Excursion 5 Kirkcudbright: a volcanic vent, Hawick Group turbidites, graptolites

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1:50 000 Sheet 83 Newton Stewart & Kirkcudbright

BGS 1.50 000 Sheet 5W Kirkcudbright

Route map: (Figure 22)

Main points of interest A Siluro-Devonian volcanic vent, Silurian turbidite greywackes and Wenlock graptolites, complex Caledonian folding.

Logistics All the localities lie SW from Kirkcudbright and involve relatively easy coastal walking: about 1.5 km at Locality 1, about 3.5 km at Locality 2, and about 7 km for Localities 3 and 4 if the coastal path is walked in both directions. A shorter return route from Locality 4 requires prior permission from Ross Farm. A low tide is advantageous but much can be seen under all but the highest tidal conditions. Vehicle access is good for Locality 1, where there is ample car or coach parking. However, as access for the other localities is via minor roads and parking space is limited, the full excursion should not be attempted in any vehicle larger than a minibus. Total driving distance from and back to Kirkcudbright is about 25 km.

Introduction

Kirkcudbright is an attractive small town with a picturesque harbour situated on the estuary of the River Dee. Maclellan's Castle, a ruined tower house dating from about 1580, may be seen in the town centre. Close by the Tollbooth dates from 1627 and the old Merkat Cross still features the jougs (a form of pillory) 'for the public humiliation of offenders'. About 3 km north of the town, on the A711, the Tongland dam and hydro-electric power station may be visited and a guided tour could form an appropriate adjunct to the geological excursion (for booking details phone 01557 330114).

The Kirkcudbright area is underlain by Carghidown Formation (Hawick Group) greywackes, and siltstones. These were deposited during the Silurian period about 430 million years ago. The coastal sections to the SW of the town provide splendid outcrops, illustrating turbidite sedimentology and complex Caledonian structure, and it is these that provide the focus for the excursion. Examples of igneous intrusive rocks will also be seen and graptolites of Wenlock age may be found in the Ross Formation beds, a Hawick Group component slightly younger than the Carghidown Formation and exposed farther south. Still younger strata of the Riccarton Group crop out to the SE of Kirkcudbright and are examined in detail by Excursion 11. It would be possible to include some elements of that excursion as an extension of the itinerary described here. The complex fold structure may be further examined in the excellent coastal exposures slightly farther NW at Barlocco [NX 585 486] which are described in detail by Treagus (1992).

1 Shoulder O'Craig: volcanic vent

The excursion is best begun at the car park and picnic area adjacent to The Doon and Gull Craig beside Nun Mill Bay [NX 658 487]. This is situated about 5 km from Kirkcudbright and is reached via the A755 and B727. About 600 m NE from the parking area an agglomerate-filled volcanic vent (Figure 23) cuts Silurian greywacke and siltstone (Carghidown Formation). The sedimentary rocks are exposed on the foreshore in Clinking Haven as steeply inclined beds striking NE and locally folded into tight, upright structures. A good array of turbidite features can be seen on the wave-smoothed surfaces and includes graded bedding and loaded bed bases. A penetrative cleavage is developed subparallel to bedding in the finer-grained lithologies but does not continue into the vent agglomerate which was therefore a post-tectonic intrusion. The agglomerate, believed to have been intruded in latest Silurian or early Devonian times, is one of a number of such vent features scattered across SW Scotland. A fresh kersantite (biotite-plagioclase lamprophyre) phase of the vent intrusion has given a K-Ar age of 410 ± 10 Ma (Rock et al., 1986a). The vent occupies the northern

side of Clinking Haven forming the Shoulder O'Craig cliffs [NX 663 491] and probably extends for a short distance inland. Lamprophyre dykes cut both the vent agglomerate and the turbidite country rock. Detailed petrographical and geochemical data for the intrusive rocks are given by Rock et al. (1986a).

