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# Sgavoch Rock

[NX 075 810]

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## Introduction

The coastal sections on the mainland opposite the offshore Sgavoch Rock provide the finest array of pillow lavas to be seen in Britain. Individual pillow shapes range from almost spherical, through elliptical 'bolster' shapes into sheet flows; lava tubes can also be clearly identified with well-preserved pillow buds at their margins. The lava sequence is structurally confined between the Stinchar Valley Fault to the north and the Dove Cove Fault to the south (Figure 2.41). Extensive coastal exposure is continuous from the Sgavoch Rock area southwards to Downan Point but the outcrop narrows inland as the two faults converge towards the NE. These lavas have traditionally been associated with the Arenig (early Ordovician) Ballantrae ophiolite complex with which they are juxtaposed across the Stinchar Valley Fault. However, recent interpretations have given more weight to relationships at the southern margin of the Sgavoch–Downan lavas where the faulted base of the sequence is intimately associated with chert and shale containing a *gracilis* Biozone (Caradoc, mid- to late Ordovician) graptolite fauna. On this basis the lavas should be regarded as the earliest accreted unit within the Southern Uplands imbricate thrust belt. A poorly constrained radiometric (Sm-Nd) age of  $468 \pm 22$  Ma (Thiriwall and Bluck, 1984) does not differentiate between the two alternatives. A summary of the debate is given by Stone and Smellie (1988) who introduced the lithostratigraphical name Downan Point Lava Formation.

The spectacular pillow structures within the Downan Point Lava Formation (DPF) were first noted and illustrated by Peach and Horne (1899) and subsequently discussed in more detail by Bloxam (1960). A more recent description of the Sgavoch Rock locality was given by Bluck (1992). The pillow lavas exposed preserve a range of features characteristic of submarine eruption and are arguably the best British examples of their kind; they also occupy an important position in terms of the regional geology of southern Scotland. To the north, the ophiolitic Ballantrae Complex was generated and obduct-ed onto the Laurentian continental margin during the early Ordovician. To the south the Southern Uplands Terrane was sequentially accreted at the Laurentian margin during the late Ordovician and early Silurian. The DPF represents renewed volcanicity within or marginal to the Iapetus Ocean immediately prior to the initiation of Southern Uplands accretion and in this context the DPF represents the most extensive volcanic fragment preserved within the Southern Uplands Terrane.

## Description

The geological setting of the Sgavoch Rock area is shown in (Figure 2.41). The lavas and the associated breccias, cherts and shales accumulated in a submarine environment and it is the process of eruption under water that produces the characteristic pillow shapes. The pillows form as lava is squeezed out from points of weakness in the walls of lava tubes, a phenomenon known as budding. Each emerging tongue of lava is rapidly chilled by contact with the water and by the time it has grown to pillow size the hardening skin prevents further growth. The pillow may then break free of the lava front or be overtaken by new tongues, which similarly swell into pillows. Since the pillows accumulate in a semisolid state they settle and mould around each other, finally solidifying into interlocking patterns. In an ideal example the top surface of each pillow is a convex dome whereas the base may be flat or irregular, moulded to the shape of the underlying surface; vesicles are typically concentrated towards the top of the pillow and in many of the examples seen they form prominent concentric zones. These features are illustrated in (Figure 2.42).

The full array of pillow lava features is most spectacularly displayed on the small rocky headland due east from the Sgavoch Rock; note that the latter feature is covered at high tide. On the headland the pillow attitude shows bedding to be steeply dipping or vertical with an approximately NE–SW strike; the asymmetry of the pillows establishes that the original top of the lava pile lies towards the NW. Since the lavas were erupted onto a probably sub-horizontal sea floor they have therefore been rotated through  $90^\circ$  and now become sequentially younger seaward. The Sgavoch (DPF)

pillows range from slightly elliptical with long axes of 20–50 cm through to larger, elongate 'bolster' shapes up to 2 m across. Within the pillow lava sequence there are other sheet-like lava bodies which probably represent original lava tubes carrying magma forward to the eruptive front. In some cases lava pillows can be seen budding from the extremities and top surfaces of the sheets in a remarkable illustration of their mode of formation. The proportion of unpillowed sheet-flows in the succession increases southwards towards Downan Point.

