Southern ‘Dinantian’ successions, Carboniferous, Northern England

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Jump to navigation Jump to search

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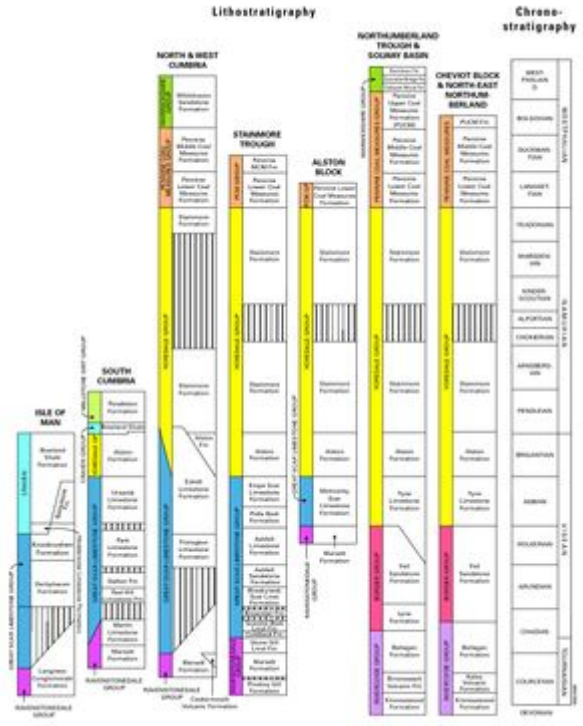
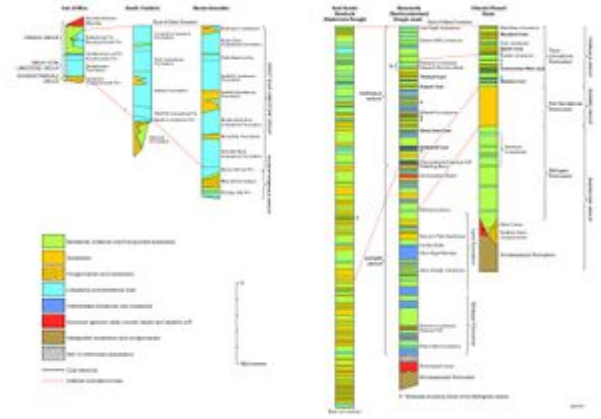
Contents

Introduction



Summary chart of lithofacies for the

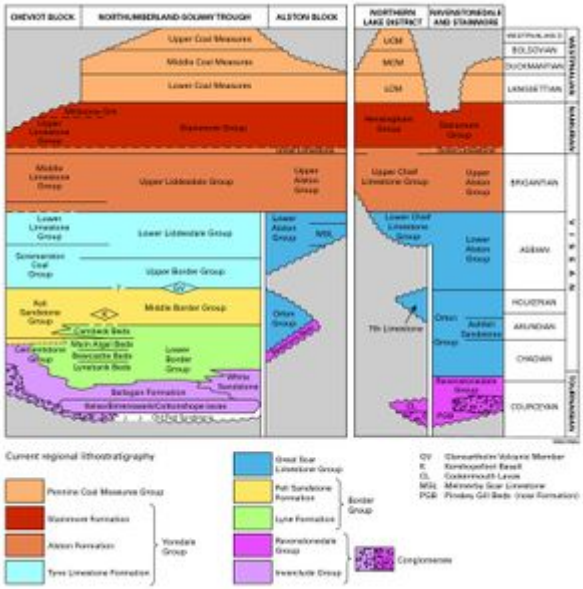
Carboniferous successions in northern England (after Waters et al., 2007. BGS Research Report RR/07/01). P916067.



Representative sections and correlations for theTournaisian to middle Visean (Asbian) sequences. P916072.

‘Basement Beds’ conglomerate from the Marsett Formation, exposed in Ardale Beck [NY 6610 3490], Cumbria, on the Pennine escarpment to the west of Cross Fell. (P006879).