The texture of the vent agglomerate is best seen on the wave-polished surfaces on the NW side of Clinking Haven. The cliff sections provide more extensive outcrop in three dimensions and confirm that the agglomerate consists principally of variably rounded greywacke, siltstone and sporadic microdiorite or basaltic clasts set in a finegrained matrix; the latter is largely altered to carbonate and chlorite. Clast size is very variable and ranges up to rafts of country rock a few metres in length. The preponderance of sedimentary clasts in the vent suggests that initially it emitted steam and gases for the most part and did not directly tap a source of magma. Thus the vent agglomerate should more accurately but less descriptively be termed an intrusion breccia. It is cut by a number of basalt bodies and lamprophyre dykes the larger of which are shown in (Figure 23). Note the irregular and fractured biotite-olivine basalt mass which intrudes the agglomerate in the western end of the vent. It is generally clast-free and its contact with the surrounding agglomerate varies from sharp to diffuse and gradational. Oval, pillow-like textures and possible flow fractures may suggest that the intrusion was emplaced in a semi-solid state (Rock et al., 1986a). However, it does imply that the vent developed from a steam and gas escape route to a conduit for magma.

Other dykes cut the greywacke country rock and a noteworthy example occurs about 20 m beyond the NE extremity of the vent. This has been dubbed the 'Loch Ness Monster' dyke on account of its bizarre outcrop pattern. It is a kersantitic lamprophyre consisting of biotite phenocrysts set in a dark grey feldspathic matrix. The highly irregular form is thought to reflect high volatile pressure during emplacement.

2 Brighouse Bay: Carghidown Formation greywackes and structure

From Locality 1 follow the B727 Kirkcudbright to Borgue road for about 2 km SW towards Borgue before turning left towards Brighouse Bay. About 2 km of unclassified road leads to the head of the bay where parking is available on the raised beach. The west side of the bay (Figure 24) provides extensive exposures of well-bedded greywackes of the Carghidown Formation (Hawick Group, (Figure 2)), but the structural complexity is considerable. The greywacke beds are repeatedly folded and sheared out, with remarkable variability in the attitude and orientation of the fold hinges. The relationships are best examined between Point of Green and Dunrod Point [NX 628 445] on the SW corner of the bay, reached by a coastal walk of about 1.5 km. This is the recommended starting point for a traverse back along the coastal section. Fold structures are abundant but one of particular interest can be seen on the west side of Point of Green (2a in (Figure 24)). This fold is downward-facing or inverted: the apparent antiform is in fact synclinal. The antiform plunges moderately to the NE and the curved upper surface is covered with well-developed flute casts and load structures, marking it out as an inverted bed base. A non-axial planar slaty cleavage is also clearly seen to transect the axial surface and both limbs of the fold by a few degrees clockwise. Traversing eastwards across Point of Green several other steeply plunging folds are separated by shear planes which on a large scale merge to form an anastomosing zone. At Point of Green some thick greywacke beds appear in the sequence and large flute casts are preserved on the base of the thickest (2b). This bed can be seen to cut down through the underlying more thinly bedded greywackes, an example of channelling. Eastward towards Dunrod Point steeply plunging fold hinges are contained within the anastomosing shear system (2c). Their inter-relationship may be conveniently examined in detail at the NE corner of Dunrod Point [NX 6286 4459], a structural summary of which is shown in (Figure 25). From this locality the coastal section continues NE towards the head of Brighouse Bay. Near-continuous exposure reveals much folding of the greywacke strata with variably but often steeply plunging hinges separated by sinuous shear zones. Thicker greywacke beds often show a good array of bottom structures and there is a strong, ubiquitous slaty cleavage. Note that the cleavage is axial planar to some of the folds but clockwise transecting in other examples; hinge plunge variation commonly occurs within the axial plane. These folds are believed to have formed in a transpressive stress regime when a variable component of sinistral shear was imposed on the overall NW-SE regional shortening. A detailed discussion of this phenomenon was given by Stringer and Treagus (1980). The incidence of folding decreases, and the frequency with which the section is cut by shear zones increases, towards the NE as the route leads back to the parking area at the head of the bay.

3 Meikle Ross: Ross Formation greywackes and siltstones

This small peninsula forms the southern extremity of the west side of Kirkcudbright Bay. It is reached by means of unclassified roads which link Brighouse Bay with Ross Farm [NX 646 447]. Manor Point forms the headland on the south side of Ross Bay (about 1.5 km SE along the footpath from Ross Farm) and from the Point about a kilometre of well-exposed coastal section extends south. It is most readily accessible if the path is followed to the southernmost point of Meikle Ross and the coastal section then traversed northwards.

The strata are well-bedded greywackes and siltstones with sporadic interbedded grey-green shale and belong to the Ross Formation (Hawick Group, (Figure 2)). Restricted graptolite faunas (Figure 26) of the *M. riccartonensis* Biozone (early Wenlock) have been found in rare hemipelagite horizons (localities 52–55 of White et al., 1992).

