late, brittle structures, post-D2 structures are uncommon at this GCR site. However, in the deformed metamudstone at locality C (Figure 2.25), two later generations of crenulation cleavage are seen superimposed upon the S2 crenulation cleavage. The earlier of these has a dip of 50–60° south, strike 070°; and the later one dips at 30° north-east, strike 330°.

11.3 Interpretation

It could be argued, that graphitic and pyritous slaty metamudstones, and other lithologies more representative of the Easdale Slate Formation, are best seen in the less intensively deformed section at Cuan Point on Luing, 5.5 km north of Black Mill Bay. However, the sequence at the Black Mill Bay GCR site includes a debris flow deposit (debrite), which may be correlated with slump and slide deposits found a few kilometres to the west and south-west that constitute the Scarba Conglomerate, described by Anderton (1979) (see the *Lussa Bay* and *Kinuachdrachd* GCR site reports). That conglomerate formed because of the depositional basin margin becoming unstable during Easdale Slate times, and the debrite at Black Mill Bay, together with a few turbidite deposits, represents the more distant effects of that disturbance.

The rocks are affected by an early generation of strongly curvilinear, isoclinal folds (F1), linked with the development of slaty cleavage in mudstones and spaced cleavages in siliciclastic and carbonate rocks. These structures are temporally and geometrically related to the development of the F1 Loch Awe Syncline to the south-east, but fold vergence is difficult to demonstrate at Black Mill Bay due to the cleavage being at a small angle to, or parallel with, the bedding. In addition, a low-angle crenulation cleavage (S2) is strongly developed locally, to the extent that it overprints and reworks the slaty cleavage. This crenulation cleavage has a similar orientation to a much weaker fabric seen at Cuan Point, and that seen at an early stage of development at the *Fearnach Bay* GCR site. It is likely that it may also be correlated with the low-angle crenulation cleavage that commonly affects the slaty cleavage in metamudstones, and similar rocks found in the Easdale Subgroup on Jura, and reworks the earliest penetrative fabric in older strata at the *Camas Nathais* GCR site to the north (Treagus et al., 2013).

