
18 West Tayvallich Peninsula

[NR 732 878]–[NR 690 803]

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18.1 Introduction

This large GCR site is on the west coast of the Tayvallich peninsula, which lies on the Argyll mainland, east of the Isle of Jura. It provides some of the best exposures of Neoproterozoic submarine extrusive rocks and associated reworked volcanic rocks in the British Isles, including spectacular pillow lavas and hyaloclastites. The site is of stratigraphical importance as it provides a well-exposed section through the Crinan Grit Formation, the Tayvallich Slate and Limestone Formation and the Tayvallich Volcanic Formation. The lower boundary of the Tayvallich Volcanic Formation is particularly well exposed. The southern end of the peninsula also displays the controversial Loch na Cille Boulder Bed which lies within the volcanic sequence.

This area has been a classical geological site since the early 20th century when B.N. Peach discovered the pillow lavas and so established the existence of extrusive igneous rocks in the Dalradian of the South-west Grampian Highlands (Peach, 1904; Peach *et al.*, 1911). His observations and interpretations of pipe amygdalites and lava flow morphology were essential in establishing the stratigraphical sequence of the area. Elles (1935), in her study of the Loch na Cille Boulder Bed, disputed Peach's proposed stratigraphy but Allison (1941) conclusively vindicated the original interpretation. Wood (1964) described in detail structures observed in pillow lavas on the peninsula. Wilson and Leake (1972) carried out the first major geochemical study of a wide range of rocks from the Tayvallich peninsula (including lavas, intrusive rocks and sedimentary rocks) and Graham (1976) made further analyses of the meta-igneous rocks as part of a wider study of metabasalts in the South-west Grampian Highlands. Recent geochemical studies of the Tayvallich lavas were carried out by Hyslop and Pickett (1999), Pickett *et al.* (2006) and Fettes *et al.* 2011 as part of investigations of Dalradian basic meta-igneous rocks and their tectonic significance. The most recent detailed study on the entire sequence was carried out by Gower (1977) who described a series of localities along the west coast of the peninsula. Much of the following description is based on his observations.

A feature of great importance within the site is a trachytic ('quartz keratophyre') intrusion that is believed to be contemporaneous with the extrusion and deposition of the volcanic and volcanoclastic rocks. This intrusion was dated by Halliday *et al.* (1989) who obtained a conventional multi-grain U-Pb zircon age of 595 ± 4 Ma, thus providing an age for the Tayvallich Subgroup and indicating that most of the Dalradian Supergroup is of Neoproterozoic age. Dempster *et al.* (2002) subsequently reported a U-Pb TIMS (Thermal Ionisation Mass Spectrometry) zircon age of 601 ± 4 Ma from a tuff on the west coast of the Tayvallich peninsula at Port Bhuaileir [NR 688 810] (Figure 2.41). This date is within error of the earlier determination, and confirmed the age of the Tayvallich Volcanic rocks.

The structure of the area is dominated by the F1 Tayvallich Syncline, which plunges at 20–50° to the south-south-west and has an axial plane which dips to the east-south-east at 70–80°. This fold is an important component of the major Loch Awe Syncline. There is a strong axial planar slaty cleavage associated with the fold although subsequent deformation episodes have overprinted this cleavage with a crenulation cleavage locally. A stretching lineation plunges down the dip on the slaty cleavage surfaces.

18.2 Description

This large site is best considered as a number of separate sections (Figure 2.41):

(1) the axial zone of the syncline at Loch na Cille, (2) Rubha Riabhag to An Aird, (3) An Aird to Port an Sgadain, (4) Port an Sgadain to Port Bealach nan Gall, 5) the closure of the Tayvallich Syncline around the northern slopes of Barr na h-Iolaire.