Great Scar Limestone Group exposed in the western escarpment of Holmepark Fell, Cumbria [SD 540 795], viewed from Farleton Knott. (P689698).



Correlation chart for the traditional district-based Carboniferous lithostratigraphies (named on the figure) and the regional group lithostratigraphy adopted in this account (identified by colour). P916068.

Interbedded hemipelagic limestone and mudstone of the Scarlett Point Member,Bowland Shale Formation, exposed in the sea cliff at Scarlett Point [SC 257 661], Isle of Man (GS1039), (P703191).

Pillow lavas of the Scarlett Volcanic Member, Bowland Shale Formation, seen at Close ny Chollagh [SC 245 670], Isle of Man (GS1042).(P703196).

A different lithostratigraphy from that described above from the Solway–Northumberland Trough is applied to the rock sequences deposited during Dinantian rifting to the south of the Maryport–Stublick–Ninety Fathom fault system, (P916067) and (P916072). The southern successions described in this section are peripheral to the Lake District and Isle of Man blocks, spread across the Alston Block, or form the lower part of the Stainmore Trough stratigraphy.

Ravenstonedale Group

The oldest strata of the Ravenstonedale Group, the Pinskey Gill Formation, crop out south of the River Lune between Tebay and Kirkby Stephen. There, 50 m of mudstone, fine-grained sandstone, and limestone-dolostone rest on a smooth marine planation surface cut across Silurian rocks and contain an impoverished Courceyan marine fauna. Deposition of the formation was apparently in a shallow embayment with restricted marine circulation at the western limit of the Stainmore Trough, where the beds were probably laid down in somewhat shallower-water conditions than pertained across the main part of the trough. The Pinskey Gill Formation is unique to this district, but shows similarity in stratigraphical position and lithology to the subsurface Raydale Dolostone Formation, which is known only from boreholes located farther to the east in the Stainmore Trough.

In scattered outcrops across Ravenstonedale, the Courceyan marine beds are overstepped by quartz-pebble conglomerate, lithic sandstone and mudstone, gypsiferous in places, which comprise what were formerly called the Basal or Basement Beds (P006879). All of these occurrences are now brought together as the Marsett Formation in the north of England, and the equivalent Langness Conglomerate Formation in the Isle of Man. These formations encompass the first regionally extensive Carboniferous deposits, which originated as an accumulation of contemporaneous regolith, alluvial fan, river and marginal marine sediment. The two formations vary in thickness across the region. In some places only 10 to 30 m of strata are seen, which may be banked around local irregularities in the underlying syndepositional topography. Much thicker deposits, up to 500 m, occur in proximity to known, or suspected, early Carboniferous growth faults such as the North Solway Fault, the Kirkby/Foxfield Fault system north of the Duddon Estuary in Furness, the Butterknowle Fault on the West Pennine Escarpment and the Shag Rock Fault on the Isle of Man. Extensional faulting may also have been a controlling influence on eruption of the basaltic lavas that form the Cockermouth Volcanic Formation and lie near the base of the Marsett Formation on the south side of the Solway Basin. These lavas have been described earlier in association with the volcanic rocks that occupy a similar position in the Inverclyde Group.

The Marsett and Langness Conglomerate formations are imprecisely dated, but their palaeofloras indicates a Courceyan age in many areas. However, the sequences in west Cumbria and the Isle of Man contain internal disconformities and in their upper parts are interbedded with limestones that range in age from Chadian to Arundian, depending on location. Hence the sequences may represent accumulation, or cycles of erosion and re-accumulation, over a long period of time.