Several types of pelagic sediment are intimately associated with the lavas. Lenses of laminated black chert, up to 3 m long and 30 cm thick, occupy what were probably hollows in the lava pile topography and indicate local breaks in lava accumulation. Red chert or dark siliceous mudstone may fill gaps left between pillows and in some cases the partial draining of pillows has left spaces that are now filled with either chert or laminated carbonate. Euhedral calcite crystals are seen growing from the pillow margins into the inter-pillow sediment and appear to have done so while the sediment was still soft, displacing sedimentary laminae. Carbonate is also the most common filling for the original vesicles.

Lava breccias are interspersed in the volcanic sequence and are usually dominated by small pillows as little as 10 cm in diameter. These show intact chilled margins and so are not clasts resulting from the disintegration of larger pillows although such clasts are also present. The breccias are commonly rich in fine-grained matrix and may have been emplaced as debris flows from the lava front. However, they are also pervasively bleached to a pale yellowish-green colour, probably by hydrothermal alteration, and the restriction of this alteration to the clastic zones means that an origin as intrusion breccia cannot be entirely ruled out.

The pillows all have green chloritic rims, which are the result of alteration of the original glassy chilled margins; the basalt forming the pillow cores is tholeiitic, fine grained, mostly aphyric and generally vesicular. Plagioclase, clinopyroxene and chlorite form the matrix, which encloses rare, but very locally abundant, small plagioclase phenocrysts.

## Interpretation

The magnificent array of pillow lavas exposed in the Sgavoch section provides a rare opportunity to examine in detail the products of submarine volcanic eruptions. The age of this particular eruption remains uncertain: the lavas could be of Arenig age and a part of the Ballantrae Complex ophiolite that crops out immediately to the north; alternatively, and perhaps more likely, the lavas may be of Caradoc age and form the oldest accreted unit within the Southern Uplands imbricate thrust terrane. Several GCR sites within the Ballantrae Complex show comparable (although less spectacular) pillow lava developments but there are only comparatively meagre equivalents within the Southern Uplands. The DPF lava pile at Sgavoch has been rotated to a sub-vertical attitude but has otherwise escaped deformation. There is no penetrative cleavage and no evidence that the pillow shapes have been modified tectonically. The consistent westward younging of the steeply inclined flows militates against structural complexity introduced by folding or faulting. The metamorphic grade is very low. This fortunate state of affairs contributes to the value of the Sgavoch section as an ideal site for the investigation of submarine volcanism.

The submarine environment of eruption is not in dispute and broadly similar lava flow morphologies have been observed forming at mid-ocean ridges and around Pacific islands. The alternation of pillowed and sheeted flows reflects varying rates of extrusion on an unstable sea-floor, the more rapid the advance of the lava front the less opportunity there is for the production of pillows. Submarine slopes are indicated by a preponderance of jumbled, elongate pillows with the steeper slopes producing breccias as lava pillows and fragments cascaded downwards. The interpillow chert may represent either background pelagic sediment or be an essentially hydrothermal deposit; the laminated chert lenses are most likely to have a sedimentary origin and may even indicate intermittent turbidity current activity. A fairly deep water setting seems probable.

