Chapter 13

Northumberland Trough and Solway Basin

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Carboniferous rocks within this region occupy a broadly east–west graben, referred to as the Northumberland Trough within Northumberland (Bewcastle to the North Sea coast) and the Solway Basin in the vicinity of the Solway Firth, where much of the succession is obscured by Permo-Triassic strata (Fig. 13.1). The graben is bounded to the south by the Maryport-Stublick-Ninety Fathom Fault System, which forms the northern boundary of the Lake District and Alston blocks (see Chapter 12). The Carboniferous rocks are broadly separated from the Midland Valley of Scotland (Chapter 14), to the north, by the Lower Palaeozoic rocks of the Southern Uplands, which formed an emergent upland area throughout much of the Carboniferous, with local deposition within small basins. At the eastern onshore extent of the Southern Uplands a relatively condensed Carboniferous succession was deposited upon the Cheviot Block.

All of the regional stages of the Carboniferous are present at outcrop, though strata of Stephanian age have not been proved biostratigraphically. The oldest Tournaisian strata occur at outcrop along the northern margins of the Northumberland Trough-Solway Basin, represented by alluvial and peritidal deposits, typically separated by volcanic rocks (Inverclyde Group). These strata extend offshore within the North Sea (Chapter 15), linking directly with the outcrop of Inverclyde Group present within the Midland Valley of Scotland. Within the Northumberland Trough-Solway Basin, the Inverclyde Group passes southwards into, and is overlain by, an lower to middle Viséan heterolithic clastic and non-marine carbonate and fluvio-deltaic succession (Border Group). The middle to upper Viséan succession above the Cheviot Block is dominated by relatively condensed fluvio-lacustrine and Yoredale facies deposits, which pass southward into the relatively deeper water mixed shelf carbonate and deltaic deposits of the Northumberland Trough (Yoredale Group).

Namurian and Westphalian strata occur at outcrop toward the south and east of the region within the Northumberland Coalfield, with the succession broadly younging towards the east (Fig. 13.1). Small outliers also occur in the Canonbie and Midgeholme coalfields. The Canonbie Coalfield extends southwards beneath Permo-Triassic strata to link with the Cumbrian Coalfield (Chapter 12). The early Namurian strata represent a continuation of the Yoredale facies deposits, although with a gradual decrease in the number and thickness of marine carbonate units and dominance of fluvio-deltaic deposits (Yoredale Group). The overlying Westphalian strata are dominated by fluvio-lacustrine deposits (Pennine Coal Measures Group), with subsequent deposition of late Westphalian red-bed alluvial deposits (Warwickshire Group) locally preserved in the Canonbie Coalfield.

The lithostratigraphical nomenclature is that of Waters et al. (2007) and Dean et al. (2011).
Tournaisian

The Inverclyde Group, deposited upon the flanks of the Southern Uplands High, crops out in the Solway Basin (Fig. 13.2, Cols. 1 & 2) and northeast Northumberland (Col. 7). The Kinnesswood Formation, composed mainly of sandstone with red mudstone and calcere, developed as alluvial fans deposited in a series of small, linked basins with internal drainage that formed along parts of the northern margin of the Northumberland Trough during early stages of crustal extension (Chadwick et al. 1995). The formation is typically included within the Old Red Sandstone Group by many previous workers (Lumsden et al. 1967; George et al. 1976), though a Courceyan age is postulated by these authors for at least the upper part of the formation. The Ballagan Formation, comprising interbedded sandstone, mudstone, limestone and anhydrite, represents both alluvial fan, fluvial and fluvio-deltaic sediments sourced from the Southern Uplands High, intercalated with lacustrine and arid coastal plain deposits. The formation has been variously referred to in the Solway Basin as the Kirkbean Cementstone Formation (Lintern & Floyd 2000), an unnamed part of the Lower Border Group (Lumsden et al. 1967) and in the Solway Basin-Northumberland Trough as the Cementstone Group (e.g. Fowler 1926). In the central part of the Northumberland Trough a lateral facies change sees the upper part of the Ballagan Formation pass into the Lyne Formation of the Border Group (Fig. 13.2, Col. 3). Locally, the Kinnesswood and Ballagan formations are separated by the Birrenswark Volcanic and Kelso Volcanic formations in the Solway Basin (Lumsden et al. 1967) and Berwick-Upon-Tweed area (Greig 1988), respectively (Fig. 13.2, Cols. 1, 2 & 7). Whole rock K-Ar dates for the Birrenswark Volcanic and Kelso Volcanic formations of 361±7 Ma (de Souza 1982), would suggest a latest Famennian age.