In Ravenstonedale, the Vale of Eden and south Cumbria, deposition of the Marsett Formation was ended by a late Chadian marine transgression, extending out from the Craven and Stainmore basins onto the southern margin of the Alston and Lake District blocks. Initially, conditions were supra-to peritidal and the lower parts of the Martin Limestone Formation in south and west Cumbria and the Stone Gill Limestone Formation in Ravenstonedale are largely composed of dolostone, algal limestone (both oncolites and stromatolites are present) and calcareous mudstone with bedding surfaces marked by desiccation features. In the Shap and south Cumbria areas, the marginal, shallow-water marine environment was maintained through to the end of the Chadian and the Shap Village Limestone Formation comprises dolostone, shelly ooidal limestone, cross-bedded calcareous sandstone and pebbly calcarenite. Mudstone seatearths occur in the lower part of the formation,

whilst the top is defined by palaeosol developed from a breccia deposit.

The upper part of the Martin Limestone Formation was deposited in a broadly shallow-water marine environment and comprises partially dolomitised limestone, some of which is ooidal. Mudstone, sandstone and calcarenite are not present, and the lithological range is similar to that of the open marine, platform and ramp carbonates that typify the overlying Great Scar Limestone Group. Accordingly, in some accounts, the Martin Limestone Formation is included within the Great Scar Limestone Group. The top of the Martin Limestone Formation is prominently marked by a reddened palaeokarst zone.

Great Scar Limestone Group

The type area of the Great Scar Limestone Group (P689698) is the Askrigg Block, where it accumulated as a platform sequence about 400 m thick and Arundian to Asbian in age. Regionally, the group name is used to unify all equivalent, locally named, thick carbonate platform successions of Dinantian and earliest Namurian age in the north of England (P916068). The greatest exposed thickness is seen in Ravenstonedale where about 800 m of strata range from Chadian up to Asbian in age. The sequence in west Cumbria is a little thinner, at about 740 m, but ranges a little higher stratigraphically, from Chadian up to Pendleian (but with no evidence for Arundian rocks). In contrast, on the Alston Block only about 107 m of strata are present and are largely Asbian in age. In the south of the Isle of Man, the group is up to about 157 m thick and Arundian to Asbian in age. In the north of the island, approximately 7.3 m of strata at the bottom of the Ballavaarkish (Shellag North) Borehole (NX 460 007) are assigned to the Great Scar Limestone Group but may possibly be more closely related to the Yoredale Group; a broadly Dinantian or early Namurian age is the best biostratigraphical estimate that can be made from the poor evidence available.

Chadian to Arundian

The lowest formation in the Great Scar Limestone Group, forming the base of the sequence in the Stainmore Trough and extending north-west to just south of Shap, is the Coldbeck Limestone Formation. A dolostone with a characteristic abundance of algal structures (oncoliths) interbedded with mudstone, it was deposited on a west- to east-sloping marine shelf on which the characteristic Chadian coral *Dorlodotia* flourished. The conformably overlying Scandal Beck Formation comprises a succession of cyclically bedded bituminous limestone with thin siltstone interbeds.

At the end of the Chadian there was a general reversion to shallow water conditions and block areas suffered erosion. In the Stainmore Trough, where marine environments persisted until late in the Chadian, the Brownber Formation was deposited as a sequence dominantly made up of ooidal limestone, but interspersed with beds of calcareous sandstone and cross-bedded calcarenite. The sandstone beds are laterally discontinuous, due to channelised deposition, and contain distinctive layers of well-rounded pebbles of white quartz and calcite.

In the early Arundian, a fault-controlled acceleration in basin subsidence rates resulted in deeper marine conditions becoming re-established in the Stainmore Trough and across south Cumbria. At first, high-energy, shallow-marine conditions resulted in deposition of the cross-bedded ooidal limestone typical of the Red Hill Formation. Subsequently, water depths increased and the Dalton Formation of south Cumbria, and time equivalent Breakyneck Scar Limestone Formation of Ravenstonedale and the Stainmore Trough, are thick (200–300 m), marine shelf successions of dark grey, well-bedded crinoidal grainstone with siltstone interbeds.

