
3 Cove Bay to Kilcreggan

[NS 215 836]–[NS 242 804]

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3.1 Introduction

The Cove Bay to Kilcreggan GCR site consists of a 5 km-long strip of coastal exposure, interrupted only by a few pebble beaches, that runs between Knockderry Castle and Kilcreggan Pier on the west side of the Rosneath peninsula (Figure 4.9). The site is of national importance as it provides the only well-exposed coast section across the putative closure of the Tay Nappe, one of the largest folds in the British Isles. Plentiful minor structures document the development and present-day geometry of this major fold. There is undisputed evidence for four deformational episodes (D1–D4) in the Dalradian rocks farther north (see the *Portincaple* GCR site report), but only D1 and D2 are fully developed at this site. However, a major feature here is the manner in which the D2 deformation, that responsible for the southward propagation of the Tay Nappe (Harris *et al.*, 1976), increases in intensity northwards (downwards in the originally near-horizontal nappe), overprints, and finally destroys most field evidence for the prior existence of the D1 structures.

The sequence of Southern Highland Group rocks within this GCR site formed the original upper limb of the Tay Nappe and occupies a structural setting comparable to that of the *Ardscalpsie Point* GCR site. It consists mainly of right-way-up turbidite beds of the Bullrock Greywacke Member of the St Ninian Formation, which dip to the south-east and lie both stratigraphically and structurally above the Dunoon Phyllite Formation. This formation in turn overlies inverted strata of the Beinn Bheula Schist Formation. The simplest geological interpretation of these relationships is that the Bullrock Greywacke is the lateral stratigraphical equivalent of the Beinn Bheula Schists, and that these two units represent the two limbs of a downward-facing anticline, the Tay Nappe, which has the Dunoon Phyllites in its core (Shackleton, 1958; Roberts, 1974).

All of the rocks have been affected by greenschist-facies regional metamorphism. White mica-chlorite-bearing assemblages are ubiquitous and give many of the rocks a greenish tinge.

Although the first published map of the Rosneath peninsula was produced by the Geological Survey in 1878, it was not accompanied by a sheet explanation or memoir. The first account of the geology was by Roberts (1966a), who concentrated mainly on analysing the depositional environment of each stratigraphical unit. This work was followed by the publication of two field guides that described the salient features of several localities within this GCR site (Roberts, 1977b; Tanner, 1992). The geology of the peninsula was also described succinctly by Henderson (in Paterson *et al.*, 1990) in the memoir to accompany the BGS 1:50 000 Sheet 30W/29E (Greenock, 1990).

3.2 Description

The Bullrock Greywacke consists of gritty and pebbly feldspathic metagreywacke, interbedded with some finer-grained metagreywackes and metasiltstones, and some layers of black slaty metamudstone. The pebbles are mainly of quartz and feldspar. Normal graded bedding, confirmed in some cases by an accompanying erosional base to the bed, or the presence in the same bed of bottom structures, trough cross-bedding or channel infills, is seen at a number of places. Sets of finely spaced cross-laminae are present in the silty tops of a few turbidite beds. However, many of the beds are apparently homogeneous or show evidence of amalgamation. Calcareous concretions of diagenetic origin are common locally. They occur as bedding-parallel lenses and pods up to a few decimetres thick and reaching several metres in length, and as pod-shaped bodies oblique to bedding. In each case, bedding laminations preserved in the calcareous body are continuous with those in the host greywacke (Tanner, 1992).

Due to faulting, combined with a 200 m gap in exposure, the contact between the Bullrock Greywacke and the Dunoon Phyllites is not seen on the coast, but evidence from outwith the area in Aldownick Glen [NS 270 850] shows that it is a normal transitional contact (Paterson *et al.*, 1990).

The Dunoon Phyllite Formation consists mainly of black, purple, grey, and olive-green slaty and phyllitic metamudstones, with some beds of gritty metagreywacke, and of finer-grained metagreywacke and metasiltstone. Rare beds of pebbly metagreywacke up to 2 m thick are also present. Thin lenses and pods of metacarbonate rock occur in the black, phyllitic, graphitic metamudstones. They weather to a dull brown colour and are probably dolomitic in composition. The un-named bed of metagreywacke within the Dunoon Phyllites, exposed on the coast at Barons Point (Figure 4.9), appears to be in normal stratigraphical contact with the metamudstones to either side of it. There is sparse evidence of way-up from channelling and cross-lamination in most of the coastal outcrop of the Dunoon Phyllites, but the northern part appears to young towards the Beinn Bheula Schists.

