2 The geology of Eyemouth and Burnmouth

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Purpose

This excursion examines folded Silurian greywackes of the Hawick Group, early Devonian autobrecciated lavas unconformably succeeded by late Devonian (Old Red Sandstone) breccias, a transitional sequence across the Devonian–Carboniferous boundary, and an abandoned Pleistocene drainage channel.

Logistics

Most are coastal outcrops and Locality 5 (Burnmouth Foreshore) requires low tide. Localities 1, 2 and 3 can be visited at half tide and Locality 4 is not tide-dependent. The itinerary described here should be adjusted to take account of tide times. Eyemouth has good parking with toilet and refreshment facilities. Parking at Burnmouth is possible along the side of the minor road. Parking at Burnmouth Harbour at the foot of the cliffs is limited.

The foreshore rocks may be slippery. Hard hats and wellingtons are essential. Localities 4 and 5 are not recommended for large parties.

Maps

O.S. 1:50 000 Sheet 67 Duns, Dunbar & Eyemouth; B.G.S. (Scotland) 1:50 000 Sheet 34 Eyemouth.

Geological background

By the early Silurian, the microcontinent of Eastern Avalonia, including the area of England, Wales and southeast Ireland, had moved northwards to lie in close proximity to the margin of Laurentia (Figure 3)a. The intervening Iapetus Ocean had been reduced to the width of a narrow seaway. On the Laurentian side; thick deposits of poorly sorted sand grade sediments, derived from rising land to the north, began to cover the thin sequences of black, graptolitic shales that had accumulated on deep shelf and, in some places, oceanic crust. These coarser sediments were introduced by turbidity flows, each resulting in a few cms to i m+ thick greywacke, usually separated by thin bands of background mud-grade sediment, sometimes graptolitic. In southern Scotland, these beds extend from the Llandovery up into the Wenlock when sedimentation ceased as the seaway narrowed, filled up and was eventually uplifted as a result of the final oblique compression between Avalonia, Baltica and Laurentia at the end of the Caledonian Orogenic Cycle (Figure 3)a. In the Southern Uplands, the Lower Palaeozoic rocks are arranged in a series of northeast–southwest trending fault-defined slices, variously interpreted as reflecting a syn-depositional accretionary prism, or the post-depositional thrust slicing of the thick sediment wedge on the Laurentian margin by the late Silurian compressional event. In the Eyemouth area, individual greywacke beds are seldom more than 0.5 m thick and are strongly folded; the sequence is unfossiliferous but is compared to the Hawick Group elsewhere and is thus most likely to be of Llandovery age.

Magmas generated at depth by the Caledonian continental collision resulted in extensive late Silurian/early Devonian intrusions and volcanic activity, represented by dykes and extensive lavas, agglomerates and tuffs in the Eyemouth area and, to the southwest, by the Cheviot Volcano (Excursion 4). Locally, contemporary sediments were largely derived from the newly formed volcanic centres. More earth movements in the mid Devonian produced gentle folds in the early Devonian rocks. In the late Devonian, this hilly landscape of Lower Palaeozoic greywackes and younger volcanic rocks was deeply weathered in a semi-arid climate and the debris stripped off by flash floods to form fans of breccias and channel sands on the lower ground. By the early Carboniferous, the relief was somewhat reduced and the Cementstone Group was deposited on a broad floodplain crossed by meandering to low sinuosity channels with the formation of early diagenetic cementstones during periods of non-deposition. Subsequently, rivers flowing from the east and northeast brought thick sequences of fluviodeltaic cross-bedded medium- to coarse-grained sandstones into the area, building out to the southwest. The Fell Sandstone Group succeeds the Cementstones on the coast south of Burnmouth.

A full Carboniferous sequence is developed further south in Northumberland. Locally, however, the next events of geological interest were the intrusion oflate Carboniferous/?Permian basic dykes and the effects of the Variscan Orogeny. The latter resulted in local folding and faulting, but the most spectacular structure is the basement controlled, east facing Berwick Monocline, striking just west of north along the coast and responsible for the vertical Cementstone Group sequence at Burnmouth, where the steep limb is cut by a high-angle reverse fault.

Locally, the effects of the Pleistocene glaciation include a variable covering of till, thick in the valleys but thin and patchy on the high ground extending to the coast at Burnmouth. An infilled preDevensian river valley occurs in Eyemouth bay. The present form of Burnmouth Glen and the Eye Water gorge below Ayton are the result of post-glacial deepening of older valleys.