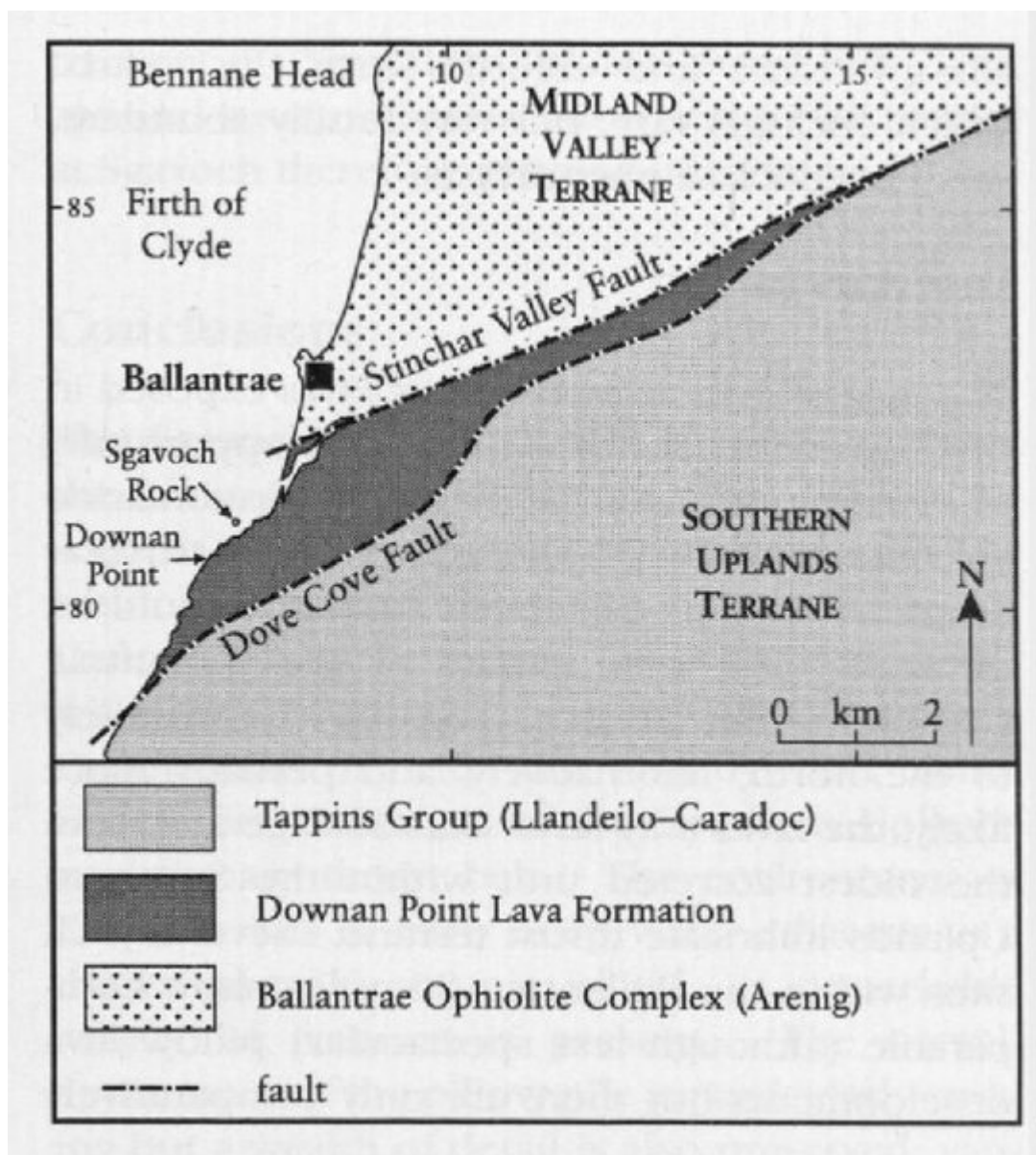
Several geochemical studies of the DPF pillow basalts have been carried out and the results were summarized and assessed by Thirlwall and Stuck (1984). A consensus view considers that they are most closely comparable to modern oceanic island, 'Hawaiian-type' basalts and thus a within-plate geotectonic setting has been proposed for their eruption. The source of the magma erupted at Sgavoch was therefore a mantle plume of some sort. Lavas of closely similar composition are found within the Ballantrae Complex at the Slockenray Coast and Balcreuchan Port to Port Vad GCR sites but are also known from small, scattered outcrops contained within fault zones defining the northern tracts of the

Southern Uplands thrust belt. The age and structural association of the DPF basalts at Sgavoch therefore remains uncertain.

