Yoredale Group, Visean to Namurian, Carboniferous, Northern England

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Introduction

Towards the end of the Visean, tectonic extension was replaced by a prolonged period of thermal relaxation and crustal sag, resulting in widespread marine transgression and the gradual submergence of the distinctive block-and-basin structure beneath an increasingly terrigenous sediment cover. Thereafter, during the Namurian and Westphalian, a broad region of subsidence developed across the north of England, between the Southern Uplands and the Wales–Brabant massifs, and is known as the Pennine Basin. Within this basin the cycles of Namurian sedimentation were still strongly influenced by the broad pattern of structural features established earlier in the Carboniferous, but this effect was diminished by the beginning of Westphalian times.

The Visean to Namurian Yoredale Group is characterised by repeated upward-coarsening sedimentary cycles ('Yoredale' cycles, (P916071) on a wide range of scales. It is divided, in upward sequence, into the Tyne Limestone, Alston and Stainmore formations; divisions are based largely on the relative abundance of the different rock types within cycles. The base of the group is diachronous and ranges from early Asbian in the Northumberland Trough and Solway Basin, to Brigantian on the Alston and Askrigg blocks, in the Stainmore Trough and in south Cumbria, and to Pendleian in West Cumbria.

The Asbian Tyne Limestone Formation is restricted to the Northumberland–Solway Trough where its presence accounts for the greater part of the diachroneity at the base of the Yoredale Group (P916067) and (P916068). At the end of the Asbian, the sediment-starved carbonate platforms of the

Great Scar Limestone Group were overrun from the north by a regionally extensive river-delta system that experienced repeated marine incursions. Simultaneously, the margin of the Craven Basin advanced northwards, bringing deepwater conditions to the former carbonate shelf across the Furness and Cartmel peninsulas of south Cumbria and the River Keer valley in Lancashire. Across the Alston Block and in the Stainmore Trough, the Yoredale Group is divided into two formations, the mainly Brigantian Alston Formation and the Namurian Stainmore Formation; the lithological characteristics of the constituent limestones differ between the two formations and the division also reflects the decrease in limestone abundance in the latter relative to the former. At the boundary between the two formations the Great Limestone (formally, the topmost unit of the Alston Formation) represents the depositional response to a significant transgressive event that took place at the beginning of Namurian times, when marine conditions were established across a wide area of northern England and beyond.

In the Isle of Man and north Lancashire, the equivalent rocks to the Brigantian to Namurian part of the Yoredale Group are of prodelta and basinal facies and, as previously described, are accommodated in the Bowland Shale Formation, where mudstone dominates.

Tyne Limestone Formation

The Asbian, Tyne Limestone Formation displays variable Yoredale-type cyclicity, with the limestone and sandstone components absent from parts of the succession. Where present, the sandstones tend to thicken into troughs and half-grabens. A range of lithofacies is present, which includes strata originating in marine, shelf carbonate and deltaic environments, with some local lacustrine deposits; the shelf-carbonate assemblage is more fully developed farther south as part of the Great Scar Limestone Group (P916067) and (P916068). Much of the formation comprises upward-coarsening cycles, each overlying a thin but extensive bed of marine limestone. The limestone is succeeded in each sedimentary cycle by marine mudstone, which is commonly bioturbated, and then by sandstone topped in places by seatearth and a thin coal seam. These marine to deltaic, Yoredale-type cycles are best developed and up to about 400 m thick in the west of the region, in the Solway Basin and western part of the Northumberland Basin. Thence, in the lower part of the formation, there is a lateral eastward transition into a sequence of lacustrine-deltaic cycles of limestone, mudstone, and sandstone with thick coal seams, traditionally known in Northumberland and Berwickshire as the ‘Scremerston Coal Group’.