The Beinn Bheula Schist Formation consists of generally well-bedded grey-green metagreywacke, less feldspathic than the Bullrock Greywacke, with bands of phyllitic metamudstone and metasiltstone, and uncommon pods of brown-weathering metacarbonate rock. Based on the evidence of sporadic graded bedding and cross-lamination, that part of the sequence exposed south of Knockderry Castle is inverted. The formation includes an 18 m-thick unit of metabasaltic sheets and (?) tuffaceous rocks just to the south of Knockderry Castle (Figure 4.9) which resemble the green beds of the Loch Lomond area. The contact between the Beinn Bheula Schists and the Dunoon Phyllites is well exposed at [NS 220 828] and is transitional over more than 20 m. Way-up structures show clearly that the structurally overlying Dunoon Phyllite is the older formation and that both formations young to the north close to their mutual contact.

The structures seen at this GCR site are almost entirely due to the first two deformations, D1 and D2. The S1 cleavage is seen as a centimetre-spaced set of anastomosing microlithons in the gritty rocks; a shape fabric (deformed grit particles) in the finer grained metagreywackes; or a slaty cleavage in the metamudstones. No structures or fabrics related to D3 have been detected. The D4 deformation is very localized and is expressed as NNW-verging, step-like folds, associated with a steep to vertical, millimetre-spaced crenulation cleavage that folds S1 and S2.

Three major folds of D1 age occur in the Bullrock Greywacke west and north of Kilcreggan Pier, but their hinge-zones are poorly exposed. However, one of the closures is well exposed along strike at Creag na Goibhre, Camsail Bay, north-east of Kilcreggan [NS 262 822] (Figure 4.9), and provides an analogue for the closure of the Tay Nappe itself (Tanner, 1992). Structural analysis of the orientations of bedding, S1 cleavage (axial-planar to millimetre-scale minor folds and warps), bedding/cleavage intersection lineations, and minor fold hinges show that this fold is a synform with a near-vertical axial plane and a fold axis plunging at less than 10° to the south-west. Way-up evidence from graded bedding and cross-lamination shows that it is a downward-facing anticline.

D1 structures in the south of the area are in their pristine state, unaffected by later deformation, but north of a line drawn approximately through the Cove Burgh Hall a few hundred yards south-east of Barons Point, the early cleavage can be seen in the field to have been affected by the development of a later spaced cleavage (S2). From this point northwards, the D2 deformation takes over and S2 rapidly becomes dominant. It is the main, and in some places only, planar structure in the Ben Bheula Schists in the northern half the area, where the sedimentary structures are progressively destroyed; in places only the coarser grained, granule to pebbly metagreywackes and calcareous concretions and layers preserve evidence of bedding surfaces.

D2 microlithons developed in the coarser metagreywackes have centimetre-scale spacing, and in homogeneous gritty metagreywackes, the anastomosing microlithons very closely resemble those of undoubted D1 age seen farther south. The difference is that further inspection usually reveals relics of the earlier spaced cleavage within the D2 microlithons, a striking example of which is shown in (Figure 4.10). The S2 fabric in metamudstones is subtle; in the field, it appears to be a slaty cleavage (S1), but under the microscope it is a very closely spaced crenulation cleavage that has clearly deformed an earlier fabric (Tanner, 1992).

F2 minor folds are rare; they fold an earlier cleavage and have hinges plunging at moderate angles to the south-west. The latter are statistically parallel to local bedding/cleavage intersection lineations on a micro-crenulation cleavage (S2)

that poses as 'slaty cleavage'.

Inland mapping shows that three major faults cross the coast section and cause a significant displacement of the outcrop of the Dunoon Phyllites (Figure 4.9). Evidence for only one of these faults is seen on the coast section. The Highland Boundary Fault is marked by an erosional hollow at the south-eastern limit of the GCR site but is not exposed.

3.3 Interpretation

The lateral correlation of stratigraphical units recognized on the Rosneath peninsula is well established. The Bullrock Greywacke, a right-way-up unit of gritty and pebbly, feldspathic metagreywackes, correlates with rocks having a similar character from the Isle of Bute to Loch Lomond side; the Dunoon Phyllites equate with slaty metamudstones on the Isle of Bute and the Luss slates at Loch Lomond; and the inverted sequence of Beinn Bheula Schists seen north of the Dunoon Phyllites occupies the same relative structural position at all of these localities. The metabasaltic and associated rocks at Knockderry Castle may be correlated with the green beds seen east of Loch Lomond.