Further details will be found in Greig (1988; in McAdam *et al.* 1992).

Excursion details

From the A1 about 11 km north of Berwick, take the A1107 to Eyemouth. Cross the Eye Water and turn right. At the church keep straight on to the northern end of the town, then turn sharply back to the right to the car park with toilets and cafe on the esplanade [NT 944 645].

Locality 1, Eyemouth Beach [NT 944 646]

From the car park, turn left and walk to a point where access to a corner of the beach can be obtained via a ramp (Figure 2.1). On the lower foreshore and in the cliffs where they rise towards the north are extensive exposures of rocks of agglomeratic texture which have been interpreted by Greig (1988) as autobrecciated lavas of early Devonian age. Around mid-low tide level, exposures are heavily coated with seaweed, but at the edge of the beach are a number of good, sand polished surfaces in which the fragments are relatively small, angular to rounded and variable in shape, set in an igneous matrix. These dark coloured, reddish weathering rocks with scattered green reduction spots are pyroxene andesites, with well formed phenocrysts of plagioclase feldspar. Some outcrops have the appearance of debris flows of volcaniclastic material. Further north round the bay and in the cliffs, however, the rocks are paler, purplish grey dacites, more acid in composition. Clast size increases, some in excess of 1 m across, and most are tabular with little intervening matrix. They show good flow-banding, with aligned feldspar, hornblende and biotite phenocrysts.

In the back of the bay, the volcanic rocks in the cliff are cut by a channel reaching to beach level. The softer fill, of strikingly reddened layers of unconsolidated breccio-conglomerates and sands capped by several metres of till, is weathered back to form a gully. The mixture of angular and rounded clasts in the coarse unit accessible at beach level is dominated by fragments, <30 cm, of Silurian greywackes, fine–medium grained red sandstones and volcanic rocks, with a vague imbrication indicating water flow towards the sea. The channel is interpreted as that of a pre-Devensian stream.

Locality 2, Eyemouth Fort [NT 944 649]

Proceed with care across the foreshore to a small bay on the point beneath the fort, where the unconformity between the autobrecciated volcanic rocks, here with individual blocks several metres in length, and the overlying red breccias and sandstones of the Upper Old Red Sandstone can be seen. The deposits represent alluvial fans of a semi-arid environment, fed by flash floods stripping material from the surrounding hills. The texture of the Devonian rocks can be studied in the many fallen blocks. Towards the far end of the small bay, a large joint face shows excellent imbrication in the breccias indicating flow from the east. The clasts are similar to those in the Pleistocene channel but more dominantly greywackes, with red sandstones and volcanic rocks. At some levels, where the fines have been washed out of the deposit, they are cemented by calcite.

The small offshore islands are of Silurian greywackes just on the east side of the westerly downthrowing, north-northeast trending Eyemouth Fault which is responsible for juxtaposing the Devonian rocks against the Silurian greywackes seen on the east side of Eyemouth harbour.

Return to the car park in Eyemouth and drive out of the village to the A1107. Turn left, cross the Eye Water and then immediately left again down The Avenue. Follow the road to a parking point [NT 947 643] on the east bank of Eyemouth harbour just before the old Customs House.

Locality 3, Nestends [NT 950 647]

Walk in front of the Customs House straight ahead to Nestends, then follow the cliff-edge path southeast round the golf course. Superb exposures of folded and faulted Silurian greywackes of the Hawick Group can be seen from the cliff top and along the promontories, with access to foreshore level possible in several bays. The rocks are fine sand-grade turbidites of varying thickness with reddish mudstone interbeds; no diagnostic fossils have been found. Graded bedding is apparent in places and some units have poorly developed sole structures at the base and small scale ripples and channels towards the top, all indicating way up. The folds strike east-northeast–west-southwest and have a complex form, due to a significant sinistral shear element during compression. They are tight, almost isoclinal in places, with highly variable 1–15 m wavelengths as folds develop or die out along strike. Fold axes vary considerably in their plunge and in some cases, the cleavage, which is well developed in the mud grade beds, is folded. Just beyond the end of the golf course, in a north–south zone about 150 m wide west from Agate Point [NT 955 642], the shearing associated with the compressional event has resulted in the juxtaposition along strike of southwest plunging folds which are upward-facing with downward-facing folds plunging to the northeast (Figure 2.2). These are probably sheath folds and all these features are the result of a single phase of deformation.