The ‘Scremerston Coal Group’ is generally about 300 m thick but this figure increases locally and reaches almost 2000 m around Falstone (NY 725 875) thanks to the effects of synsedimentary fault movement. The sequence comprises sedimentary cycles similar to those of the Tyne Limestone Formation in Cumbria, but with more terrigenous material and with thinner, more argillaceous limestones. Coals are thicker and more numerous than is the case in the Cumbrian succession; the thickest, at 2 m, is the Plashetts Coal which has been widely worked. The marine influence is re-asserted above the ‘Scremerston Coal Group’, with the sedimentary cycles comprising a limestone overlain by mudstone, which commonly shows evidence for storm-driven reworking of the sediment, then by a shallow-marine sandstone. Some of the cycles are topped by a terrestrial development of calcrete, seatearth and coal.

The base of the Tyne Limestone Formation is formally defined in the Solway Basin by a limestone known as The Clattering Band that contains a distinctive fauna of Lithostrotion corals and the brachiopod *Semiplanus*. Also occurring at the base of the formation, but restricted to the northern margin of the Solway Basin, is the Glencartholm Volcanic Member; up to 180 m of interbedded basaltic and trachytic, pyroclastic and volcaniclastic strata. The upper boundary of the Tyne Limestone Formation is conformable with the base of the Alston Formation, and is taken at the base of another distinctive limestone with algal features and a variety of local names: the Low Tipalt or Callant Limestone in the central part of the Northumberland Trough, the Watchlaw Limestone farther east, and the Peghorn, Askham or Hawes limestones on the Alston and Askrigg blocks.

Alston Formation

The Alston Formation crops out over wide areas of the Alston Block, Edenside and Northumberland. As currently defined, it contains Yoredale Group strata of mostly Brigantian age, which had previously been assigned to several locally defined groups (P916068). Representative lithostratigraphical sections and correlations are summarised in (P916073) with the lithofacies illustrated in (P643531)a, b. The formation is up to about 250 m thick on the Alston block, but thickens considerably into the Northumberland and Stainmore troughs, reaching over 400 m in the former and exceeding 1000 m in the eastern part of the latter.

On the Alston and Askrigg blocks, the base of the Alston Formation is taken at the change from the platform limestone facies of the Great Scar Limestone Group, to cyclical, marine-deltaic Yoredale facies. In most areas this change occurs close below the Asbian– Brigantian boundary, coincident with a band containing *Girvanella* algal structures, within the equivalent, but variously named, Askham, Peghorn or Hawes limestones. From Coldbeck, through Edenside to Stainmore, and also in upper Teesdale, the base is marked by a laterally persistent, erosionally based sandstone unit, the Wintertarn Sandstone Member (equivalent to the Thorney Force Sandstone on the Askrigg Block). Across the axis of the Stainmore Trough, the Wintertarn Sandstone Member is in places underlain by a thin, but complete Yoredale cycle with the Birkdale Limestone at its base. In these areas the base of the Alston Formation is formally taken at the top of the Robinson Limestone Member of the Melmerby Scar Formation, described earlier in this chapter.

At the top of the Alston Formation lies the Great Limestone Member (= Main Limestone on the Askrigg Block, First Limestone of Cumbria, Dryburn Limestone of north Northumberland). The Great Limestone is of early Namurian age, since a basal Pendleian index fauna has been found in closely adjacent mudstone at several localities in south Northumberland, for example in Greenleighton Quarry (NZ 034 917). The Great Limestone attains a maximum thickness of over 20 m in Weardale, on the north-east flank of the Alston Block. When traced northwards from there into the Northumberland Trough, the lower part of the member, comprising richly fossiliferous massive limestone beds, maintains a remarkable consistency in thickness of 4 to 4.5 m with up to three distinctive biostromes: the *Chaetetes*, Brunton and Frosterley bands, each with a rich fauna of corals and sponges (P222338)e — Frosterley Marble). The upper part of the Great Limestone Member contains mudstone interbeds and passes gradually into a dominantly mudstone sequence as it extends northwards across the Northumberland Trough (P548113). The Great Limestone is of economic importance as a host for mineral deposits (see Chapter 10) and the source of a variety of mineral products including limestone flux, ornamental stone and crushed rock for aggregate (see Chapter 12).