11.4 Conclusions

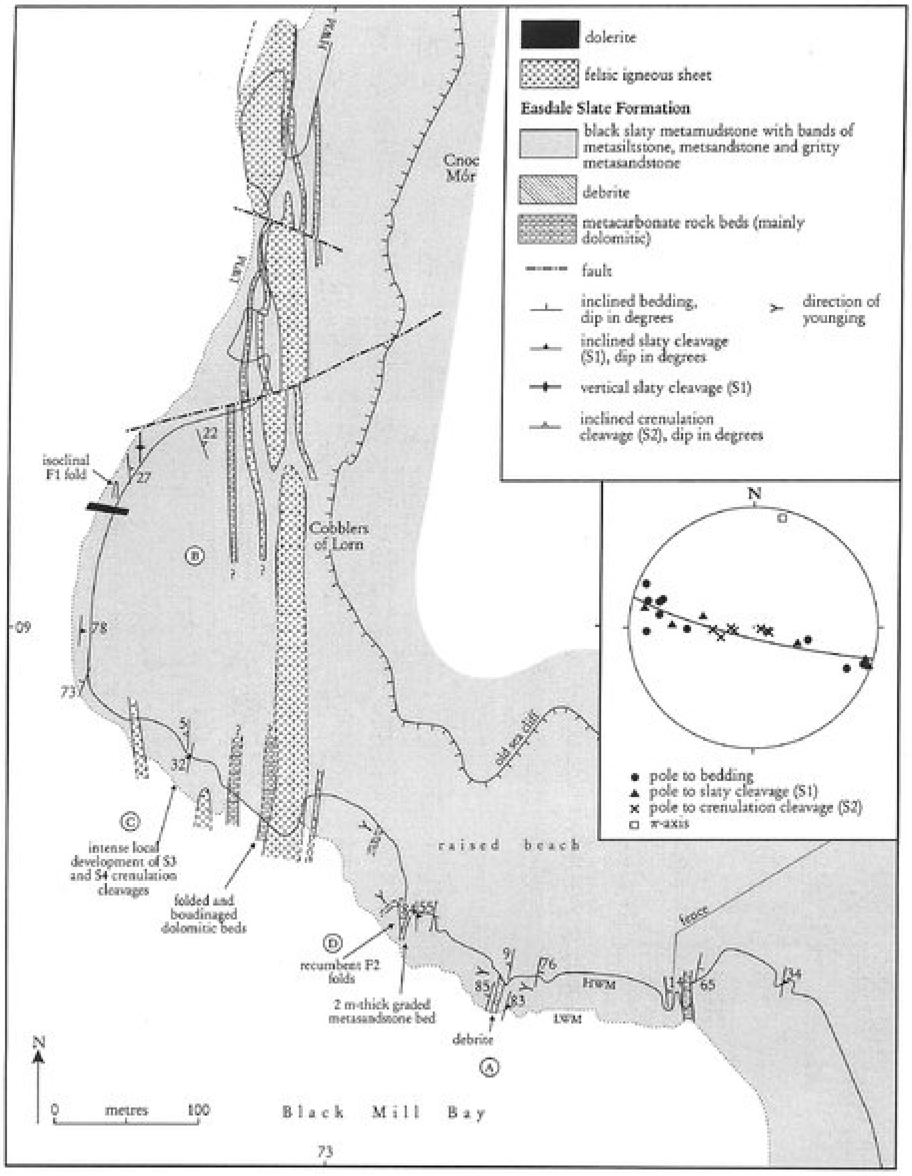
The Black Mill Bay GCR site provides a well-exposed coastal section across part of the Easdale Slate succession, which comprises black slaty metamudstone, making up the major part of the sequence, with units of metasiltstone and metasandstone, and horizons of metacarbonate lenses. Structurally, a wealth of minor structures and fabrics, resulting from varying degrees of interaction between two separate deformational episodes, are preserved within a relatively small area.

The feature that makes this site of wider interest is the preservation of a 4 m-thick debris flow deposit. A typical deposit of this type consists of a stratiform unit of matrix-supported clasts that vary greatly in size; these are enclosed in a muddy or silty matrix and are commonly accompanied by rafts and large blocks of sedimentary rock. Such flows originate at the basin margin and are capable of transporting detritus for long distances out into the basin.