From Agate Point, follow the wall along the southern edge of the golf course into the housing estate, then turn right to reach the car park. Return to the A 1107, turn left and after t km turn left again onto the Burnmouth road. Park on the roadside where the houses of Burnmouth start on the left [NT 953 612].

Locality 4, road cutting below Burnmouth Hill [NT 957 611]

Immediately north of the railway bridge, take the road to the east that descends steeply to the shore (Figure 2.1). At the top of the hill, fork left and follow the narrow road downhill with outcrops of Silurian Hawick Group greywackes dipping predominantly about 65° northwest on the left. After some 180 m, approach a roadside outcrop on a left-hand bend, where the first beds are near vertical and younging towards the sea. A 0.7 m greywacke sandstone bed has excellent flute marks, suggesting turbidity flow from the northeast; these sole structures can be traced around the folds here and are well seen just off the road lower down the hill. Viewed along strike, the cleavage in the soft, shaly interbeds can be seen refracting and dying out in the more competent greywacke sandstones. Immediately downhill is a synclinal axis, cut on its seaward side by a 4.25 m wide Siluro-Devonian porphyrite dyke, in which the chilled margin and the coarser centre with plagioclase feldspar phenocrysts can be compared. Beyond the dyke is the nose of a small anticline followed immediately by a sharp syncline with a faulted axis. It is in the seaward limb of this syncline that the sole structures can be well seen.

If time and tide allow, descend the hill to where similar rocks can be studied on the foreshore north of Partanhall [NT 958 612]. Here the cross-cutting relationships of the porphyrite intrusions, roughly parallel to the north–south strike of the Silurian greywackes, can be seen, together with a later generation (late Carboniferous-?Permian) of east–west quartz dolerite dykes. On the foreshore at low tide, the northward extension of the faulted Berwick Monocline can be seen with the Carboniferous Cementstone Group on the seaward side.

From the foot of the hill at Partanhall, cross to Burnmouth Harbour [NT 959 609]. Alternatively, return to the vehicle and take the road down to Burnmouth Harbour, or to Cowdrait at the end of the narrow tarred road along the seafront, where there is limited parking for one or two cars or a minibus.

Locality 5, Burnmouth Foreshore [NT 958 611]

At low tide the foreshore section provides continuous exposure over a distance of some 2 km, and involves rough walking and scrambling over vertically dipping and differentially eroded, wet, slippery rocks.

The sediments exposed include the Upper Old Red Sandstone and Lower Carboniferous Cementstone Group, overlain by the Fell Sandstone Group (Figure 2.3). The sediments young seawards on the steep northerly limb of the east-facing Berwick Monocline, with the beds vertical to slightly overturned and dipping between 55 and 80° to the west-northwest and west-southwest. The structure is most tightly compressed in the north where it is also more extensively faulted.

The upper 50 m of Old Red Sandstone, exposed on the foreshore west of Burnmouth Harbour (Figure 2.3), contains up to five relatively poorly exposed fining-upward sequences, each comprising an erosively based, coarse-grained, trough cross-bedded fluvial channel sandstone overlain by fine-grained fluvio-lacustrine sandstones, siltstones and silty mudstones containing calcretes similar to those at Pease Bay (Excursion 1). The Old Red Sandstone on the foreshore is faulted and intruded by a northeast–southwest trending quartz dolerite dyke. Further west in the hillside above the harbour Old Red Sandstone is faulted against the Silurian greywackes.