Bedding is fairly regular with a general dip of about 60–70° to the SE; beds are commonly inverted and young towards the NW. Bottom structures are abundant, and ripple marks and sand volcanoes can be seen on the top surfaces of some beds. Fold hinges are far less evident than was the case at Brighouse Bay; the best examples are seen around Thunderhole Bay (Figure 22). However, the evidence for variable plunge of fold hinges is merely more subtle in this locality and can be demonstrated by a systematic examination of the lineation formed by the intersection between bedding and cleavage. The cleavage is axial-planar to the folds, as can be demonstrated along strike on the island of Little Ross (beyond the scope of this excursion) and so the lineation can be taken as parallel to local fold hinge orientation. Overall there is a smooth variation in the plunge of the lineation, from 47° to the ENE at the north end of the section to 38° to the WSW in the south passing through a maximum plunge of 64° where the lineation is parallel to the dip of the cleavage. Diachronous formation of the cleavage under a varying stress regime seems the most likely explanation for these relationships, a similar mechanism to that proposed at Brighouse Bay. Further discussion of the tectonic implications of the Meikle Ross section is given by Kemp (1986; 1987a).

4 Fauldbog Bay: graptolitic hemipelagites.

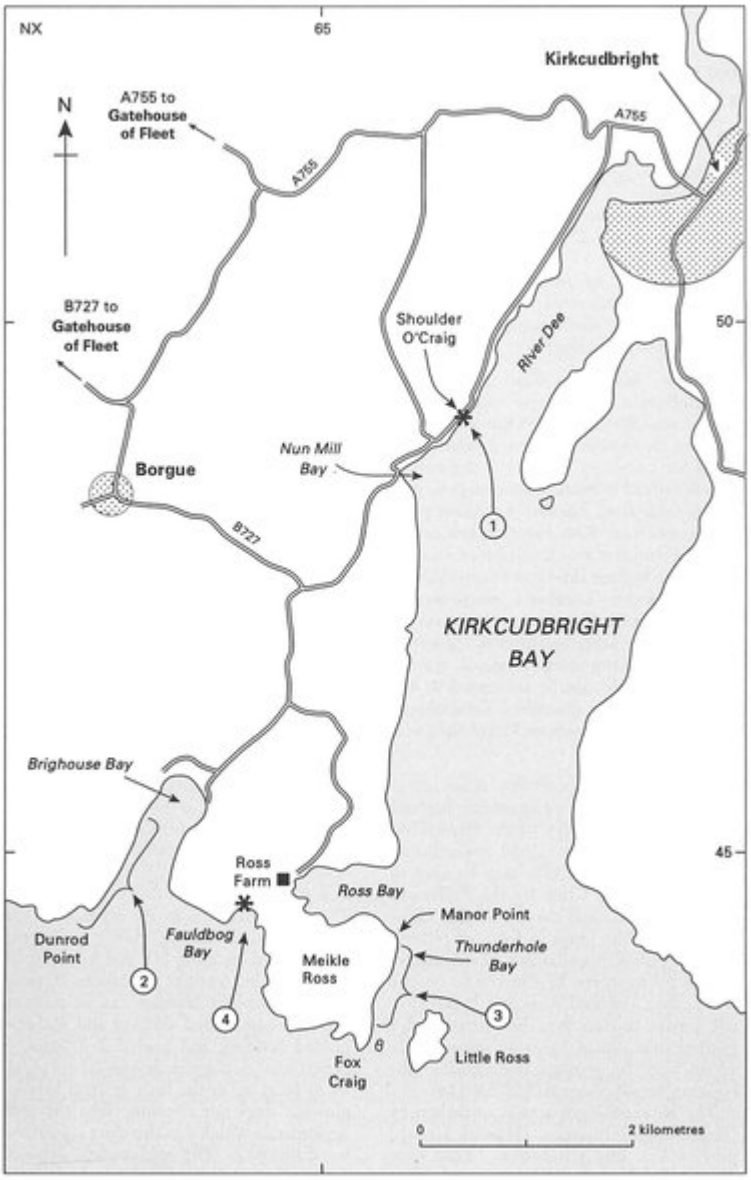
Well-developed fold structures can be seen on the west side of Meikle Ross at Fauldbog Bay [NX 642 444], a locality which is also notable for the abundance of graptolites in the interbedded hemipelagite horizons. The west-facing coast of the bay exposes strata lithologically similar to the Ross Formation but containing some thin red mudstones characteristic of the Carghidown Formation. The boundary between the two formations is taken at a fault in the northern extremity of the bay, the strata on the east side are assigned to the Ross Formation and those on the west to the Carghidown Formation. Variable and complex folding may be seen in many parts of the shore section. Sheared zones separate the folded areas from units of more uniformly bedded strata.