Visean

The Border Group (Tournaisian-early Visean) was deposited within the axis of the Northumberland Trough – Solway Basin and the Cheviot Block. In the Solway Firth (Fig. 13.2, Col. 1) the Lyne Formation (former Southerness Limestone Formation) at Kirkbean, comprises cyclical sequences of sandstone, siltstone, mudstone and thin limestone (Lintern & Floyd 2000). Coastal-marine shelly faunas contain abundant brachiopods including *Antiquatonia teres*, *Pustula pyxidiformis* and the corals *Palaeosmilia murchisoni* and *Michelinia megastoma*, indicative of Chadian to possibly Arundian age *1* (George et al. 1976). In the Bewcastle area (Fig. 13.2, Col. 3) the formation is subdivided into the Lynebank, Bewcastle, Main Algal and Cambeck members (Day et al. 1970; Dean et al. 2011). W. J. Varker, in Ramsbottom (1977), reported the presence of Chadian foraminifers and conodonts *Mestognathus beckmanni* and *Polygnathus bischoffi*, indicating a latest Tournaisian to Chadian age for the basal part of the Lynebank Member *01*. The limestones are typically peritidal, containing stromatolites and vermetid gastropod bioherms and biostromes. Brachiopod–coral assemblages found in the Cambeck Member are typical of the C2 Zone *2* (Day et al. 1970) of late Chadian to early Arundian age. In the Easton No 1 Borehole [NY 44124 71694], 16 km north of Carlisle, subaqueous anhydrite beds form a significant component of a 1153 m thick cyclical succession, the base of which was not proved (Ward 1997). Formally defined as the Easton Anhydrite Member by Dean et al. (2011), the member may be overlain by the equivalent of the Main Algal Member. The formation has not been proved in the eastern part of the Northumberland Trough, and north of Berwick-upon-Tweed area (Fig. 13.2, Col. 7)
absent, with the Fell Sandstone Formation with a markedly erosive base resting unconformably upon strata of the Inverclyde Group (Greig 1988).

Deposition of the Fell Sandstone Formation occurred earliest in the north-east of the Northumberland Trough (Chadian to Holkerian) as both braided and meandering river systems (Turner et al. 1993). In the central part of the trough and in the Solway Basin, the equivalent strata are of Arundian to Holkerian age and represent deposition in a mixed fluvio-deltaic and shallow marine environment. Within this central area (Fig. 13.2, Col. 3), the base of the formation is conformable on the Lyne Formation, defined at the base of the early Arundian Whitberry Band, including the distinctive chonetoidean Rugosochonetes cumbriensis (Day 1970). In the Brampton area (Fig. 13.2, Col. 4) and the Marshall Meadows Borehole [NT 9797 5685] near Berwick-upon-Tweed (Col. 7) the uppermost part of the Fell Sandstone Formation succession contains miospores of the TS (formerly upper Pu) Zone (Neves et al. 1973).

The succeeding Yoredale Group extends across the entire Solway Basin and Northumberland Trough, with the Tyne Limestone Formation, broadly of Asbian age, overlain by the Brigantian Alston Formation.

