Border Group, Carboniferous of the Tweed and Northumberland-Solway basins

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Introduction

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The Border Group has a more-or-less continuous outcrop along the northern margin of the Northumberland–Solway Basin but in the east this lies entirely on the English side of the border (P912313). The outcrop spans the border to the north of Keilder and thence extends westward to Newcastleton, Ecclefechan and the Southerness area of the Kirkbean outlier.

**Lyne Formation**

In general, the Ballagan Formation becomes more marine in character, both upward and laterally towards the south-east, as it passes conformably and diachronously up into the Lyne Formation of the Border Group. The Lyne Formation is late Tournaisian–Arundian in age and in the main part of its outcrop, which lies south of the English border, it comprises cyclical sequences of fine-grained subarkosic sandstone, siltstone, mudstone, thin beds of limestone or dolostone, and anhydrite: the Lynebank, Bewcastle, Main Algal, Cambeck, and Easton Anhydrite members are recognised (P912354). At outcrop, the Lyne Formation is up to about 1000 m thick but the Easton Anhydrite Member has been proved in boreholes to comprise anhydrite abundantly interbedded through about 1300 m of clastic strata at about the level of the Lynebank and Bewcastle members. Deposition took place in a fluctuating network of peritidal, deltaic and fluvial environments subject to occasional marine incursions, with the anhydrite probably accumulating under sabkha conditions.

Much of the Scottish succession is assigned to the Southerness Limestone Member, about 135 m of thinly interbedded calcareous mudstone, siltstone and limestone. The member is best seen in the Kirkbean Outlier where it is richly fossiliferous, with a varied marine fauna of Chadian to Arundian age, and contains two distinctive algal stromatolite bands each about 1 m thick (P220451). The stromatolites resemble dome types from algal beds of the Lyne Formation in the Northumberland Basin. Individual domes are up to 30 cm in diameter with a relief of 10–15 cm, and are set in a calcareous mudstone matrix. They probably formed in a low intertidal to shallow subtidal depositional environment since there are signs of limited reworking. The algal bands are developed in two of three sedimentary cycles identified in the upper part of the member as follows:

1. Flaggy, micaceous sandstone with ripple marks and plant remains

5. Interbedded limestone and mudstones

4. Nodular algal band (in two of the three cycles)
Each cycle commences with sandstones deposited in a littoral environment. These are succeeded by calcareous beds, formed under shallow subtidal conditions, but with some sandy limestones containing oolites as an indication that the sediments were at times affected by wave action. The cyclicity may be attributed to variation in subsidence rate and terriginous sediment input, both perhaps related to movement on the basin boundary faults.

Around Newcastleton and Ecclefechan, the member contains an Arundian fauna of brachiopods, bivalves, foraminifera and ostracods that suggests a stratigraphical level equivalent to the Cambeck Member. Also present, both there and in the Kirkbean Outlier, are limestone beds (respectively the ‘Harden Beds’ and Syringothyris Limestone Bed) of possible equivalence to the Whitberry Marine Band that farther south marks the base of the Fell Sandstone Formation. However, stratigraphically above the Syringothyris Limestone Bed at Southerness are the two distinctive algal stromatolite bands of ‘Lyne Formation type’. If these stratigraphical correlations are correct, then the Southerness Limestone Member ranges diachronously higher than the top of the Lyne Formation elsewhere in the Solway and Northumberland basins.

In the Rerrick Outlier, the Orroland Member of the Lyne Formation comprises about 280 m of red beds formed under subaerial conditions on the margin of the Solway Basin against the syntectonically active North Solway Fault (P912351). The fining-upward cycles of conglomerate, sandstone, siltstone and calcrete-palaeosol are sporadically interrupted by marine beds of greyish red, fossiliferous limestone, which is locally oolitic. A mostly detrital fauna of corals, brachiopods and bivalves suggests correlation with the Syringothyris Limestone in the Southerness succession.

**Fell Sandstone Formation**

The Fell Sandstone Formation has an arcuate outcrop around the flanks of the Cheviot massif from Burnmouth in south-east Scotland through Northumberland and northern Cumbria, crossing back into Scotland in the Newcastleton area. Thence the outcrop continues westward along the northern shore of the Solway Firth, where the Gillfoot and Powillimount sandstone members are identified in the Kirkbean Outlier, and the Rascarrel Member in the Rerrick Outlier. The formation is mostly of Chadian–Holkerian age, though the highest strata may range up into the early Asbian. The lower boundary in Northumberland is taken at the Whitberry Marine Band, but this fails westward as the lithostratigraphical boundary becomes diachronously younger. It is Chadian in the Cheviot district where the Fell Sandstone directly overlies the Ballagan Formation, and Chadian to Holkerian in the north Solway Basin where it overlies the Lyne Formation.

Subarkosic sandstone is the dominant lithology and in its thickest development of about 350 m in central Northumberland, the formation consists almost entirely of sandstone. Northwards, the proportion of sandstone to mudstone varies considerably and in the vicinity of Berwick-upon-Tweed the Fell Sandstone Formation may contain up to 40 per cent of finer-grained lithologies. It was laid down by a fluvial depositional system that advanced from an uplifted source area to the north and east within the Grampian and Fenno–Scandinavian structural blocks. A continuous steady uplift of the source area provided a constant supply of submature clastic sediment, with complementary subsidence of the basin maintaining the fluviodeltaic depositional environment. Deposition was
probably effected by several braided river systems that were constrained to the axial region of the Northumberland Basin by intrabasinal faulting. Temperate humid conditions prevailed during deposition. The succession is largely unfossiliferous, although ostracods and the large bivalve *Archanodon jukesi* (Bailey) have been recorded together with some plant fossils. Along the axis of the Northumberland Basin the fluvial sandstone passes westward and diachronously into a succession of fluvio-deltaic and shallow marine deposits.