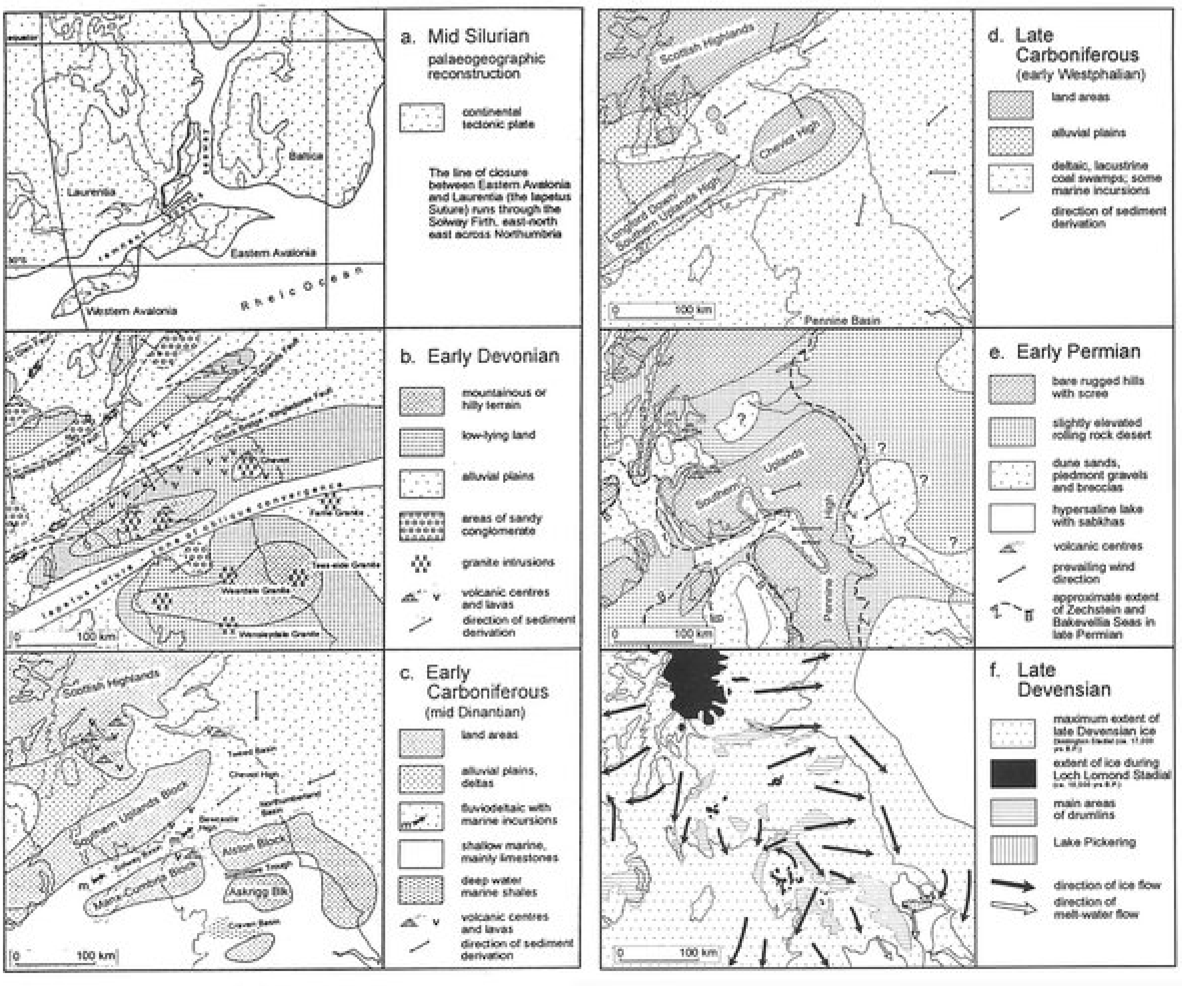
The Old Red Sandstone is conformably overlain by the Lower Carboniferous Cementstone Group which is completely exposed on the foreshore to a total thickness of 450 m. The best exposures, to the east and south of the harbour, consist of micaceous, fluvial channel sandstones regularly interbedded with fluvio-lacustrine overbank siltstones, mudstones, sandstones and subordinate cementstones composed of ferroan dolomite. The succession is characterized by a crudely cyclic pattern of deposition of the type cementstone-mudstone-sandstone-mudstone-cementstone. The cementstones are extremely hard and splinter when hit. They consist of a number of different but gradational types, including sandy and banded cement-stones, which contain a variety of sedimentary structures. A typical sequence comprises massive structureless cementstone at the base, overlain by flat laminations and convolute laminations at the top. Cementstone beds are <45 cm thick and in parts of the succession they have a nodular appearance, and locally contain vugs lined with calcite pseudomorphs of original evaporite minerals such as gypsum. Lateral accretion surfaces, indicative of point bar deposition and meandering river channels, have been identified in some sandbodies seen on aerial photographs but they are extremely difficult to recognize in the field because of the steep dip of the beds. Burrows, rootlets, bivalves, fish fragments and mudcracks have been found in the overbank fines, but vary in abundance through the succession. The lower part is predominantly argillaceous and red to purple in colour. It contains thin (<30 cm) cementstones yielding rare fish fragments and bivalves. Joints in one cement-stone bed near the east wall of the harbour are coated with galena. Plants are common throughout this part of the succession which contains three major sandbodies up to 7.7 m thick. Two of them are relatively simple, single storey, fining-upward sandbodies containing trough cross-bedding overlain by ripple cross-lamination. Channel sandstone 11 (Figure 2.3) contains a well developed local lenticular basal channel lag conglomerate whilst the other one, next to the east wall of the harbour, is more complex in its internal organisation ((Figure 2.3), sandstone 12).