To reach Fauldbog Bay continue along the coastal path around the headland and up the west coast of Meikle Ross. Good exposures of graptolitic hemipelagites of the *Cyrtograptus centrifugus* Biozone (basal Wenlock) can be examined in intertidal reefs at the northern end of Fauldbog Bay [NX 642 445] to [NX 644 443] (localities 61–63 of White et al., 1992). Graptolites collected here include *Barrandeograptus*? *bornholmensis* (Laursen), *C*. cf. *centrifugus* Boucek, cf. *C. grayi* Lapworth, *Monoclimacis vomerina* basilica (Lapworth) , Mcl. *vomerina vomerina* (Nicholson), Mcl. *vomerina* c.l., *Monograptus priodon* (Bronn), *M.* aff *priodon, M. remotus* Elles & Wood, *Retiolites geinitzianus angustidens* Elles & Wood and *R. geinitzianus geinitzianus* Barrande. Approximately 750 m to the south, [around [NX 644 437]] (localities 57–60 of White et al., 1992) hemipelagites in the intertidal reefs contain a restricted fauna of the *Monograptus riccartonenis* Biozone, mainly *M. Riccartonensis*. A selection of graptolites recovered from these localities is shown in (Figure 26). They are of Wenlock age (Figure 2) and (Figure 5).

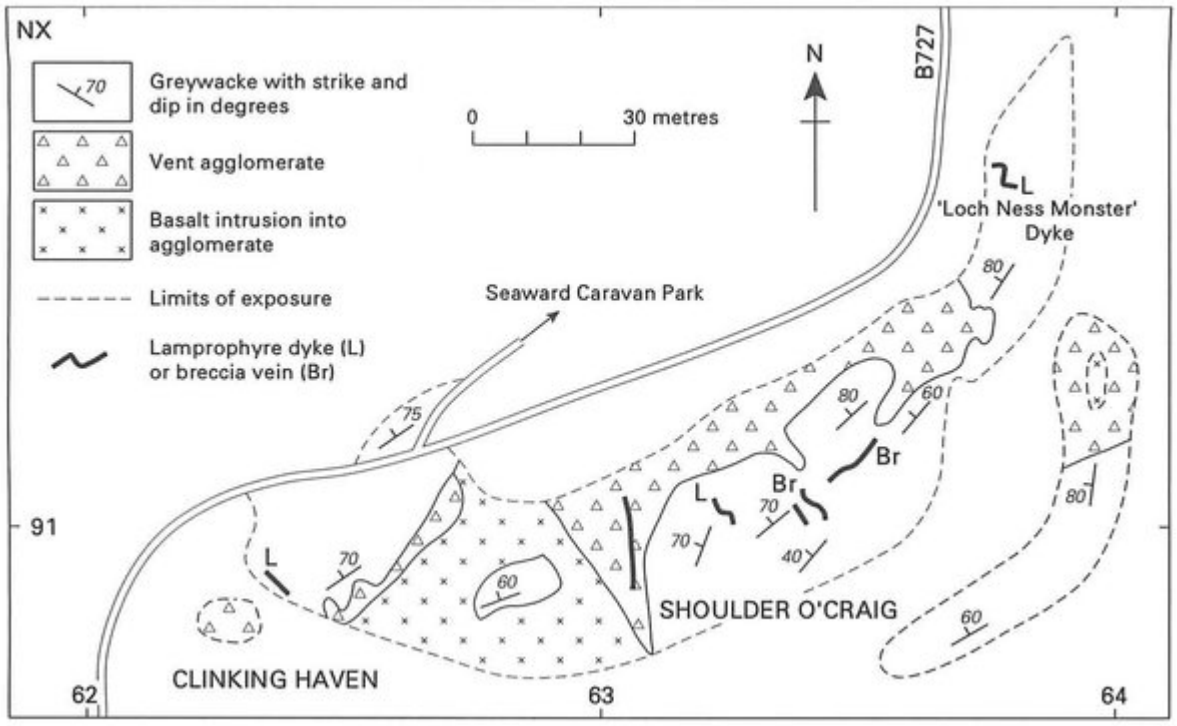
Both sides of Fauldbog Bay expose abundant minor folding but the NW side is of particular interest. Many of the folds there are inverted (downward-facing) and enclosed within shear zones reminiscent of the Brighouse Bay section; a similar origin seems likely.