18.2.1 Area 1: Loch Na Cille

This area is in the axial zone of the Tayvallich Syncline and contains the youngest rocks of the area, vertically dipping feldspathic metasandstones, which are exposed on the south-east limb of the syncline at [NR 698 806]. Mineralogically they are distinct from the older Crinan Grits in that they contain detrital epidote and more feldspar and mica. Gower (1973) proposed the name Kells Grit for these metasandstones, which have been correlated with the Loch Avich Grit of the Southern Highland Group farther north-east (Borradaile, 1973) (see the Loch Avich GCR site report).

The Kells Grit is underlain by a sequence of metalimestones and metabreccias containing clasts of igneous rock within a calcareous matrix. One of these metabreccias is the Loch na Cille Boulder Bed, which lies at the base of the metalimestone succession. It crops out down the centre of the peninsula of Rubha na Cille and is best exposed at the northern end [NR 688 803]. It stratigraphically overlies pillow lavas that are exposed on the west coast and is in turn overlain by grey metalimestone containing lava fragments. The Loch na Cille Boulder Bed is particularly well exposed on the east shore of Rubha Fitheach, where fragments of pillow and vesicular lava are deformed and flattened within the main cleavage. The clasts are predominantly fragments of mafic meta-igneous rock and pebbles of pale-coloured felsic metavolcanic rock in a chloritic, calcareous or quartzose matrix. However, Elles (1935) also recorded the presence of quartzite, gneiss and schist and noted that many of the boulders are rounded. In a recent re-examination of the metabreccias, Prave (1999) also observed a range of clasts in beds towards the top of the unit, which he termed 'extrabasinal', including granitic rocks, schists, felsic volcanic rocks and quartzite.

18.2.2 Area 2: Rubha Riabhag to an Aird

North-eastwards along the coast from Rubha na Cille progressively older members of the Tayvallich Volcanic Formation are exposed. The lithologies include massive lava, excellently preserved pillow lava, pillow breccia and stratified and reworked hyaloclastite and volcaniclastic rocks. The hyaloclastites were first recognized by Gower (1977). The pillow lavas are particularly well exposed at [NR 693 817] with pillows up to 3 m by 1 m in size (Figure 2.42). Stratigraphical way-up is well defined by the pillow morphology and by concentrations of feldspar crystals (up to 1 cm long) at the pillow bases. Many of the pillows also display concentric bands of vesicles towards their tops. Recent geochemical studies have shown that the pillow lavas have high-Fe-Ti tholeiitic compositions and were derived from a relatively enriched mantle source (Fettes *et al.*, 2011).

Within the volcanic sequence is a distinctive 8 m-thick bed of 'porphyry breccia', described by Peach *et al.* (1911), which is composed of pink-orange trachytic boulders (up to 1 m across) within a tuffaceous matrix [NR 690 813]. These boulders are lithologically similar to a trachytic 'feldspar porphyry' or 'quartz keratophyre' intrusion (over 16 m thick), which is exposed in the intertidal zone nearby [NR 695 822]. The mineralogy of this intrusion was studied in detail by Peach *et al.* (1911). It contains tabular albite crystals up to 3 mm in length displaying chess-board twinning within a finer grained albite-rich groundmass containing quartz, epidote, white mica, chlorite and opaque minerals. Parts of the intrusion show a poorly developed mineral banding of alternating mafic and felsic layers parallel to the upper contact. This contact is concordant with the surrounding bedded volcanic rocks and a chilled margin is present locally (Gower, 1977). It is from this intrusion that zircons have provided a U-Pb age of 595 ± 4 Ma, one of only two reliable radiometric dates from the upper part of the Dalradian Supergroup (Halliday *et al.*, 1989).

18.2.3 Area 3: An Aird to Port An Sgadain

The small peninsula of An Aird is composed largely of a metabasaltic laccolith, which might have acted as a feeder to some of the overlying pillow lavas. The western side of the peninsula is composed of pillow lavas, overlain to the east by pillow breccias and hyaloclastites. The pillow lavas at this locality are excellently exposed and are the ones originally described by Peach (1904) and Peach *et al.* (1911). Graham (1976) described their petrology, noting a range of features including microphenocrysts of twinned plagioclase (now albite), 'trachytic' textures and amygdals. Northwards from An

Aird, are pillow breccias and hyaloclastites (Gower, 1977). Thin rusty-weathering metalimestone lenses are also present and a distinctive dolomitic breccia occurs directly south-west of Port an Sgadain.