In the middle part of the succession the mudrocks are mostly grey and sandy, and the associated cementstones thicker and more abundant. Cementstones reach a maximum stage of development here and beds containing bivalves and serpulids become more common. Only two major fining-upward channel sandstones occur in that part of the succession, both cross-bedded in the lower part and ripple cross-laminated in the upper part, with local hard calcareous lenses. Towards the top of the succession the beds are typically calcareous. They contain a greater abundance of rootlets but bivalves and fish fragments are rare. The finer grained beds are generally red, purple and green, often variegated and mottled, but the associated cementstones are much less common and thinner. Major channel sandstones increase in abundance and thickness up-section. They differ from those in the lower part in the following ways: they have a well developed sheet-like geometry with scoured bases locally overlain by intraclast conglomerates; they commonly have a more complex, internally scoured, multistoried form with less evidence of lateral accretion surfaces; and they show little sequential ordering of stratification types which are dominated by low angle trough cross-bedding and ripple cross-lamination. The change in character of the sandbodies through the succession suggests that they were deposited by channels of variable sinuosity and size, but with a general trend towards larger, less sinuous channels towards the top of the succession. These changes relate to base level changes in response to tectonic and/or climatic factors heralding deposition of the Fell Sandstone Group. The presence of cementstone intraclasts in channel sands, and the inverse relationship between the abundance of sandstones and cementstones, indicates an early diagenetic origin for the cementstones during significant periods of non-deposition. They were precipitated below the sediment-water interface in interdistributary lakes and lagoons on a low relief, semi-arid coastal alluvial plain.

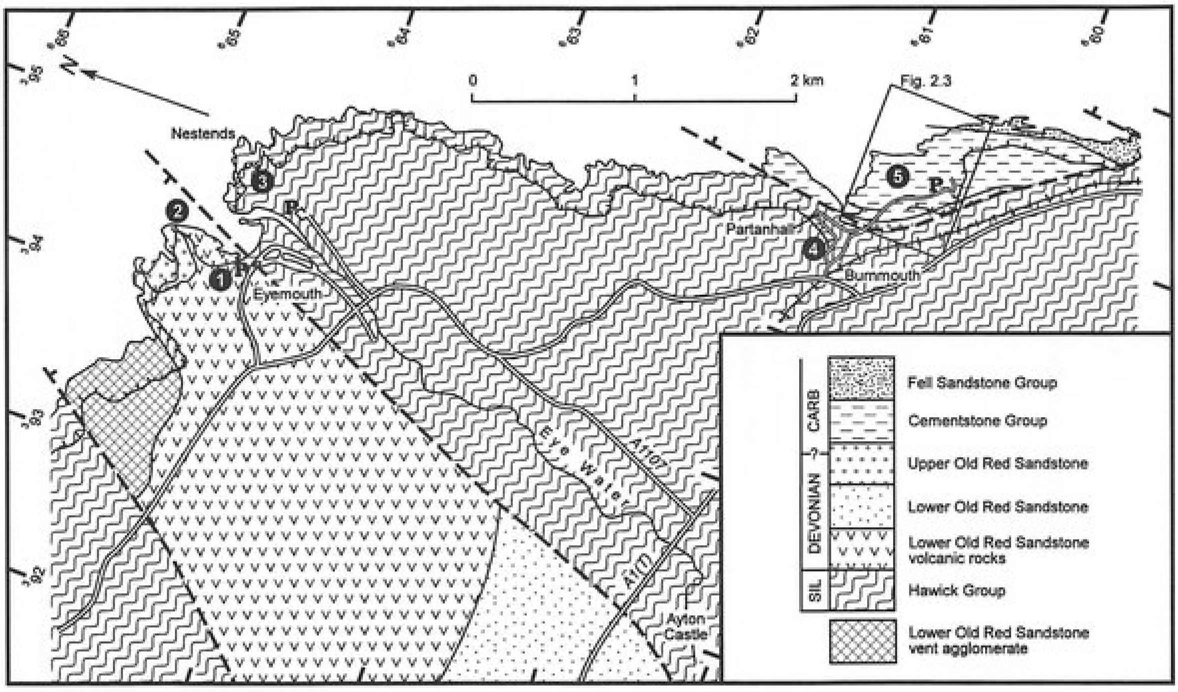
The Fell Sandstone Group conformably overlies the Cement-stones, with a sharp but locally erosive contact. Some of the best exposures occur on the foreshore by Maidenstone Stack (Figure 2.4), where the base of the Fell Sandstone cuts down 2–3 m into the underlying Cementstones. This is the most northerly exposure of Fell Sandstone in the Tweed Basin and one of the few localities where the contact between the Fell Sandstone and the Cementstones can be clearly seen. The Fell Sandstone here comprises two, erosively based fining-upward sequences, but only the lower sequence and the base of the overlying one is completely exposed at low tide. The lower sequence, about to m thick, consists of planar and trough cross-bedded, medium to locally coarse-grained pebbly sandstone containing intraclasts of cementstone. The grain size and scale of the cross-beds decreases towards the top of the sandbody which is overlain by up to 50 cm of rippled and horizontally laminated fine sandstone, siltstone and silty shale, with reddish mottling at the top. Above is the erosive, intraclast-strewn base of the cross-bedded sandstone at the bottom of the overlying sequence. Some cross-beds show evidence of liquefaction and deformation, contemporaneous with deposition. The Fell Sandstone was deposited within a tectonically active environment by perennial braided streams flowing to the southwest, in a similar direction to the Cementstone channels (Figure 2.3). The sandstones, less micaceous and more feldspathic than those in the Cementstone Group, sparkle due to the reflection of light from secondary crystal faces deposited in optical continuity on detrital quartz grains.