The Alston Block succession of the eponymous formation is some 220–250 m thick and consists of about ten main Yoredale cycles. Each of the cycles begins with a limestone bed, rarely exceeding 10 m in thickness, succeeded by a coarsening-upwards unit composed mainly of terrigenous mudstone, siltstone and sandstone. The major limestone units display a remarkable lateral uniformity in thickness, lithological character and fossil content. The intervening clastic beds tend to remain constant in overall thickness, but their lithological make- up is far more variable and some contain channel sandstone bodies. The channels may show significant erosion at their bases and the stratigraphically important limestone beds are cut out locally. Mudstone beds with a shelly marine fauna occur at some levels and may grade laterally into thin secondary limestone developments.

Seatearths are recorded at the top and within some cycles and at least one seam of workable coal is recorded in some areas: for example, the high-quality Shilbottle Coal of Northumberland and the Reagill Coal of Edenside.

Limestone units within the Alston Formation (P916073) are generally dark grey, but some are notably bituminous and almost black in colour. They show an overall upward change from massive, fine-grained wackestone with a notable algal component, to current-bedded crinoidal packstone and grainstone. Some limestones comprise a single bed, but others are made up of two or three beds separated by thin mudstone or sandstone intervals. When these composite members are traced across the region from south-west to north-east, the separation of the individual limestone beds increases as the mudstone-sandstone intervals thicken and develop as separate cyclothems. This has given rise to a confusing array of locally named subdivisions, many with 'upper' and 'lower' derivatives.

In north Lancashire, east of Morecambe Bay, the general Yoredale cyclicity is still evident, but the limestone beds were deposited in deeper water; they are fewer in number, thinner, often composed of crinoid debris, and grade locally into shelly mudstone. Chert is common, and some beds are ferruginous, such as the Undersett Limestone that develops a characteristic ochreous patina where weathered; its correlative on the Alston Block is the Four Fathom Limestone (P916073).

North-west of Morecambe Bay, in Furness and Cartmel, borehole records show that the Pendleian strata have a north to south transition from shelf to basin lithofacies. The succession encountered at Holker and around the Duddon estuary retains the Yoredale cyclical pattern of the Alston Formation, but at Roosecote, Gleaston and south of the Cark Fault, it comprises uniform dark grey, cherty, argillaceous limestone and mudstone. Rocks of the latter character were previously included in the, now obsolete, Gleaston Formation, but in view of their deep water affinities, are now assigned to the Bowland Shale Formation of the Craven Group.

Stainmore Formation

The Stainmore Formation comprises a largely deltaic, cyclical succession of terrigenous mudstone, siltstone, coal (mostly of indifferent quality), and sandstone. Some of the sandstone occurs in channel-fill deposits, fining upwards and with erosional bases cross-cutting the underlying strata. Otherwise the succession is dominated by mudstone–siltstone–sandstone coarsening-up cycles, with beds of limestone mostly confined to the lower part. Very rarely, a mudstone bed contains Namurian Stage, index nautiloids, and though uncommon, these establish the occurrence of intermittent marine incursions. The sandstone lithology is generally fine- to medium-grained, micaceous and often carbonaceous, with cross- and ripple-bed forms; some coarser-grained, channel-fill sandstone bodies are locally present. Lithostratigraphical variations and correlations across northern England are summarised in (P916074) with the lithofacies illustrated in (P643531)c and d.

Traditionally, the general term 'Millstone Grit' has been used for the Namurian succession in the north of England, although it had long been apparent that north of the Askrigg Block the lithological assemblage is distinct from the thick development of coarse 'gritstone' and marine mudstone of the South Pennines and Derbyshire, type area for the Millstone Grit. Rather, across northern England, the northern succession displays 'Yoredale-type' cyclicity, albeit limestone beds are less prominent in many of the cycles in comparison with those of the Alston Formation beneath. The name 'Stainmore Group' has also been used as a lithostratigraphical designation for the Namurian sequence in northern England, and that term is now formalised as the Stainmore Formation; it also subsumes the coeval and lithologically similar Hensingham Group of west Cumbria.