18.2.4 Area 4: Port An Sgadain to Port Bealach Nan Gall

At the southern end of this section, the base of the Tayvallich Volcanic Formation and its contact with the underlying Tayvallich Slate and Limestone Formation are very well preserved. Here the lava flows have pipe amygdales at their base and scoriaceous tops, commonly with rusty-weathering carbonate veins penetrating between the blocks of lava (Gower, 1977). Peach *et al.* (1911) used these exposures to demonstrate that the sequence here is the right way up and dips at 40° to the east. During its extrusion the lowest lava produced load structures and push folds in the underlying soft sediment. In places bulbous masses of lava became detached and isolated within the sediment (Wood, 1964). The Tayvallich Slate and Limestone Formation is very variable and includes dolomitic metalimestones, phyllitic rocks, thin-bedded and massive metalimestones and conglomeratic beds. The metalimestone beds contain numerous quartz clasts (up to 1.5 cm across). The formation exhibits a variety of sedimentary structures including grading, cross-bedding, channels and flute casts, possibly reflecting a turbiditic origin. At Port Bealach nan Gall, the quartzitic Crinan Grits are exposed beneath the metalimestones. At this locality the Crinan Grits comprise graded, very coarse-grained, locally conglomeratic metasandstone containing excellent examples of flute casts (50–60 cm long). Beds of metamudstone, one of which contains large carbonate nodules (up to 2 m in diameter), are also exposed.

18.2.5 Area 5: Barr Na H-Iolaire

The closure of the Tayvallich Syncline can be traced out by following the scarp that represents the base of the lavas around the northern slopes of Barr na h-Iolaire. Although the underlying metalimestone is largely obscured, the base of the Tayvallich Volcanic Formation can be traced around the minor folds associated with the closure of the syncline. In their detailed map of this area, Wilson and Leake (1972) showed the distribution of beds of meta-agglomerate within the Tayvallich Volcanic Formation. They described the distinctive geochemical composition of one meta-agglomerate, the 'Barbreack Agglomerate', which they found to be much more siliceous than the pillow lavas and to contain very high levels of Nb, Zr, U, Th, La and Ce.

18.3 Interpretation

The sequence preserved along the west coast of the Tayvallich peninsula is interpreted as recording a period of rapid subsidence and basin deepening associated with active rifting along a continental margin during late-Dalradian times (Anderton, 1985). The Crinan Grit, which is the oldest formation at this GCR site, was interpreted by Anderton as the result of turbidite deposition in submarine fan channels.

The overlying Tayvallich Slate and Limestone Formation is also largely turbiditic. The orientation of cross-bedding and flute casts suggests current directions from the south and south-east (Gower, 1977). Anderton (1985) interpreted the abrupt change from clastic to carbonate sedimentation as the result of a relatively sudden re-organization of the palaeogeography. This stopped or diverted the clastic input and the sediment-starved shelves began to accumulate carbonate-rich deposits. Erosion and reworking of the carbonates generated turbiditic deposits in adjacent basins.

The overlying Tayvallich Volcanic Formation indicates a period of magmatism caused by eventual rupturing of the continental crust within the widening rift (Anderton, 1985). Wood (1964) used the orientation of push folds in underlying metasedimentary rocks to determine that lavas at the base of the section flowed northwards into soft sediments. Extrusion of the volcanic pile was largely submarine, as indicated by the pillow lavas and hyaloclastites, and many of the lavas are extensively spilitized, probably reflecting sea-floor hydrothermal processes that occurred soon after extrusion. Graham (1976) interpreted the geochemistry of the lavas and associated intrusions as indicating initial continental rifting preceding ocean-floor spreading. Recent work has confirmed that the lavas have enriched characteristics, typical of within-plate ocean-island basalts (OIB) but also found on extensional plate margins where thinning of the continental lithosphere prior to rupturing results in basin formation and relatively low degrees of decompression melting of the underlying mantle (Fettes *et al.*, 2011). Geochemical evidence of crustal contamination has been found in some of the

Tasyvallich lavas, though not in those from the Tayvallich peninsula.