The Bullrock Greywacke and Beinn Bheula Schists in the area of this GCR site, the 'greywacke affiliation' of Roberts (1966a), originated mainly as sequences of siliciclastic turbidites deposited in a submarine fan environment. In contrast, the Dunoon Phyllites were most likely deposited in a deeper water, oceanic setting, and consisted of pelagic muds diluted by the periodic influx of siliciclastic turbidites.

The structural situation is more enigmatic. On the Rosneath peninsula and at this GCR site in particular, the limbs of the major D1 structure, the Tay Nappe, are clearly defined by the thick unit of consistently inverted Beinn Bheula Schists (in the north-west) and the largely right-way-up Bullrock Greywacke (in the south-east), but the hinge-zone of this structure is difficult to locate.

This problem had been recognized earlier (Roberts, 1974; Paterson *et al.*, 1990) and it was suggested that there is a major slide along the south-eastern margin of the Dunoon Phyllite outcrop, which cuts out some of the southern limb of the major fold. However, this does not agree with the evidence from outwith the peninsula that this boundary is a normal sedimentary contact (Paterson *et al.*, 1990). There are two alternative possibilities; either the actual hinge-zone is poorly defined and is represented by a number of mesoscopic fold closures, or it is hidden by faulting. There is no field evidence to indicate the presence of mesoscopic folds in the Dunoon Phyllite. On the other hand, three large N-S-trending faults, each having a component of sinistral transcurrent displacement, cause a considerable displacement of the Dunoon Phyllites (Figure 4.9). The combined effect of this faulting is to remove about three kilometres of cross-strike exposure of the Dunoon Phyllites from view on the coast section within this GCR site. This 'hidden section' probably contains the closure of the Tay Nappe, with the folds seen to the south in the Bullrock Greywacke being congruous with the major fold.

The coastal section at this GCR site represents a depth profile of some 4 km through the Tay Nappe, at a time when it was a flat-lying, or recumbent, anticline closing to the south-east (Tanner, 1992) (see the *Introduction* to Tanner *et al.*, 2013b for a fuller explanation). At that time, the rocks at Kilcreggan formed part of the top limb of this structure, and were at a higher level in the Earth's crust than those at Knockderry Castle, on the lower limb.

D1 minor structures dominate the southern part of the section, but north of Barons Point, the pervasive spaced or slaty S2 fabric overprints the earlier one and evidence of D1 vergence can no longer be recognized. D2 shear results in very regular planar S2 surfaces but several stages in the development of the D2 microlithons that formed at a high angle to the spaced S1 cleavage are preserved. These features provide a reliable fingerprint for identifying the D2 fabric in rocks of the Flat Belt to the north and enable complex fold interference patterns to be unravelled (see the *Portincaple* GCR site report, (Figure 4.12)). In some cases they show the relative shear sense during D2 deformation (Harris *et al.*, 1976; Krabbendam *et al.*, 1997).

Subsequently, the nappe was affected by two further deformations (D3 and D4), the second of which was responsible for rotating the rocks at this GCR site into their present steeply dipping attitude. The effects of these phases are best seen in the *Portincaple* GCR site, where the relationship of D2 to both D3 and D4, and the geometry of the Highland Border

Downbend, may be examined.