In the Solway Basin at Kirkbean-Arbigland Bay (Fig. 13.2, Col. 1) the base of the Asbian lies within the middle part of the Arbigland Limestone Member, taken at the first appearance of a coral–brachiopod fauna comparable with the Clattering Band (George et al. 1976). In the Archerbeck Borehole [NY 4156 7815] (Fig. 13.2, Col. 2) the lower part of the Tyne Limestone Formation, including the Glencartholm Volcanic Member contains miospores of the TC Zone (Neves et al. 1973). Within the central part of the Northumberland Trough (Fig. 13.2, Cols. 3 & 5) the base of the Tyne Limestone Formation is taken at the base of a marine limestone with a distinctive coral/brachiopod fauna of Siphonodendron martini, Lithostrotion portlocki and Semiplanus marking the base of the Asbian Substage, e.g. Kingbridge Limestone in the Bellingham area (Frost & Holliday 1980), and the Clattering Band in the Bewcastle area (Day et al. 1970). In the Brampton area (Fig. 13.2, Col. 4) the ammonoid Beyrichoceratoides redesdalensis of B1-B2a Zones age is recorded from the Redesdale Ironstone Shale in the upper part of the Tyne Limestone Formation (George et al. 1976). In northeast Northumberland (Fig. 13.2, Col. 7) the Marshall Meadows Borehole proves the Scremerston Coal Member lies within the TS (formerly upper Pu) and TC miospore zones, with the top taken at the base of the Dun Limestone Member, which contains NM miospore assemblage in this borehole (Neves et al. 1973). At Berwick-on-Tweed (Fig. 13.2, Col. 7) the Dun Limestone Member contains the colonial coral Siphonodendron junceum (Fowler 1926), supporting an Asbian age. The top of the Dun Limestone Member represents the top of the Tyne Limestone Formation (Dean et al. 2011), and can be traced throughout the Northumberland Trough (Frost & Holliday 1980).

The base of the Alston Formation is taken at marker limestones used to define the base of the Brigantian Substage. This includes the Callant Limestone of the Solway Basin, and the Low Tipalt Limestone of the Bewcastle and Brampton areas in the central part of the Northumberland Trough, and the Watchlaw Limestone in the north-
eastern parts of the Northumberland Trough (George et al. 1976; Frost & Holliday 1980). The Callant Limestone, present in the Archerbeck Borehole (Fig. 13.2, Col. 2), marks the transition from NM to VF Zone miospores $^{2}$ (Neves et al. 1973). A recent proposal by Owens et al. (2004) is to replace the NC miospore Zone in the upper part of the Brigantian with a new CN Biozone and a new subzone (Cc), see Chapter 3. The base of this zone and subzone, which coincides with the $\text{P}_2b$-$\text{P}_2c$ ammonoid boundary, is defined in a section near Hayden Bridge in Northumberland.

**Namurian**

The base of the Namurian is taken a few metres below the base of the Great Limestone Member, the uppermost limestone unit of the Alston Formation (Dean et al. 2011), which can be traced throughout the Northumberland Trough and Solway Basin (Holliday et al. 1975). The diagnostic Pendleian (E$_1$) ammonoid Cravenoceras ($=\text{Emstites}$) leion has been recorded from below the Great Limestone Member (Dunham 1990) and a change in foraminiferal assemblage at the base of the Catsbit Limestone (local equivalent of the Great Limestone Member) in the Archerbeck Borehole (Fig. 13.2, Col. 8) suggests the base of the Namurian occurs at this level (Cummings 1961).

Above the Great Limestone Member, the Yoredale Group is represented by the Stainmore Formation, which ranges throughout the Namurian. The Stainmore Formation is distinguishable from the underlying Alston Formation by a decrease in the number and thickness of limestone units. The upper part of the Namurian succession is notably distinctive from the underlying Stainmore Formation, with an absence or presence of only thin limestones within the Yoredale cycles and the occurrence of thick, often pebbly, coarse-grained sandstone units with ribbon-like geometries. These fluvial sandstones have historically been mapped as the First and Second Grit of “Millstone Grit” facies (Ramsbottom et al. 1978, fig. 9), although the correlation of such a simple stratigraphy for a complex of channel sandstone bodies is now questioned.

