Balcreuchan Port–Bennane Head

[NX 0968 8750]–[NX 0910 8638]

Introduction

The sea-cliffs between Balcreuchan Port and Bennane Head expose local sedimentary units within the dominantly volcanic Balcreuchan Group that contain early and mid-Arenig graptolites, including the only British examples of the important basal Arenig zonal fossil *Tetragraptus approximatus.* These graptolite faunas, which are best correlated with the Australasian succession (Figure 14.2), not only give a biostratigraphical age for part of the Ballantrae Complex but also demonstrate structural repetition of parts of the sequence.

The Ballantrae Complex plays an important role in assessing the geological evolution of southern Scotland. Church and Gayer (1973) regarded it as an ophiolite emplaced tectonically by northward obduction at the margin of the Midland Valley Terrane (Bevins *et al.,* 1992, p. 20). Stone and Smellie (1988) reviewed the whole complex and concluded that although it is an amalgam of disparate elements, most can be related to an oceanic crustal setting. Smellie and Stone (1992) envisaged the assembly of the complex through a process of southward subduction followed by northward obduction, whereas northward subduction prior to obduction was favoured by Bluck (1992) and Armstrong *et al.* (1999).

Broadly speaking, the Ballantrae Complex is composed of ultramafic rocks (serpentine and gabbro) and the Balcreuchan Group, which is made up of volcanic rocks (especially basaltic pillow lavas) and sedimentary rocks (sandstone, mudstone and chert). The Balcreuchan Group is exposed in three belts: a northern or Pinbain outcrop, which has yielded early Arenig graptolites in its lowest part (Rushton *et al.,* 1986); a southern outcrop, so far unfossiliferous, extending along the Stinchar Valley; and the central outcrop, or Bennane Head sector, described by Stone and Smellie (1988, p. 51) and summarized below. The Bennane Head sector was formerly considered to be a conformable succession of great (kilometre-scale) thickness, but Stone and Rushton (1983) demonstrated repetitions in the stratigraphy, suggesting a thinner sequence that has been imbricated by thrusting. Guides to the section are given by Bluck (1992) and Stone (1996), who refer to more detailed accounts of particular localities.

Description

The coastal exposures between Balcreuchan Port and Bennane Head show a varied succession of steeply dipping rocks that strike NNW and young consistently westwards (Figure 14.3). Lavas dominate and have been divided into two petrogenetic types, based on their geochemistry. South of Balcreuchan Port [NX 0968 8750], faulted against a sequence of island-arc lavas, is an ocean-island sequence: a thin sedimentary unit (numbered 1 in (Figure 14.3)) of chert and sandstone, in which the early Bendigonian (early Arenig) graptolites *Tetragraptus approximatus* Nicholson (Figure 14.4) and *T.* (*Pendeograptus*) *fruticosus* (Hall) were found, is overlain by (2) reddened feldsparphyric balsaltic pillow-lavas 100–200 m thick, followed abruptly but conformably by (3) unreddened aphyric pillow-basalts also 100–200 m thick. These are succeeded conformably by (4) a succession of conglomerate and tuffaceous sandstone, near the top of which a thin (1–2 cm) bed of laminated grey mudstone at [NX 0948 8737] contains many fragmentary Chewtonian (mid-Arenig) graptolites. Among these are *Didymograptus d. protoindentus* and others listed by Stone and Rushton (1983, p. 301); their '*Acrograptus?*'was rightly assigned to *Paradelograptus* by Erdtmann *et al.* (1987) but wrongly identified with the latest Tremadoc species *P onubensis* Erdtmann, Maletz and Gutierrez-Marco (see Rushton and Stone, 1988).

To the west of unit 4, a major fault introduces clastic sedimentary strata overlain conformably by (5) reddened feldsparphyric pillow-basalts identical to those of Unit 2, and at the top of these [NX 0945 8731] a red chert bed (Figure 14.5) (Stone and Smellie, 1988, fig. 17) yielded *Tetragraptus approximatus,* indicating a late Lancefieldian or early Bendigonian age. These lavas are again succeeded by (6) aphyric basaltic lavas, considered to be a tectonic repetition of unit 3.

About 1 km to the south, just south of Bennane Head, aphyric lavas overlie thick basalt breccia and are succeeded by a unit (7) of sandstone, breccia and chert [NX 0910 8638], at the base of which a dark-coloured bed of siliceous mudstone yielded a graptolite fauna of approximately Chewtonian age (Stone and Rushton, 1983, locality 5).