The earliest fluvial deposits accumulated in the north-east. There, to the south of Burnmouth (NT 956 610) on the Berwickshire coast, some 200 m of pale-coloured, cross- and con-volute-bedded sandstone contain bands of quartz pebbles and lenses of red sandy mudstone. The sandstone is overlain by some 75 m of interbedded mudstone, sandstone and seatearth with a few thin coals (worked at Lamberton, just north of the border, in the 19th century) and argillaceous dolostone. Near the top of this sequence lies the 1.5 m thick ‘Lamberton Limestone’ which is a likely correlative of the Cove Marine Bands, part of the Aberlady Formation (Strathclyde Group), farther north in the Oldhamstocks Basin (see below).

To the south-west, in the vicinity of Langholm, a coarsening-upwards siliciclastic sequence culminates in a fluvial sandstone unit up to 250 m thick, known locally as the ‘Larriston Sandstone’, overlain by a more mixed, thinly bedded sandstone–mudstone succession. The ‘Larriston Sandstone’ was derived from the north-east as channel-fill deposits within a braided river system, which by the mid Arundian was of increasing regional importance and fed into a delta system farther to the south-west. There, around Ecclefechan, the sequence comprises sandstone (some conglomeratic, with quartz pebbles), mudstone and sporadic seatearth with roots, the latter suggesting intermittent emergence of the delta surface. In the Newcastleton outcrop there is evidence for a syndepositional, extensional tectonic regime from the presence, in mid sequence, of about 30 m of porphyritic olivine basalt lava: the Kershopefoot Basalt (P912354).

In the Kirkbean Outlier, on the north Solway coast, the 120–150 m-thick Gillfoot Sandstone Member comprises quartzose sandstone, conglomerate and red mudstone, with a few thin beds of sandy limestone containing detrital fossils. Conglomerates form about 20 per cent of the succession and have a calcareous matrix. They contain intraformational fragments in addition to pebbles of Silurian wacke-type sandstone and Devonian dyke rocks. The member is sparsely fossiliferous and an Arundian age is likely. The lithologies indicate a marginal coastal depositional setting with the conglomerates deposited by sheetfloods flowing over low-lying supratidal areas.

Succeeding the Gillfoot Sandstone are about 160 m of strata, of Arundian to Holkerian age, that make up the Powillimount Sandstone Member. Lithologies include calcareous and Fault plane cuts Early Devonian microdiorite intruded into Silurian strata of the Ross Formation quartzose sandstones, sandy limestone and mudstone, with sporadic thin coals and associated rooted seatearth. Sandstone beds range in thickness from 0.3 to 3 m and are laterally extensive. They are well sorted and commonly exhibit ripple cross lamination, contain abundant carbonaceous plant remains and are extensively bioturbated. Limestones range from arenaceous to argillaceous types and contain detrital fossil remains, oolites and rolled algal nodules (or oncolites). The characteristic lithologies, and the evidence of oncolites and detrital fragments, point to deposition in a shallow marine environment subject to wave action. Conversely, the presence of thin developments of coal and associated seatearths indicates periodic shallowing of lagoonal waters and the development of highly vegetated coastal plains and low lying supratidal flats.

It is likely that the sediments of the Powillimount Sandstone Member were deposited in a tidal lagoon protected from the effects of severe storms by some form of offshore sand barrier. That barrier may now be represented by the prominent and thickly bedded Thirlstane Sandstone Beds, 25 m of quartzose sandstone, which form the top of the member. At the base of the Thirlstane
Sandstone, the contact with the underlying strata is irregular and intraformational fragments and wood remains are present in the lowest beds. The rocks are characterised by large-scale cross-bedding (P220455) and an increasing number of penecontemporaneous liquefaction deformation structures from south to north along the strike of the outcrop (P001161). The magnitude and frequency of the liquefaction structures may perhaps be attributed to seismic activity on the nearby and syndepositionally active North Solway Fault.

Farther west, in the isolated faulted blocks of the Rerrick and Colvend outliers, the Fell Sandstone Formation is represented by its Rascarrel Member. At Colvend, east of Castlehill Point, the spectacular basal Carboniferous unconformity is represented by a veneer of carbonate cemented breccia, overlain by conglomerate, clinging to cliffs cut in Silurian strata and a microdiorite dyke (P220436). The breccia clasts comprise Lower Palaeozoic sandstone and igneous rock derived from the hinterland to the north. The breccia and conglomerate dip seawards at high angles as a result of syndepositional faulting on the line of unconformity, and the conglomeratic sandstone grades upwards into mudstone; thin inter-beds of sandy limestone contain algal fragments and a sparse marine fauna of Arundian to Holkerian aspect. At both Rerrick and Colvend, at least 350 m of much-faulted strata are present, comprising arkosic and conglomeratic fluvial sandstone, siltstone, calcareous mudstone and a few coals, making this potentially the thickest development of the Fell Sandstone Formation, a situation strongly influenced by the proximity of the syndepositionally active North Solway Fault.

**Bibliography**


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