In the Canonbie Coalfield (Fig. 13.2, Col. 8) the Stainmore Formation shows a thickness variation from 425 m in the flanks of the syndepositional Solway Syncline to c. 600 m in the core of the syncline (Chadwick et al. 1995, map 12). The Archerbeck Ochre Bed, a marine sandstone above the Penton coals in the Archerbeck Borehole, is considered to be of late Pendleian age from the presence of the bivalve Streblopteria ornata $^{2}$ (Ramsbottom et al. 1978). In the Throckley Borehole [NZ 1456 6762] (Fig. 13.2, Col. 10) miospores of Pendleian age are proved between the Great Limestone and Pike Hill Limestone, the base of the Arnsbergian Substage occurring above the Thornbrough Limestone (Owens 1972), whereas foraminifers in the nearby Rowlands Gill Borehole [NZ 1664 5815] would suggest the base occurs at a lower level, the base of the Lower Fell Top Limestone $^{2}$ (Riley 1992b). Miospores indicative of the $\text{E}_2b$ Subzone are recorded in the Throckley Borehole between the Newton and Styford limestones $^{3}$ (Owens 1972; Owens et al. 2004). The $\text{E}_2b$ age of these limestones is confirmed elsewhere in the Newcastle area by the presence of the nautiloid Tylonautilus nodiferus (Mills & Holliday 1998).
The Chokierian and Alportian mudstone-dominated successions are condensed, typically as little as 5 m thick, though there is no evidence of a regional unconformity at this level in the Newcastle area (Mills & Holliday 1998).

The upper part of the Namurian succession is sandstone dominated, lacking limestone typical of the remainder of the Yoredale Group, and comparable with the late Namurian “Millstone Grit” facies recognised on the Alston Block (see Chapter 12). The first appearance of common *Crassispora kosankei* miospores about 14 m above the base of the first thick sandstone (“First Grit”) in the Throckley Borehole (Fig. 13.2, Col. 10) marks the base of the KV Zone (Stephenson et al. 2008) of Kinderscoutian age.

The upper 140 m of the Stainmore Formation in the Langholm area (Fig. 13.2, Col. 8), includes strata of the FR miospore Zone (late Marsdenian to Yeadonian age) in the Rowanburnfoot Borehole [NY 4103 7574] (Owens 1980).

In the Midgeholme Coalfield (Fig. 13.2, Col. 9) the 82 m-thick succession between the Namurian Burnfoot Shales and the Low Main Coal was interpreted as Lower Coal Measures by Trotter & Hollingworth (1932), but may in part include Namurian strata equivalent to the Millstone Grit Group.

**Westphalian**

During the Langsettian to early Bolsovian, the grey, mudstone-dominated fluvio-lacustrine deposits (Pennine Coal Measures Group) were deposited across the region. The Pennine Coal Measures Group crops out in the Canonbie Coalfield of the Solway Basin (Fig. 13.2, Col. 8), as a series of outliers immediately to the north of the Stublick Fault, along the southern margin of the Northumberland Trough (Fig. 13.1), the largest of which is the Midgeholme Coalfield (Fig. 13.2, Col. 9), and the Northumberland Coalfield (Cols. 6, 10 & 11), the northward continuation of the Durham Coalfield (see Chapter 12). During the Asturian (Westphalian D), red mudstone- and sandstone-dominated alluvial successions (Warwickshire Group) may have been widespread, but are now only recorded in the Canonbie Coalfield (Fig. 13.2, Col. 8). Inversion of the basin during late Carboniferous deformation may have resulted in the erosion of much of the Warwickshire Group.

None of the marine bands recognised within the Westphalian succession of the region contain diagnostic ammonoid fauna and biostratigraphical zonation is dependent upon non-marine bivalves. In the Canonbie Coalfield (Fig. 13.2, Col. 8; Fig. 13.3), Lumsden et al. (1967) recorded a thin (c. 30 m), sandstone-dominated Pennine Lower Coal Measures on the flank of the Solway Syncline, which they determined occurred within the Modiolaris Chronozone. They demonstrated evidence that most of the Langsettian succession was absent beneath an angular unconformity. However, Owens (1980) recorded miospores of the RA Zone in the Rowanburnfoot Borehole, 5 m below the proposed unconformity and that the base of the Westphalian occurs within the underlying conformable succession. Subsequent work has argued that the unconformity is in fact a shear surface associated with channel bank collapse (Jones & Holliday 2006). In the Midgeholme Coalfield (Fig. 13.2, Col. 9; Fig. 13.3) there is
uncertainty as to the location of the base of the Pennine Coal Measure Group, which may have been taken by Trotter & Hollingworth (1932) at the base of a late Namurian sandstone. Some 90 m of Pennine Lower Coal Measures of the Communis and Modiolaris chronozones are recorded in the Plenmeller Coalfield (Turner 1999). The inferred position of the Subcrenatum Marine Band in the Throckley Borehole (Fig. 13.2, Col. 10) and in the Newcastle area (Mills & Holliday 1998) is taken at a Lingula band. In the Northumberland Coalfield, the base of the Communis and Modiolaris chronozones are taken at the Ganister Clay and Top Busty coals, respectively (Fig. 13.3; Land 1974; Mills & Holliday 1998).