Interpretation

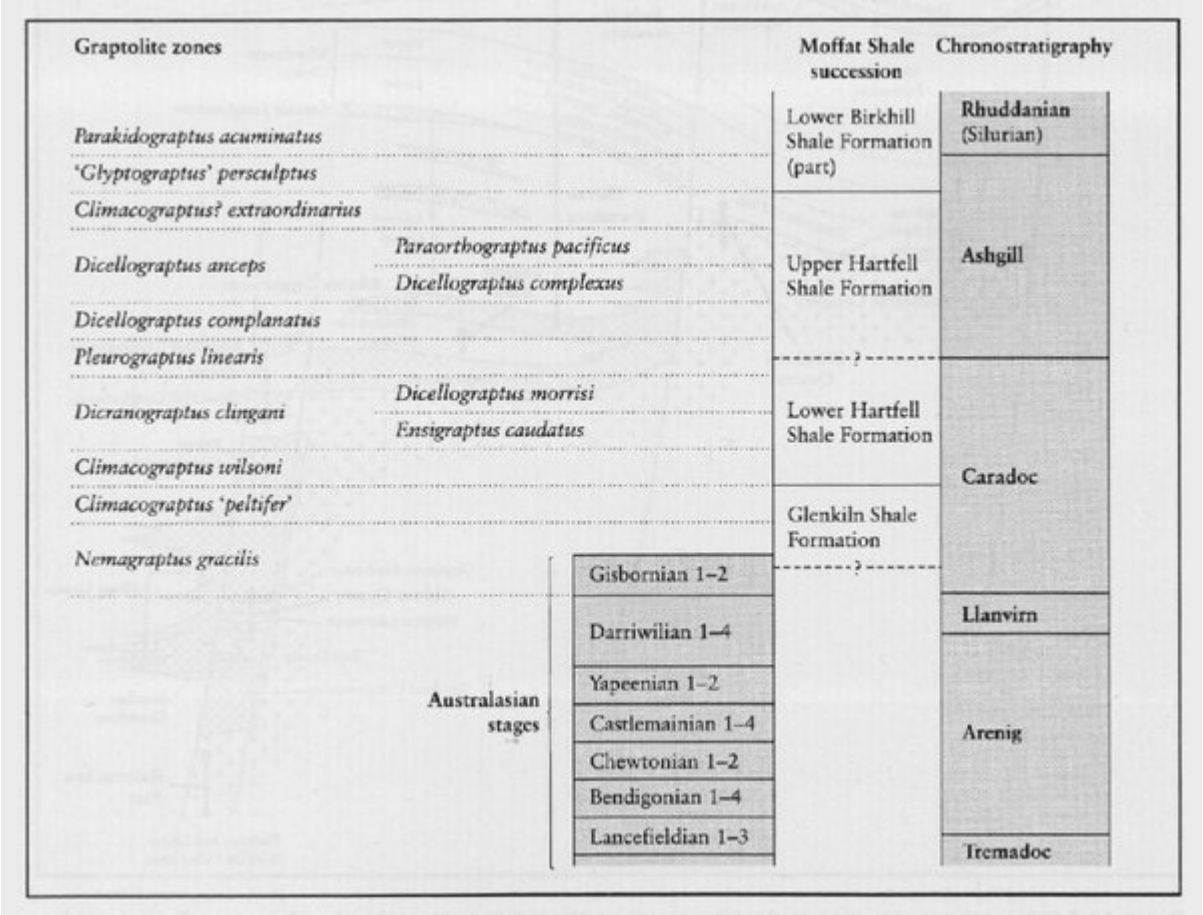
Although the rock succession faces uniformly westwards, giving the appearance of a thick, conformable sequence, the distribution of faunas is not consistent with a through succession because it shows alternations of early and mid-Arenig faunas. This suggests that the Balcreuchan Group succession is repeated by a series of thrusts: feldsparphyric basalts, overlying or containing early Arenig graptolites, are succeeded by aphyric basalts that contain or are overlain by mid-Arenig graptolite faunas. Thus, in the sequence outlined above, units 5 and 6 are considered to be a tectonic repetition of units 2 and 3. A further faulted repetition of the feldsparphyric lava is seen north of Port Vad, but there is no faunal evidence there.