When returning to the cliff top, note that the road joins the A1 at the Flemington Inn 300 m to the south.

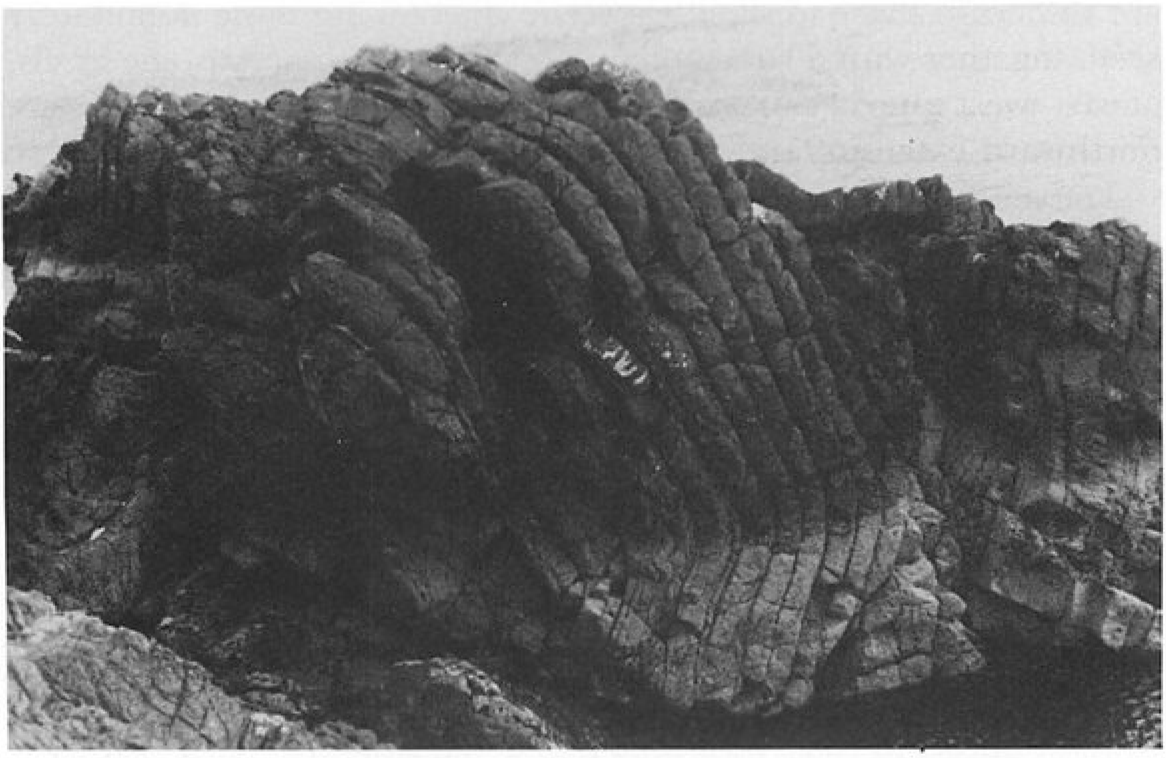
Bibliography



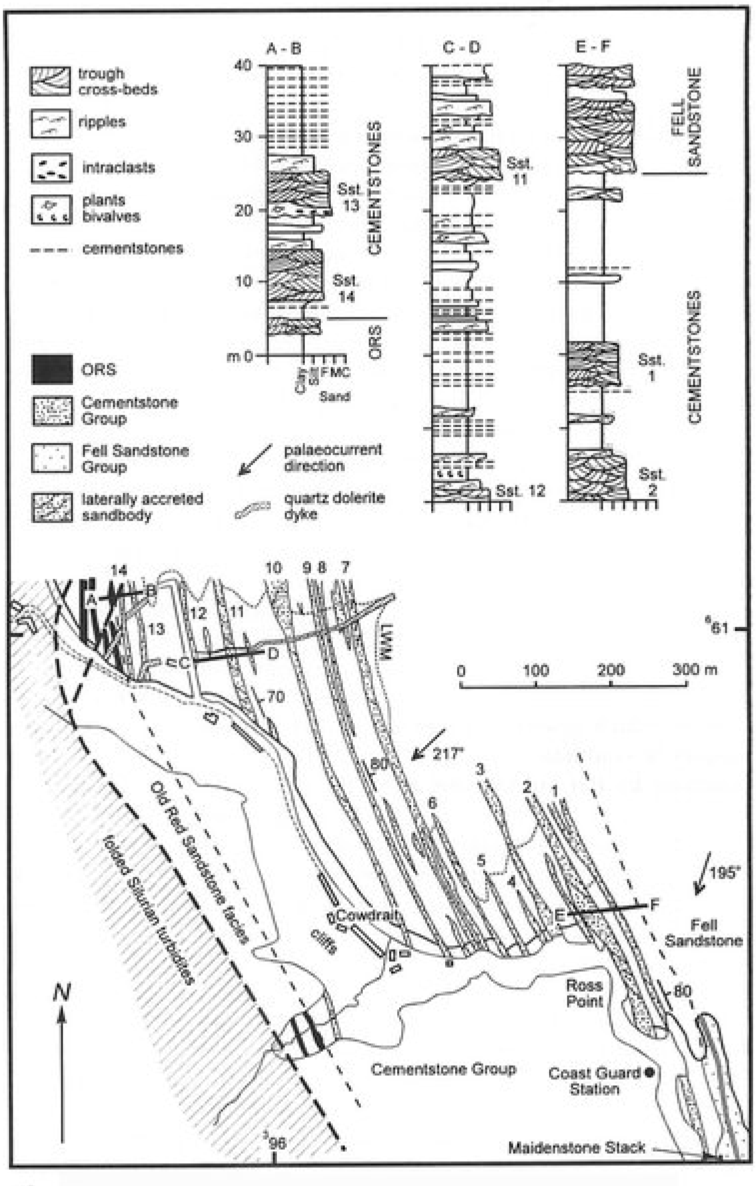
(Figure 3) Palaeogeographic maps indicating: (a) the distribution of continental plates in the mid Silurian (based on Scotese & McKerrow 1990 and other sources) and (b–f) the distribution of land and major sedimentary environments at various times in Northumbria and surrounding areas (based on Cope, et al. 1992 and other sources).



(Figure 2.1) Geological map of the Eyemouth–Burnmouth area indicating the localities described.



(Figure 2.2) Downward facing Silurian greywackes of the Hawick Group at Agate Point, Eyemouth (Locality 3). Photo: C. T. Scrutton.



(Figure 2.3) Generalized geological map and sections of the foreshore exposures of the Cementstone and Fell Sandstone Groups at Burnmouth.

(Figure 2.4) View north of Maidenstone Stack, c.15 m high, composed of near vertical Fell Sandstone. The erosive contact with the underlying Cementstone Group is at the stack foot on the left. Photo: B. R. Turner.