The Vanderbeckei Marine Band, which defines the bases of the Duckmantian Substage and the Pennine Middle Coal Measures Formation, is present in the Canonbie Coalfield as a Lingula band, with the overlying succession of the Modiolaris Chronzone dominated by relatively thick coals (Fig. 13.3). In the Tynemouth region the marine band comprises Lingula mytilloides, fish remains and rare foraminifers (Land 1974).

Across the region, strata of the Lower Similis-Pulchra Chronzone comprise thinner coals and includes the Haughton and Sutton marine bands (Ramsbottom et al. 1978), represented by Lingula bands. The base of the chronzone is taken at the base of the Nine Foot Coal (Fig. 13.3) in the Canonbie Coalfield (Lumsden et al. 1967) and Bensham Coal in the Northumberland Coalfield (Land 1974; Mills & Holliday 1998).

The base of the Aegiranum Marine Band defines the base of the Bolsovian Substage and was previously taken by Lumsden et al. (1967) to mark the base of the Upper Coal Measures. The top of the Pennine Middle Coal Measures is now defined at the top of the Cambriense Marine Band and the Pennine Upper Coal Measures Formation is largely absent in this region. The upper part of the Pennine Middle Coal Measures Formation, is typically arenaceous with thin coals and includes four regionally developed marine bands, the Aegiranum, Edmondia, Shafton and Cambriense marine bands (Ramsbottom et al. 1978) evident as Lingula bands. This upper part of the formation occurs within the Upper Similis-Pulchra Chronzone, although no non-marine bivalves are recorded in either the Canonbie or Northumberland coalfields (Lumsden et al. 1967; Land 1974).

In the Canonbie Coalfield the grey, coal-rich Pennine Coal Measures Group is overlain conformably by red, coal-poor Warwickshire Group (Fig. 13.2, Col. 8). Only strata of the Tenuis Chronzone ~6 (Asturian) have been proved within the lowermost mudstone-dominated Eskbank Wood Formation (Jones et al. 2010). The overlying Canonbie Bridge Sandstone Formation is dominated by lithic arenite of similar provenance as the Hales Owen Formation (Jones et al. in press) of the southern part of the Pennine Basin (see Chapter 9). The youngest formation is the Becklees Sandstone Formation, which is unconformably overlain by Permian strata (Fig. 13.2, Col. 8; Jones et al. 2010). Up to 750 m of Warwickshire Group are recorded on the flank of the Solway Syncline (Lumsden et al. 1967), although seismic reflection profiles (Chadwick et al. 1995, map 14) suggest a thickness in excess of c. 1200 m within the axial region.
Fig. 13.1. Geological map showing the distribution of Carboniferous strata from the Northumberland Trough and Solway Basin, adapted from IGS (1979).

Fig. 13.2. Correlation of Carboniferous successions in Northumberland Trough and Solway Basin. The nomenclature is that of Waters et al. (2007) and Dean et al. (2011), with details from the following publications: Col. 1 from Lintern & Floyd (2000); Col. 2 from Lumsden et al. (1967); Col. 3 from Day et al. (1970); Col. 4 from Trotter & Hollingworth (1932); Col. 5 from Frost & Holliday (1980); Col. 6 from Land (1974); Col. 7 from Fowler (1926) and Greig (1988); Col. 8 from Picken (1988) and Jones & Holliday (2006); Col. 9 from Trotter & Hollingworth (1932); Col. 10 from Mills & Holliday (1998); Col. 11 from Lawrence (in press).

Fig. 13.3 Correlation of Westphalian strata, showing named coals, sandstones and marine bands. Langholm (Canonbie Coalfield) from Lumsden et al. (1967), Picken (1988) and Jones & Holliday (2006); South Tyne (Midgholme & Stublick coalfields) from Trotter & Hollingworth (1932), Ramsbottom et al. (1978) and Turner (1999); Whitley Bay – Tynemouth area from Land (1974) and Amble – Ashington from Lawrence (in press).