The Stainmore Formation does not correspond exactly with the time span of the Namurian. The early Namurian Great Limestone Member, traditionally taken as the basal marker bed of the 'Stainmore Group', is now formally included in the underlying Alston Formation (P916068). However, the top of the Stainmore Formation, taken at the base of the Subcrenatum Marine Band (the lowermost unit of the Pennine Coal Measures Group), coincides with the Namurian–Westphalian boundary. Throughout northern England (and also farther south), the middle part of the Namurian, from the late Arnsbergian to the Kinderscoutian, is only represented by either a thin sequence of strata, often only a few metres thick, or, in places, by a non-sequence. The reason for this regional hiatus in deposition is not clear.

The transition southwards from the Stainmore Formation into the characteristic Millstone Grit lithofacies (now formally defined as the Millstone Grit Group) is diachronous and irregular. The overall relationship shows large channel-fill sandstone bodies of 'Millstone Grit' lithofacies, encroaching northwards from the Askrigg Block into the more typical, mixed shelf-deltaic lithofacies assemblage of the Stainmore Formation in the Stainmore Trough. In south Cumbria, the Stainmore Formation is overstepped northwards by typical Millstone Grit Group sandstone beds, though in this area their precise stratigraphical position is indeterminate.

Although the cyclical sedimentation pattern of the Stainmore Formation rocks enables lithological correlation to be made across northern England, limestone and calcareous mudstone generally take the place of the dark, goniatite-bearing mudstone that allows the biostratigraphical zonation of the Millstone Grit Group farther south. In much of northern England, goniatites are rare and the majority of the remaining macrofossils, though abundant at many horizons, are not particularly diagnostic of stratigraphical position. Exceptions to this situation are seen in west Cumbria and Stainmore, where successions of mudstone beds containing a characteristic ammonoid fauna have been recorded; in the Stainmore outlier there are key sections in Mousegill Beck (NY 835 123) and other nearby streams. A prospect of much improved correlation is offered by recent (and continuing) palynological studies.

Northumberland, Durham and the Stainmore outlier

Across the Alston Block, about 290 m of Stainmore Formation, Yoredale-type strata conformably succeed the Great Limestone (P548113). The lower part of this succession is dominated by mudstone, whereas the sandstone components are thicker in the upper part. Into the adjacent basins the succession thickens to about 500 m: northwards across the Stublick and Ninety Fathom faults into the Northumberland Trough, and southwards across the Lunedale and Butterknowle faults into the Stainmore Trough. Several Stainmore Formation coals have been worked in Northumberland, the Little Limestone Coal extensively so, and the Crag Coal near Hexham.

The most complete Namurian succession that has so far been biostratigraphically proved is contained in the Stainmore outlier, a narrow fault-block located at the intersection of the Dent and Pennine Faults, south-east of Brough. The outlier preserves 500 m of Namurian sandstone, mudstone and coal with up to 20 marine limestone bands some of which, such as the Upper and Lower Felltop Limestone, can be correlated westwards into other parts of Cumbria. Although there is not a full complement of index nautiloids, comparison of brachiopod and other faunas suggests that all but one of the Namurian faunal stages are represented at Stainmore. Coral remains are a notable feature of the Botany Limestone.

Coarse-grained sandstone bodies with 'Millstone Grit' characteristics — a strongly erosive base and channel-like morphology — are present at several levels within all of the Stainmore Formation succession, but do not necessarily correlate from area to area. They are probably relicts of the fluvial systems that fed southwards into the Millstone Grit deltas of the Askrigg Block and the central Pennine Basin — the Millstone Grit Group sensu stricto. In Northumberland such sand bodies include the Rothley and Shaftoe Grits of the Morpeth and Rothbury areas, and the Longhoughton Grits of the Alnwick area. In all of these cases there is evidence of contemporaneous tectonic control on sedimentation. A similar lithofacies dominates the upper part of the Namurian succession on the Alston Block, east from Alston. On the Askrigg Block, the base of the Millstone Grit Group is well defined, taken at the unconformable base of the Pendleian, Grassington Grit. This has a likely correlative, the Lower Howgate Edge Grit, which in the Stainmore Trough is interbedded with Namurian strata of the Stainmore Formation.