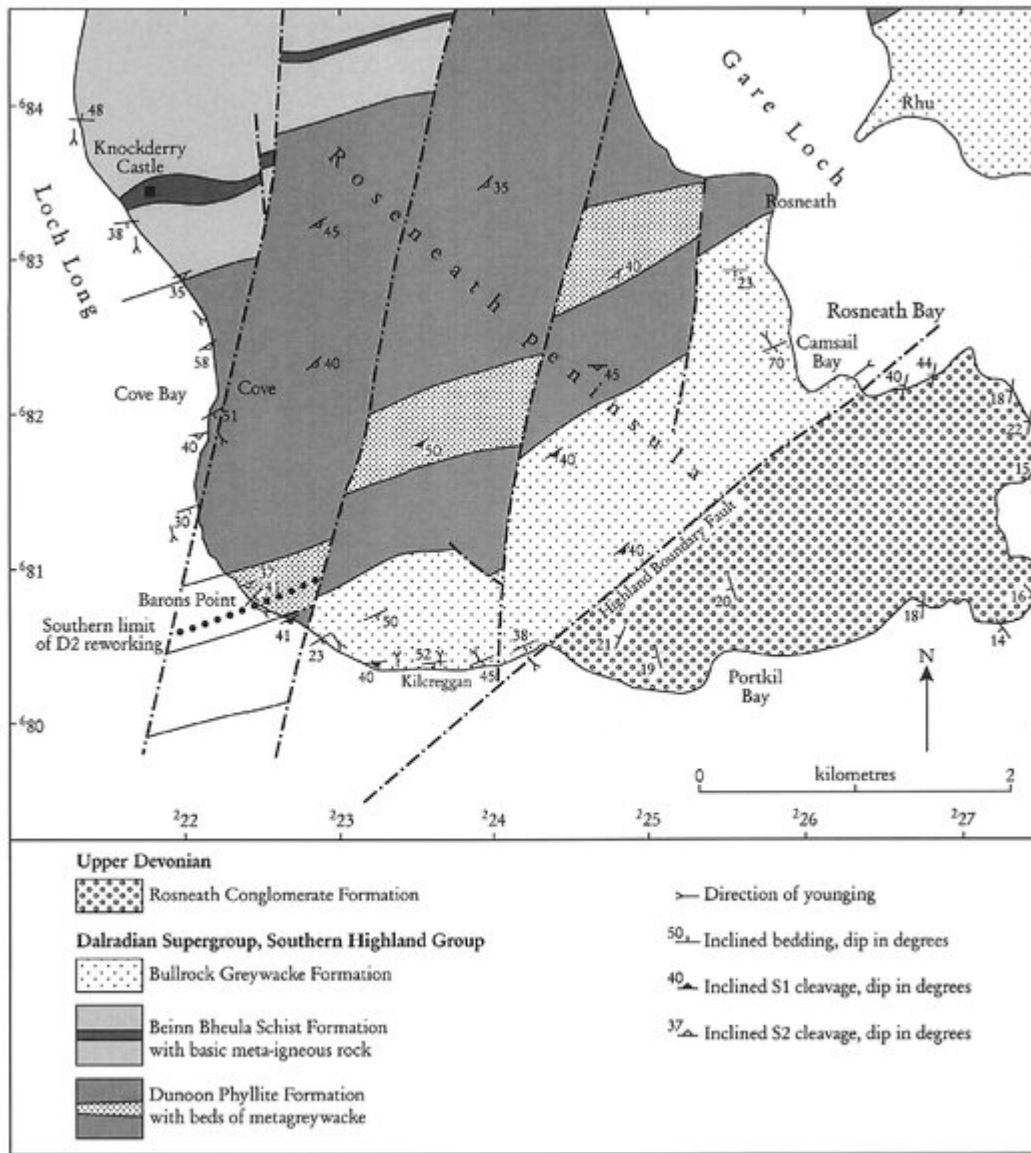
3.4 Conclusions

The rocks seen in the coast section between Cove Bay and Kilcreggan belong to the upper part of the Southern Highland Group and are divided into three stratigraphical units. Both the Bullrock Greywacke and the Beinn Bheula Schists consist of coarse-grained, sometimes pebbly, metagreywackes that show graded bedding and cross-lamination. They were deposited in a submarine fan environment, whereas the Dunoon Phyllites, which consist largely of varicoloured slaty rocks, were deposited farther away from the continental margin in an oceanic basin setting. The exposures of the Dunoon Phyllites are of such quality as to constitute a reference section for this formation. All of the rocks have been deformed and metamorphosed subsequently during the Grampian Event of the Caledonian Orogeny, and now dip to the south-east at a moderate angle.