The trachytic intrusion exposed at the GCR site is geochemically related to the extrusive rocks and probably represents part of the subvolcanic feeder system (Graham, 1976). Lithologically similar trachytic blocks occur as clasts in overlying volcanic breccias, supporting geochemical evidence that the intrusion is cogenetic with the volcanic rocks and hence is a suitable subject for radiometric dating of the volcanism.

Reworking of volcanic material by sedimentary processes produced a variety of volcanoclastic rocks, which are intercalated with the extrusive rocks. The Loch na Cille Boulder Bed towards the top of the Tayvallich sequence was originally interpreted by Peach *et al.* (1911) as a tectonic breccia or 'crush-conglomerate'. Various other origins were later proposed, including a glacial origin (Elles, 1935), a porphyritic lava flow including xenoliths of 'acidic' boulders (Allison, 1941) and a hyaloclastite resulting from a submarine fissure eruption (Gower, 1977). Hyslop and Pickett (1999) interpreted the unit as being deposited from debris flows and forming part of the overall Tayvallich volcanic-volcanoclastic sequence. Conversely, Prave (1999) revived the glaciogenic interpretation of Elles (1934), citing the presence of extrabasinal clasts, many of them rounded, of granite, schist, felsic volcanic rock and quartzite in beds towards the top of the unit. These observations, coupled with the stratigraphical proximity of the Loch na Cille Boulder Bed to the c. 595 Ma trachytic intrusion, led Prave to suggest that the boulder bed is evidence for a Varangerian glaciation (c. 620–590 Ma) in the Dalradian of Scotland (see Stephenson *et al.*, 2013a). On balance it would seem that there is good evidence for some form of volcanoclastic deposition, but that the higher beds with the extrabasinal clasts merit further investigation.