North and west Cumbria and the Isle of Man

In west Cumbria, the lower part of the Stainmore Formation succession contains fossiliferous mudstone, siltstone and limestone of Pendleian to Arnsbergian age. Diagnostic faunas were recovered from the BGS boreholes at Distington (NX 9967 2331) and Rowhall Farm (NY 0851 3664) near Maryport, and from commercial boreholes around Ullock (NY 0770 2400) but examples have also been found at outcrop near Hensingham. In the upper section of the Distington Borehole a Yeadonian fauna is present in sandstone beneath Westphalian Coal Measures, whilst at Rowhall Farm the Coal Measures rest directly on the Arnsbergian strata. Accordingly, and since no angular unconformity is apparent, a significant non-sequence is inferred between the strata of Pendleian to Arnsbergian age and those of Yeadonian age. Other historical accounts from both north and west Cumbria that record fossils of Marsdenian to Yeadonian age would seem to confirm the absence of middle Namurian strata. Farther afield, boreholes on the northern point of the Isle of Man similarly record a mudstone succession of Arnsbergian age followed by Yeadonian deltaic sandstone beds. This stratigraphical break seems larger than the Arnsbergian to Kinderscoutian hiatus recorded elsewhere in the north of England.

Six Yoredale-type cycles of Pendleian to Arnsbergian age can be identified in the Distington and Rowhall Farm boreholes. In the first cycle the Hensingham Grit, a prominent sandstone, 20 m thick and with large-scale cross-bedding, is interpreted as the deposit of an extensive river system that prograded from the north and terminated shelf carbonate deposition, here at the level of the First (= Great) Limestone. A similar, but un-named sandstone unit is seen in the River Lowther south of Penrith. These beds are laterally discontinuous and display cross-bedding that indicates a north to south depositional current. After this initial influx of sand, the supply of coarse-grained sediment diminished and a cyclic sequence of mainly fine-grained lithologies — mudstone, siltstone and coal — marks a change from marine to deltaic conditions; intermittent marine incursions are demonstrated by impure limestones and marine mudstones.

Across both north and west Cumbria, Pendleian and Arnsbergian limestone beds are only rarely more than 2 m thick and are commonly composed largely of crinoid debris; mudstones may contain either a marine or a brackish fauna. The Pendleian limestone beds are laterally persistent and bear the same names in most parts of their range; prominent are the Little Limestone and the Crow or Crag Limestone. However, it should be stressed that the names may apply to beds at different levels in different areas and that regional correlation remains tentative. Identifiable macrofossil remains recorded in the limestone and marine mudstone beds include brachiopods, bivalves, trilobites and gastropods, but corals are relatively rare. Age-specific nautiloids are rare, apart from the Arnsbergian index *Tylonautilus nodiferus*, reported from a number of localities such as the Snebro Gill Beds at Hensingham (west Cumbria) and a single instance of *Anthracoceras glabrum* in the Caldbeck area (north Cumbria).

South Cumbria and north Lancashire

The Namurian succession bordering Morecambe Bay is known only from boreholes in and north Furness and Cartmel and a poorly exposed faulted outlier in the Keer valley north of Carnforth. The

Furness and Cartmel Namurian (previously called the Roosecote Mudstones) has a deep-water depositional character and comprises thick mudstone-siltstone units with thin sandstone interbeds. A Pendleian age is confirmed by the index goniatites *Cravenoceras leion*, *C. malhamense* and *Eumorphoceras pseudobilingue*, which are recorded from the boreholes. In the Keer valley, the succession is of thinly interbedded mudstone, siltstone and fine-grained sandstone. In both areas the sandstone beds are interpreted as deposits of turbidity currents flowing off a 'Millstone Grit' delta front advancing broadly from the east. All of these Namurian strata, including the Roosecote Mudstones, are coeval with the Stainmore Formation but are transitional into its lateral equivalents farther south. These Namurian sequences around Morecambe Bay are now generally assigned either to the Bowland Shale Formation of the Craven Group, where mudstone dominates, or to the Pendle Grit Formation of the Millstone Grit Group if substantial sandstone bodies are present.

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