According to this interpretation, the *T. approximatus* from unit 5 should be marginally younger than the species from unit 1; given the stratigraphical range of *T. approximatus* this is quite possible, though the implication in Stone and Rushton (1983, p. 300, 301) is that the fossils of unit 5 might be slightly the older. Similarly the present interpretation would demand that the fauna from unit 7 be slightly younger than that from unit 4, and again the biostratigraphical evidence is not precise enough either to contradict or to affirm the hypothesis (Stone and Smellie, 1988, p. 53, table 5). However, a part of the faunal succession, corresponding to the upper parts of the Bendigonian Stage, is unrepresented in the Bennane Head sector, and it may be that there is a non-sequence in the stratigraphy. The obvious level for such a non-sequence is the change from feldsparphyric basalts (units 2 and 5) to aphyric basalts (units 3 and 6), which would accord with Lewis' idea (in Stone and Rushton, 1983, p. 300) that the reddened condition of the feldsparphyric basalts was caused by long exposure on the sea floor.

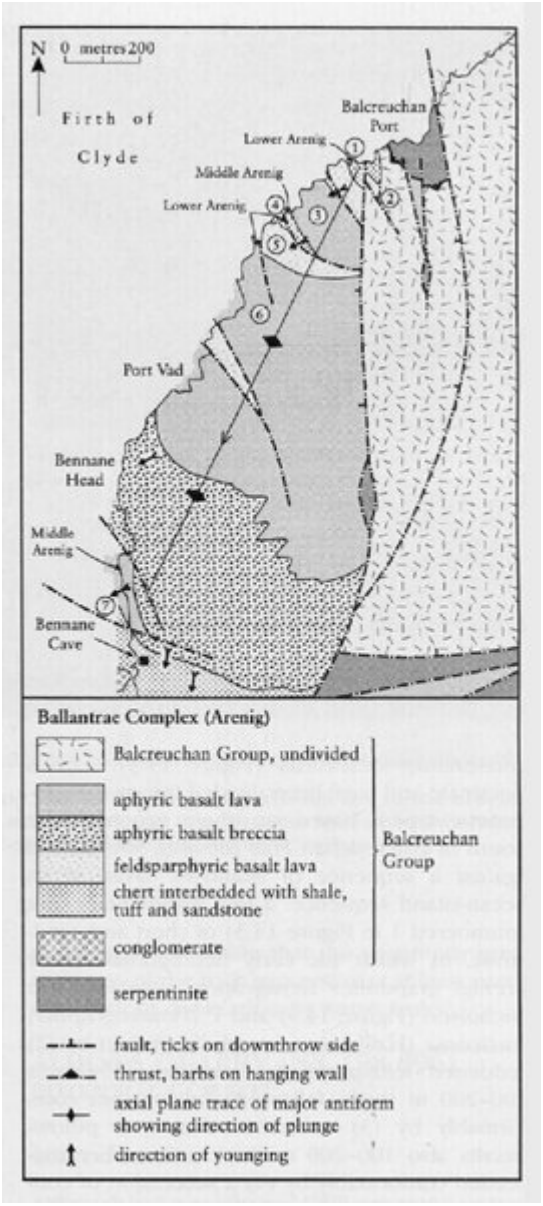
Conclusions

The coast between Balcreuchan Port and Bennane Head exposes part of the Ballantrae Complex, a fragment of ancient sea floor that has been driven by plate-tectonic processes onto a continental margin now underlying the Midland Valley of Scotland. Graptolites found at some of the coastal exposures include the only British examples of the important zonal species *Tetragraptus approximatus* and are especially significant in showing that the apparently great thickness of the rock succession is at least partly the result of duplication by thrust faults.