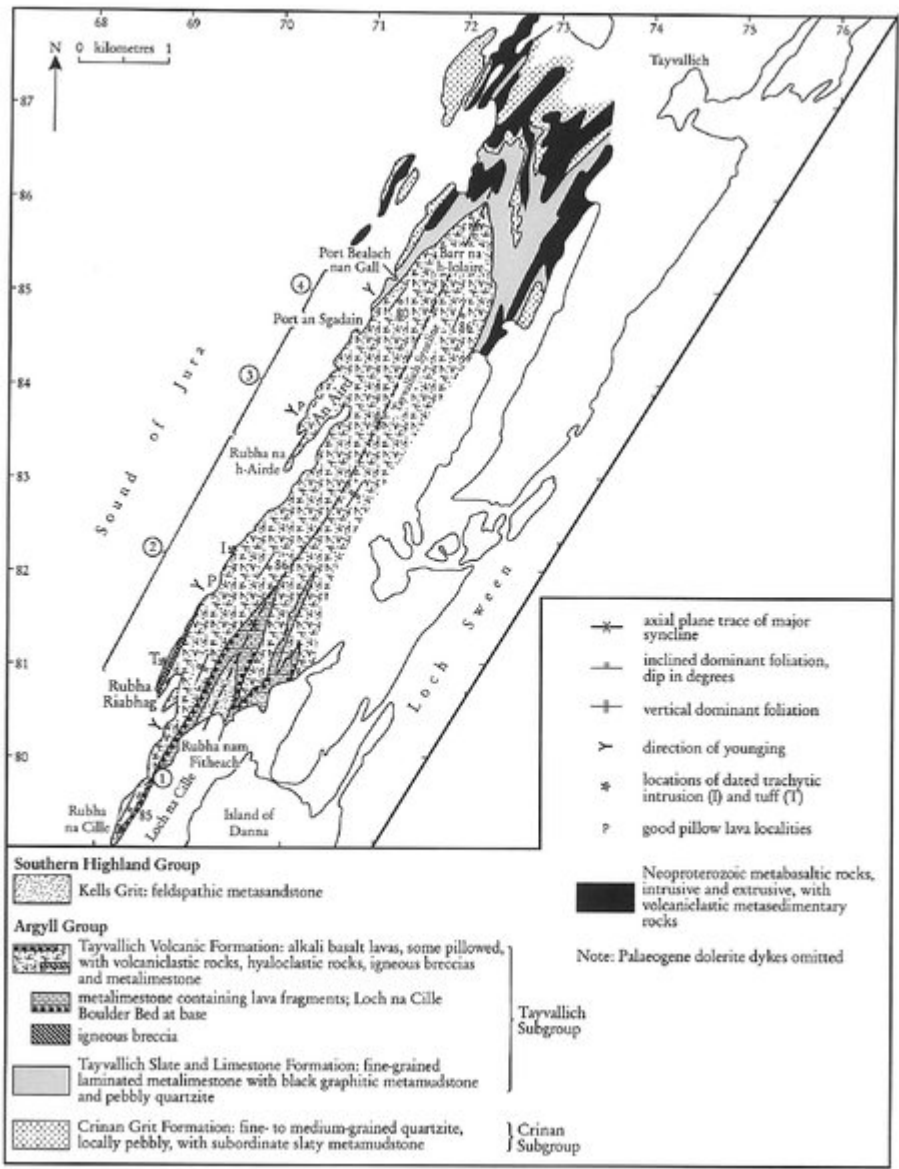
18.4 Conclusions

The West Tayvallich Peninsula GCR site preserves an excellently exposed succession that passes stratigraphically up from the Crinan Grit Formation, through the Tayvallich Slate and Limestone Formation and the Tayvallich Volcanic Formation to the Loch na Cille Boulder Bed and, at the top of the sequence, the Kells Grit. These formations comprise some of the most distinctive and persistent stratigraphical markers of the Dalradian terrane and hence are valuable for correlation purposes. In addition to its stratigraphical significance, the site is of national importance for its wide range of extrusive volcanic rocks and associated volcanoclastic sedimentary rocks, formed during rifting of continental crust in the Neoproterozoic. A variety of igneous and sedimentary processes can be demonstrated and are invaluable in current studies involving reconstructing the tectonic regime and environments in which the higher parts of the Dalradian succession were deposited. The site exhibits minor structures associated with the Tayvallich Syncline, an important component of the major F1 Loch Awe Syncline that controls outcrop patterns over a wide area of the South-west Grampian Highlands.

A trachytic intrusion and a stratiform tuff from this site have yielded concordant U-Pb (zircon) ages of c. 600 Ma. These are the only reliable radiometric dates from the upper part of the Dalradian and are therefore critical in establishing a chronostratigraphical framework for the Dalradian Supergroup as a whole.

The site has been a classic locality for teaching and research, since at least 1911, and it was here that pillow lavas, erupted underwater, were first recognized and described in the Dalradian of Scotland. The study of these exceptional volcanic rocks in terms of their geochemistry and depositional setting continues today.

[References](#)



(Figure 2.41) Simplified map of the West Tayvallich peninsula. Numbers refer to sections described in the text. Modified after BGS 1:50 000 Sheet 28E (Knapdale, 1996). Additional information from Elles (1935), Wilson and Leake (1972) and Gower (1977).



(Figure 2.42) Basaltic pillow lavas in the Tayvallich Volcanic Formation showing concentric bands of vesicles, coast of An Aird [NR 7020 8370]. Hammer shaft is 37 cm long. (Photo: BGS No. P 219459, reproduced with the permission of the Director, British Geological Survey, © NERC.)