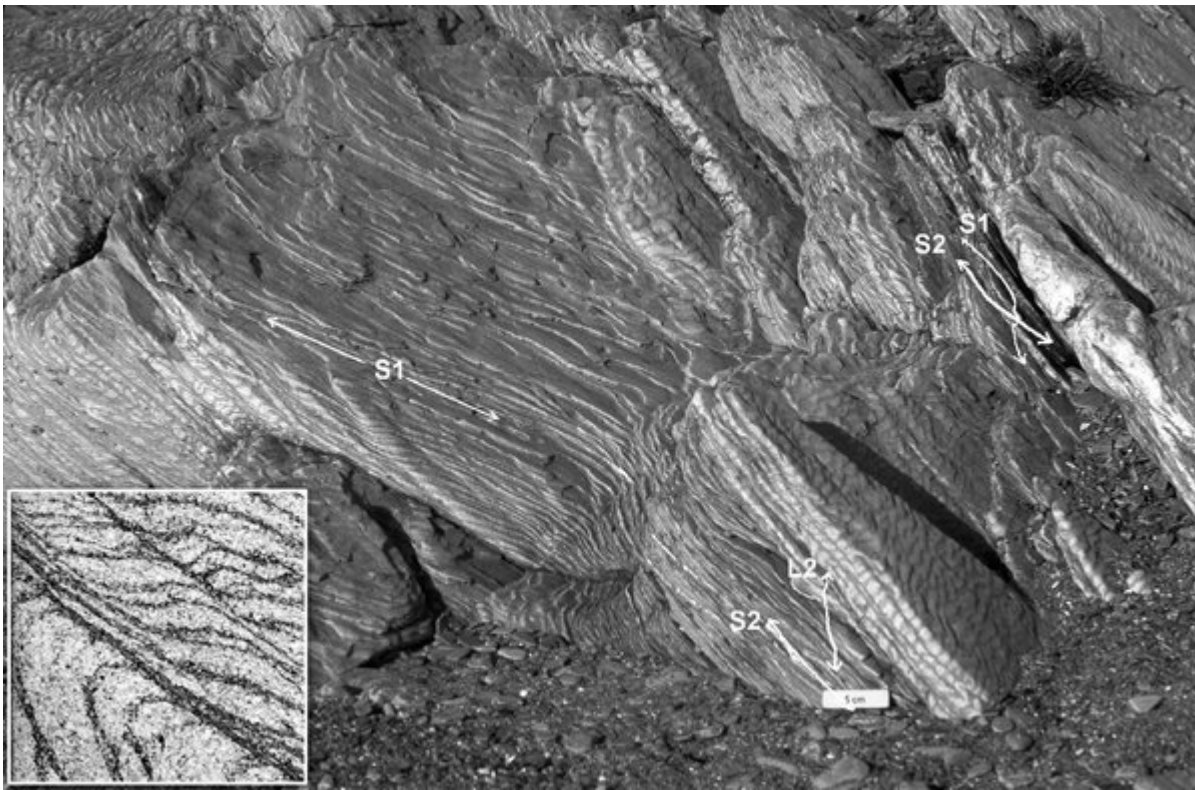
This GCR site provides a unique coastal section across the closure of the Tay Nappe, a structure that can be traced north-east–south-west across the Dalradian outcrop from the Isle of Bute to the east coast of the Grampian Highlands. The Bullrock Greywacke and the Beinn Bheula Schists, although rather different in lithology and mineralogy, have been correlated with each other, and are thought to represent the right-way-up limb and inverted limb, respectively, of the Tay Nappe. The Dunoon Phyllites, sandwiched structurally between them, occupy the core of the fold.

The great value of this GCR site is that it preserves structural information, in particular, that may be used to analyse and model early stages in the development of the Tay Nappe, and test the various hypotheses that have been proposed to explain its mode of emplacement. The evidence for the first two stages is charted by the sets of minor structures and cleavages so splendidly preserved in places in these rocks. In addition, there are few locations in the British Isles where the mechanisms involved in transforming an early, spaced, pressure-solution cleavage to a new cleavage of the same type can be studied in such detail.

[References](#)



(Figure 4.9) Map of the southern end of the Rosneath peninsula, including the Cove Bay to Kilreggan GCR site, based on BGS 1:50 000 Sheet 30W (Greenock, 1990).



(Figure 4.10) (a) Centimetre-wide microlithons, separated by narrow dark anastomosing cleavage domains which, together form the main, SE-dipping, S2 fabric in the metagreywacke unit of the Dunoon Phyllite Formation near Barons Point [NS 223 808]. The spaced S1 fabric can be clearly seen locally within the microlithons, frozen in the act of transformation to S2. The L2 intersection lineation occurs as a ribbon lineation on the main fabric surface. (b) Photomicrograph of the D2 microlithons in (a), reworking S1 pressure-solution stripes (shown in their original state in (Figure 4.7)b). (Photos: P.W.G. Tanner.)



(Figure 4.12) (a) A vertical rock face in the Bheinn Bheula Schist Formation at Portincaple [NS 2297 9327], viewed to the north-east (054°), showing asymmetrical, Z-shaped F3 folds on the southern limb of the Highland Border Downbend. The D3 structures deform the main S2 spaced fabric; the poorly developed minor upright F4 folds are accompanied by a near-vertical, crenulation cleavage that, although restricted to the pelitic seams, is clearly imprinted on and hence post-dates all of the other structures. Note the local preservation of the S1 fabric within the S2 microlithons. (Photo: P.W.G. Tanner.) (b) An explanatory outline drawing of (a). (c) Photomicrograph of the S4 crenulation cleavage at X on (b). (Photo: P.W.G. Tanner.)