From Fauldbog Bay it is possible to cross the fields eastwards towards Ross Farm if prior permission has been obtained. Otherwise the coastal route should be retraced.

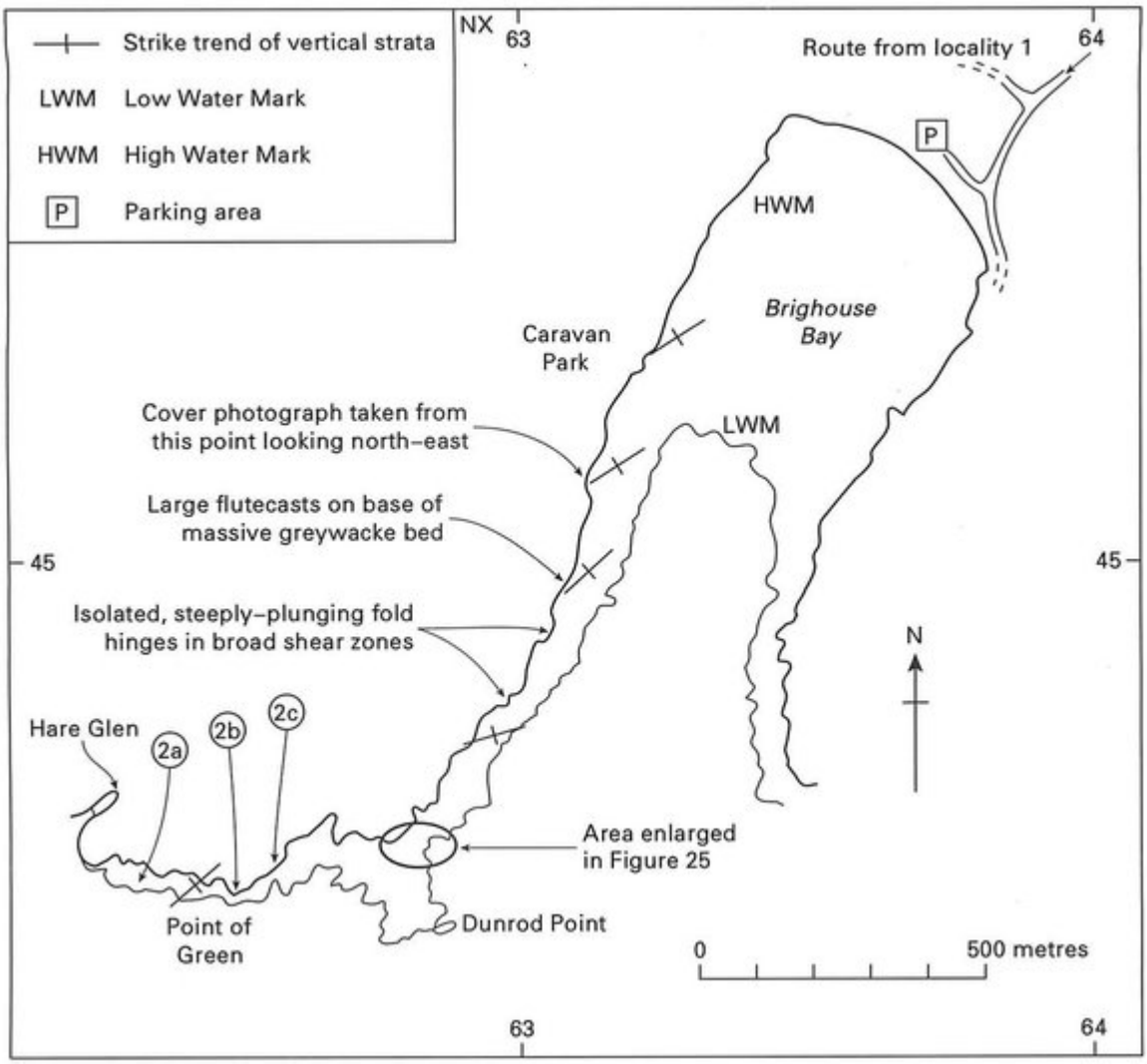
References



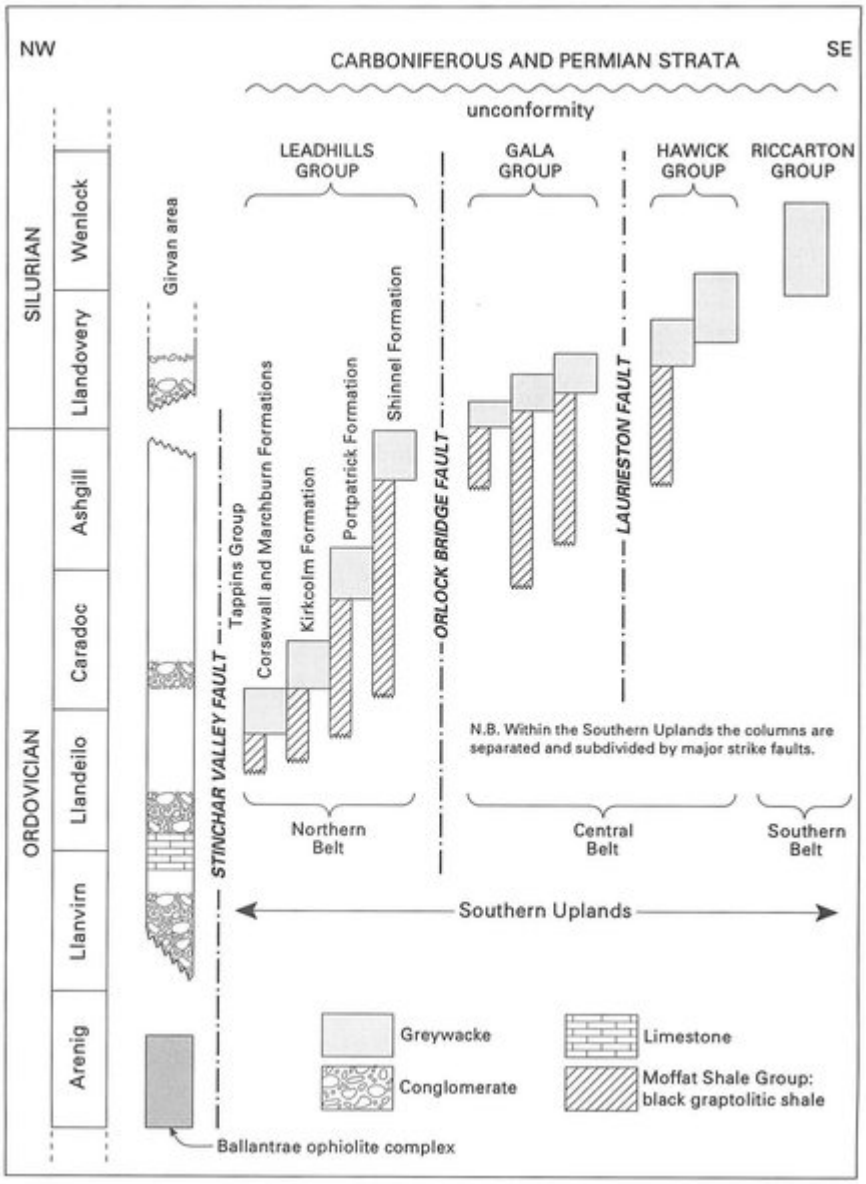
(Figure 22) Locality map and outline geology for the Kirkcudbright excursion.