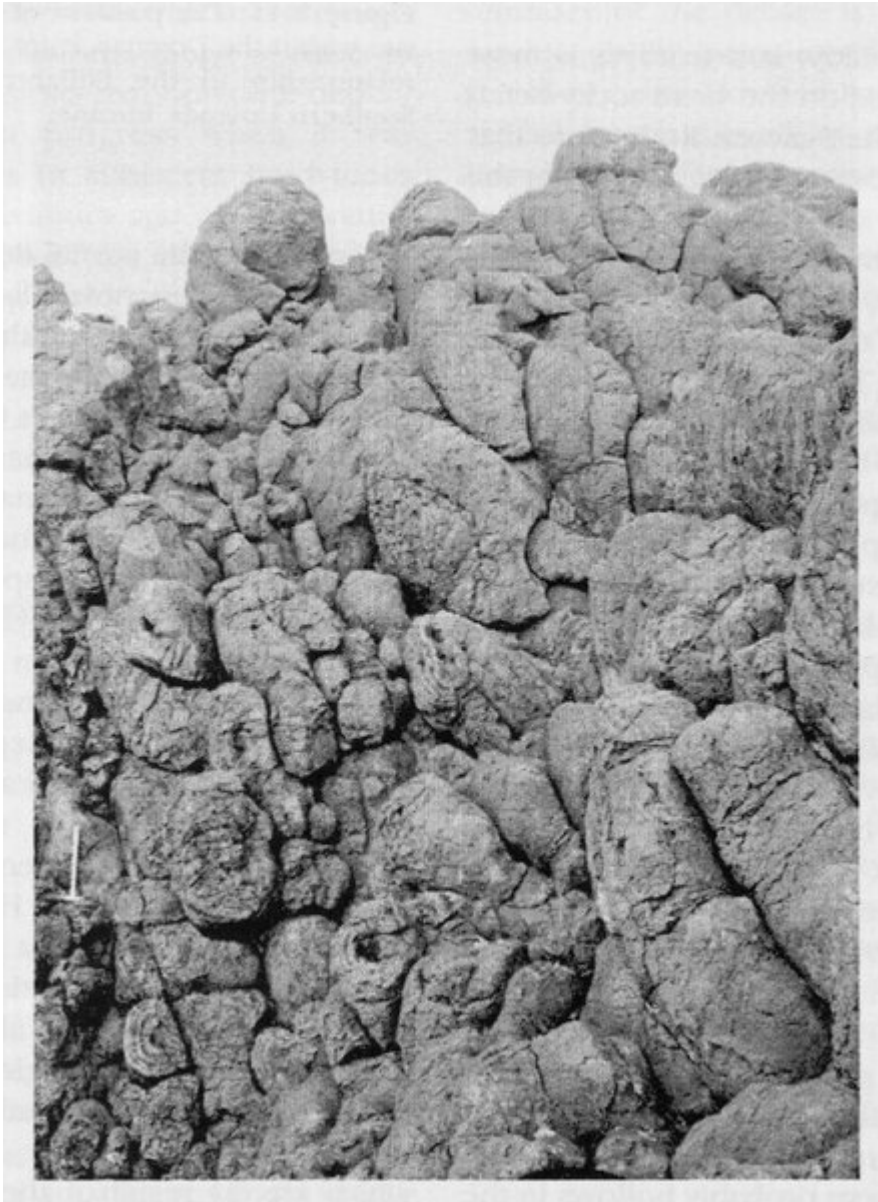
## Conclusions

The Sgavoch Rock GCR site contains arguably the finest array of submarine pillow lavas to be seen in Britain. It is a spectacular locality of major volcanological interest. The lavas are of Ordovician age but may be associated either with the Ballantrae Complex ophiolite (early Ordovician) or with the slightly later (mid-Ordovician) initiation of the Southern Uplands accretionary thrust belt. The environment of eruption was in fairly deep water adjacent to a 'Hawaiian-type' oceanic island. A remarkable variety of features is present. The overall appearance of the pillow pile is particularly striking but a wealth of detail is also preserved: variable pillow shape clearly indicating the original top of the sequence, pillows budding from lava tubes, drained pillow cores filled with sediment, marked zonation by vesicles (relict gas bubbles) and interbedded lava breccias to list only the more obvious.

## References



(Figure 2.41) The position of the Sgavoch Rock GCR site within the Downan Point Lava Formation and its relationship to the Ballantrae Complex and the Southern Uplands Terrane.



*(Figure 2.42) A spectacular array of pillow lavas from the Downan Point Lava Formation exposed on the coast adjacent to the offshore Sgavoch Rock. The lavas are steeply inclined and slightly overturned. (Photo: BGS no. D1572.)*