The early Arundian deposition of peripheral shelf limestone was interrupted where rivers flowing from the north-east introduced terrigenous sediment, now represented around Edenside and

Ravenstonedale by the Ashfell Sandstone Formation. It comprises the fluviodeltaic deposits of a river that flowed around and across the Alston Block, feeding a delta system within the Stainmore Trough. Within the upper part of the Dalton Formation in south Cumbria are sandstone beds that may have been introduced by the same fluvial system that deposited the Ashfell Sandstone farther to the east. A broad, regional link also seems likely with the approximately coeval fluvial system responsible for deposition of the Fell Sandstone Formation in the Northumberland–Solway Basin.

The early Arundian deposition of peripheral shelf limestones extended to the Castletown area in the southern part of the Isle of Man where a sequence about 90 m thick forms the Derbyhaven Formation. Three members are recognised. The lowest of these, the Turkeyland Member, consists of ooidal and bioclastic grainstone and has a sharply defined basal contact with the Langness Conglomerate. The middle, Sandwick Member, comprises dark, bioclastic packstone with an abundance of mudstone interbeds. At the top of the formation is the dark, pyritic packstone of the Skillicore Member, with an increasing proportion of interbedded fine-grained sandstone indicating a progressive shallowing of the depositional environment. The Turkeyland and Sandwick members correlate, respectively, with the Red Hill and Dalton formations of the south Cumbria succession. The Skillicore Member records a minor input of sandy sediment, though compositional differences make it unlikely to have been derived from the same source as the sands that formed similar interbeds in the Dalton Formation.

Holkerian to Pendleian

The Holkerian saw a significant extension of the shallow marine depositional environment onto the flanks of the Lake District and Alston blocks. Across north-west England the Ashfell Limestone and Frizington Limestone formations (and the equivalent Knockrushen Formation of the Isle of Man) are distinctive, dark grey, argillaceous limestone successions, cross- or tabular-bedded, with sandstone interbeds, especially towards the base. South of Penrith and into Ravenstonedale, the topmost beds record a marine regression and comprise a shallow marine to estuarine facies of cherty, porcellanous limestone, carbonaceous mudstone and ferruginous shell beds. On the Askrigg Block and in the Cockermouth area respectively, the Ashfell Limestone and Frizington Limestone formations are topped by thin fluviodeltaic intervals with a coal developed locally. In south Cumbria, the Holkerian Park Limestone Formation was deposited on a carbonate ramp with little terrestrial input, giving a lithologically uniform succession of pale grey, well-jointed, crinoidal grainstone, commonly crowded with robust gastropod and brachiopod shells.

The late Holkerian marine regression led to early Asbian emergence and erosion of the block and platform areas. However, later in the Asbian, the most extensive of the Dinantian marine transgressions re-established basinal or marine platform conditions across the entire region; even the Lake District Block was inundated at this time.

The character of the Asbian platform carbonate deposits is remarkably uniform across northern England and beyond. The limestones were formed on a sediment-starved marine carbonate platform, subject to a fluctuating relative sea level. This oscillation in water depth is expressed in a cycle of sediment type, with low-energy wackestone grading upwards into high-energy grainstone. Corals, mainly lithostrotionoids, occur commonly both fragmentally and as in situ colonies. During sea-level lowstands the exposed limestone surfaces were subject to karst development and a patchy form of diagenetic calcretisation, traditionally termed ‘pseudobreccia’. During more prolonged emergent intervals, the karst topography was wholly or partly infilled with claystone, formed from the accumulation of residual soils, decayed vegetation and subaerial deposits of volcanic ash. The Asbian limestones today form the most prominent of the scarps and upland plateaux of the north Pennines, and the spectacular glaciated limestone pavements of the Edenside and Kendal areas.

Platform carbonate rocks of early Asbian age comprise the Potts Beck Limestone Formation in Ravenstonedale and the lower part of the Urswick Limestone Formation in south Cumbria. The successions have a relatively shallow-water depositional aspect and siltstone–mudstone interbeds are common. Prominent amongst the latter is the 'Woodbine Shale', a 4–5 m thick bed of black pyritous mudstone located about 30 m above the base of the Urswick Limestone Formation; it forms a marked topographical break in many parts of south Cumbria and north Lancashire. A sandstone bed marks the top of the Potts Beck Limestone Formation above Orton Scar (NY 634 097), south of Appleby.