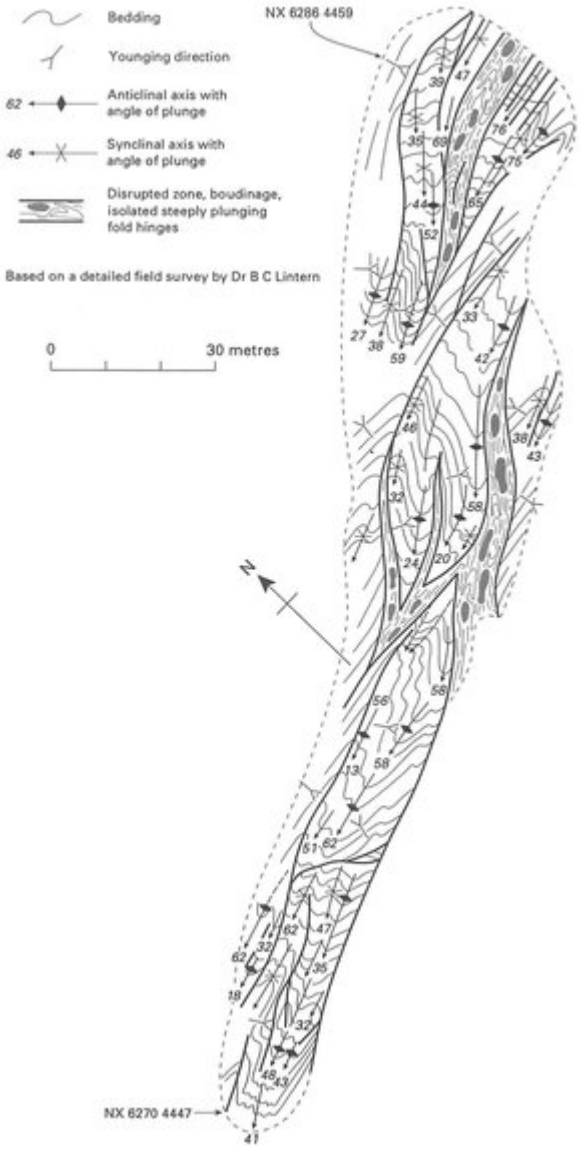
(Figure 23) Outline geology of the Shoulder O'Craig volcanic vent (Locality 1).



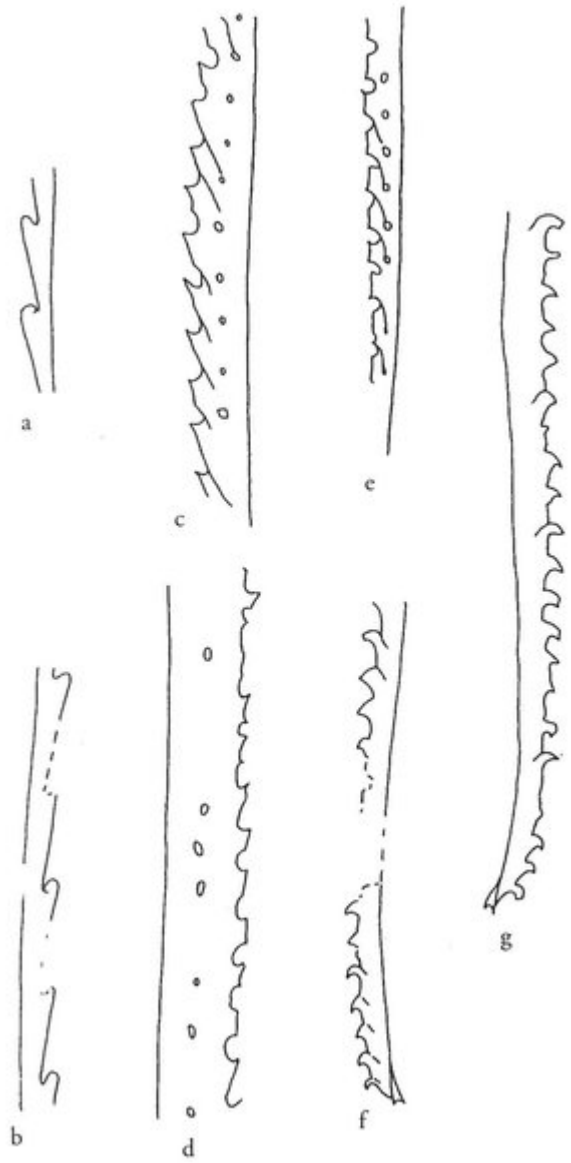
(Figure 24) Locality map and geological notes for the west side of Brighouse Bay (Locality 2).