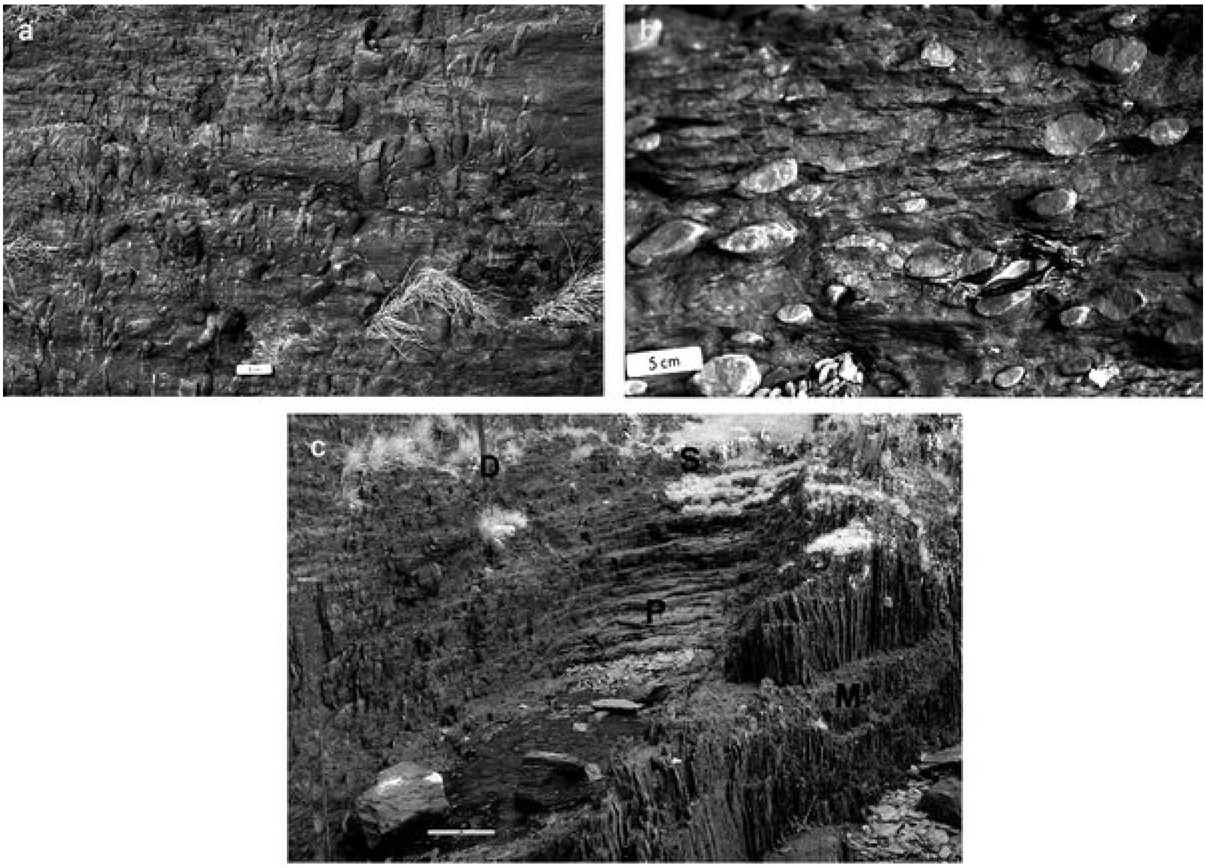
The debris flow deposit at Black Mill Bay was deformed pervasively during the earliest deformation, which caused the formation of a slaty cleavage. As a result, pebbles and cobbles of sandstone, which were originally probably equidimensional or slightly elliptical in shape, have been deformed into a series of parallel rod-like shapes. This is in strong contrast to the debris flow deposit at the *Port Selma* GCR site (Treagus et al., 2013) where the boulders are little deformed and delicate sedimentary structures are preserved within the deposit.

The main value of this GCR site is to establish a link between other sites that represent the Easdale Subgroup, and to provide a benchmark for comparing the Easdale Slate succession on the mainland with rocks thought to be of equivalent age on Islay and Jura. Likewise, there are significant similarities between the geometries of the two sets of structures at Black Mill Bay, and those at the *Camas Nathais*, *Port Selma* and *Fearnach Bay* GCR sites.

References



(Figure 2.25) Map of the area around the Black Mill Bay GCR site. A–D, localities mentioned in the text. Inset: An equal-area stereographic projection of poles to bedding, slaty cleavage (S1), and crenulation cleavage (S2), together with the best-fit line (π-girdle) containing the poles to bedding and cleavage. The nearly horizontal π-axis, gives the mean orientation of the related major fold axis.



(Figure 2.26) A gravity-flow deposit, or debrite, at locality A on (Figure 2.25) [NM 7311 0875], Black Mill Bay GCR site. The scale is 5 cm long. (a) A near-vertical face approximately parallel to S1, showing deformed clasts of sandstone in a silty matrix. (b) A horizontal, plan-view section through the deformed clasts shown in (a). (c) An illustration of lithological control on cleavage development at locality A. The near-vertical S1 cleavage dominates in metacarbonate rock (M) and in the debrite (D), whereas the S2 crenulation cleavage is more strongly developed in the intervening black pelite (P) and gives rise to a near-horizontal parting in this lithology. A sedimentary dyke (S), now folded and cleaved, cuts the debrite and the pelite. (Photos: P.W.G. Tanner.)