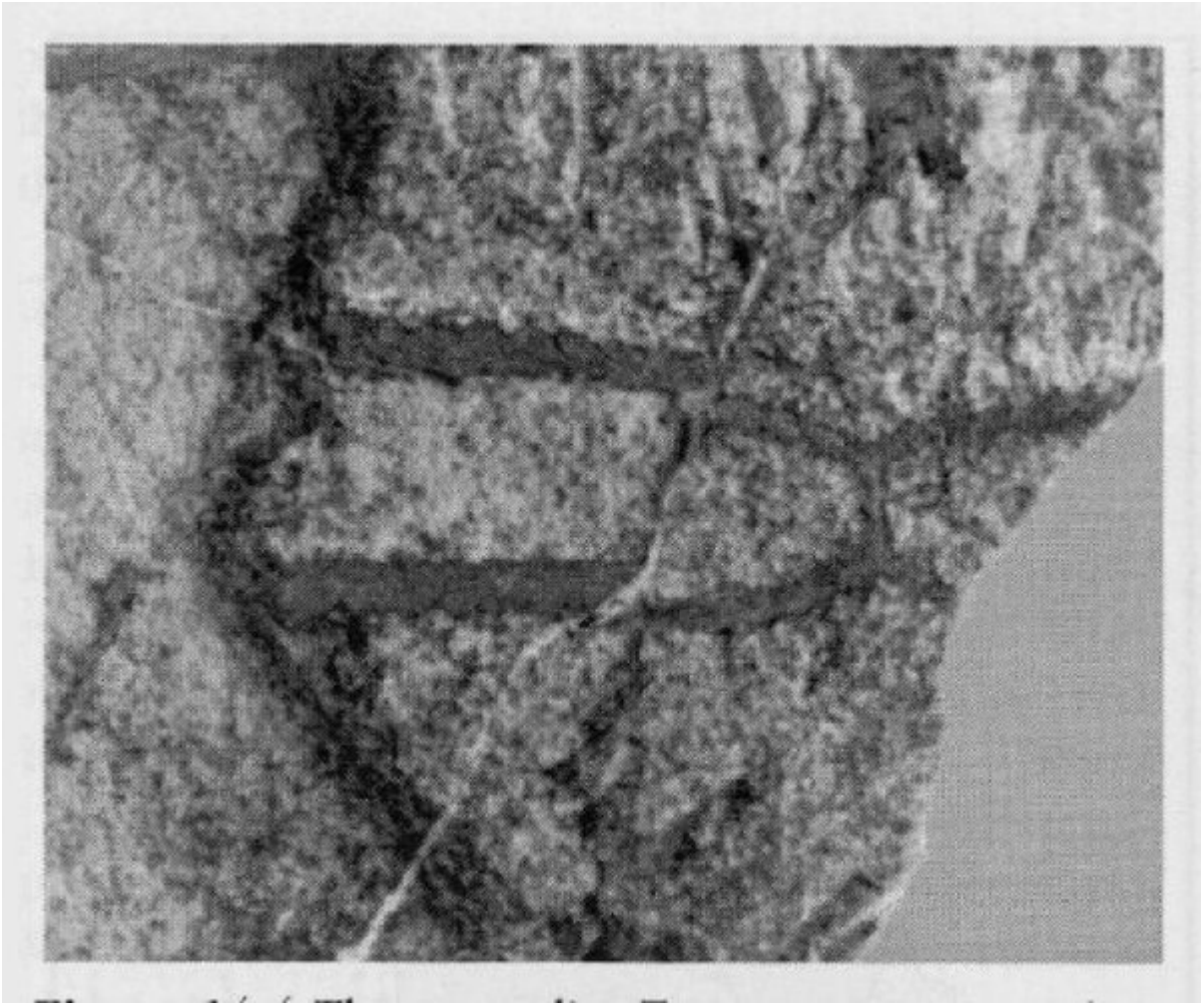
References



(Figure 14.2) Ordovician graptolite zones used in Scotland, based on the graptolitic succession in the Moffat Shale Group, and supplemented for older rocks by reference to the Australasian standard stages. British standard chronostratigraphy is shown for comparison.



(Figure 14.3) Geological map of the Ballantrae complex between Balcreuchan Port and Bennane Head, from Stone and Smellie (1988, fig. 16). Numbers 1 to 7 refer to units mentioned in the text.



(Figure 14.4) The graptolite Tetragraptus approximatus Nicholson, x3, from sandstone unit 1 (basal Bendigonian, lower Arenig) of (Figure 14.3).

(Figure 14.5) Gully 500 m south-west of Balcreuchan Port. Pillows of feldspar-phyric basalt lava (unit 5 of figure 14.3) dip steeply towards the observer and their upper surfaces protrude through a thin layer of red chert which contains Tetragraptus approximatus. (Photo: British Geological Survey photographic collection, D3587.)