There was no early Asbian sedimentation on the Alston Block nor in west Cumbria west of the Bothel Fault, and in these areas, respectively, the Melmerby Scar Limestone Formation and the lower part of the Eskett Limestone Formation are condensed late Asbian successions. Thicker developments of lithologically identical rocks comprise the upper part of the Urswick Limestone Formation in south Cumbria and the Knipe Scar Limestone Formation of Ravenstonedale and Edenside. The Robinson Limestone Member, the highest component of the Melmerby Scar Formation (and also represented at the top of the Knipe Scar Formation) is separated from the limestones below by a prominent sandstone–mudstone interval at its base. In the Isle of Man, the upper Asbian Balladoole Formation comprises a platform carbonate succession equivalent to the Urswick Limestone Formation of south Cumbria. Locally however, the Balladoole Formation includes bioherms, indicating that the southern margin of the carbonate platform lay nearby.

In general, the youngest beds of the Great Scar Limestone Group are of Asbian age, and are succeeded by the uppermost Asbian to Brigantian strata of the Yoredale Group. An exception to this pattern is seen in west Cumbria where the Eskett Limestone Formation (Great Scar Limestone Group) continues up through the Brigantian and into the Pendleian as a dominantly limestone succession but with abundant thin interbeds of mudstone and sandstone. This upper part of the Eskett Limestone Formation is a time-equivalent deposit to much of the Alston Formation and is conformably overlain by sandstone — the 'Hensingham Grit' — at the base of the Stainmore Formation (P916067).

Craven Group

The Craven Group is most fully developed in the Craven Basin area of Lancashire, to the south-west of the Craven Fault system at the margin of the Askrigg Block (P916068), but its strata extend northwards and have limited outcrop on the Isle of Man. There, in the south, reactivation of the basin margin fault system caused the Knockrushen Formation to be succeeded by a 14 m-thick band of hemipelagic, cherty wackestone and mudstone. This band has a distinctive late Holkerian fauna and is the equivalent of the Hodderense Limestone Formation seen farther south in the main part of the Craven Basin. The succeeding Asbian to Brigantian succession in the Isle of Man and north Lancashire is largely of prodelta or basinal facies, with interbedding of black, hemipelagic claystone and limestone turbidites; it is accommodated in the Bowland Shale Formation. The Asbian, Balladoole Limestone Formation (Great Scar Limestone Group) was partly coeval with the Bowland Shale Formation and was subsequently overstepped by it. In the south of the Isle of Man, the lowermost Asbian part of the Bowland Shale Formation includes the Scarlett Point Member (P703191), wherein hemipelagic claystone is interbedded with coarser-grained sediment, including large blocks (olistoliths) of reef carbonate, introduced by turbidity currents and submarine slides from the platform margin to the north. Higher in the Isle of Man succession, in the Brigantian part of the Bowland Shale Formation, submarine debris flows and slides of volcaniclastic rocks and basaltic pillow lavas form the Scarlett Volcanic Member (P703196), and indicate that the basin margin was volcanically active at this time.

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- Northern England

Navigation menu

Personal tools

- Not logged in
- Talk
- Contributions
- Log in
- Request account

Namespaces

- Page
- Discussion

□

Variants

Views

- Read
- Edit
- View history
- PDF Export

□

More

Search

Search Go

Navigation

- Main page
- Recent changes
- Random page
- Help about MediaWiki

Tools

- What links here
- Related changes

- Special pages
- Permanent link
- Page information
- Cite this page
- Browse properties

- This page was last modified on 6 May 2016, at 12:32.

- Privacy policy
- About Earthwise
- Disclaimers
-
-