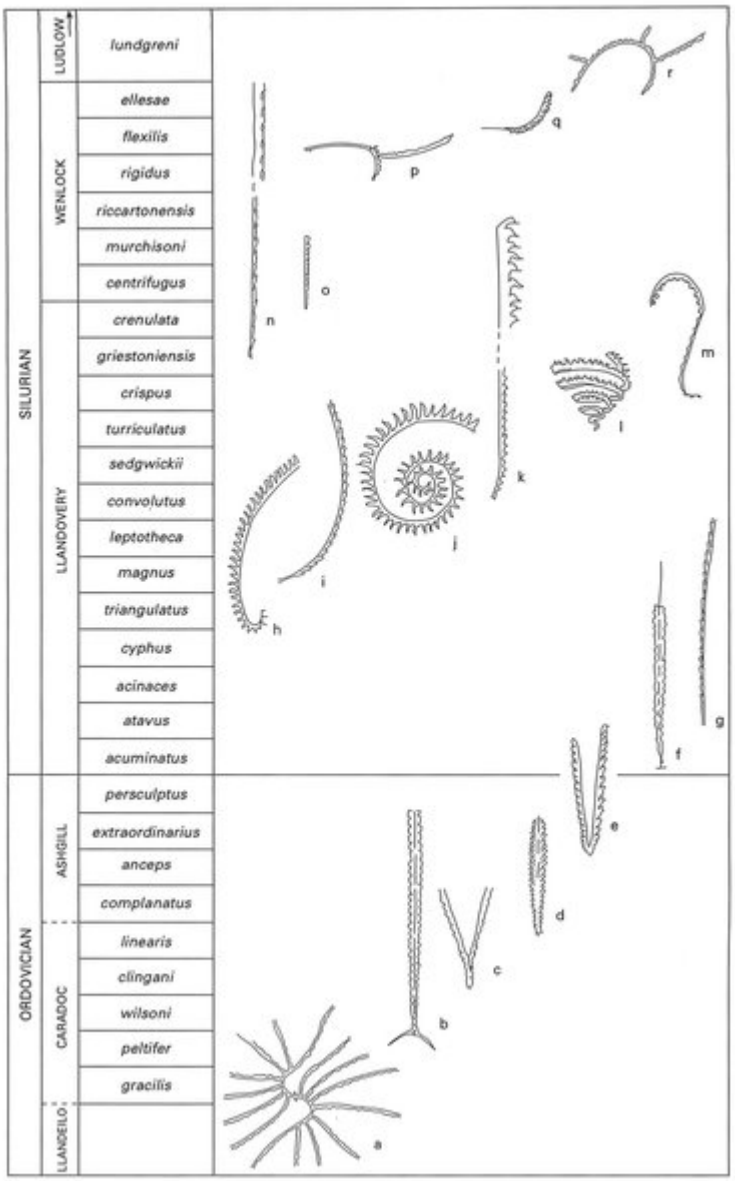
(Figure 2) Schematic representation of stratigraphical relationships in south-west Scotland.



(Figure 25) Detail of structure near Dunrod Point (Locality 2).



(Figure 26) Examples of graptolites from the Ross Formation all × 5, except for a and b, x 10. (a, b) Barrandeograptus? bornholmensis (Laursen), centrifugus Biozone. (c) Monoclimacis cf. vomerina vomerina (Nicholson), centrifugus to riccartonensis biozones. (d) Monoclimacis vomerina basilica (Lapworth), centrifugus to riccartonensis biozones. (e) Monoclimacis vomerina s.l. (Nicholson), centrifugus to riccartonensis biozones. (f, g) Monograptus riccartonensis Lapworth, riccartonensis Biozone.



(Figure 5) The sequence of Ordovician and Silurian graprolite biozones present in south-west Scotland, with line-drawings of selected graptolites, arranged in stratigraphical order. The graprolites are approximately × 1, and the species are: a. Nemagmptus gracilis (Hall) b. Climacograptus bicornis (Hall) c. Dicranograptus clingani Carruthers d. Orthograptus abbreviatus Elles & Wood e. Dicellograptus anceps (Nicholson) f. Parakiclograptus acuminatus (Nicholson) g. Atavograptus atavus (Jones) h. Monograptus triangulatus (Harkness) 1. Coronograptus gregarius (Lapworth) J. Monograptus convolutus (Hisinger) k. Monograptus sedgwickii (Portlock) l. Monograptus turriculatus (Barrande) m. Monograptus crispus Lapworth n. Monoclimacis griestoniensis (Nicol) o. Monoclimacis crenulata (Elles & Wood) p. Cyrtograptus rigidus TuUberg q. Monograptus flexilis Elles r. Cyrtograptus lundgreni Tullberg.