Lower Palaeozoic rocks of the Craven Inliers

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Purpose

To examine the stratigraphy and structure of the Ordovician and Silurian rocks, the Sub-Carboniferous unconformity, features of the Pleistocene glaciation, and economic geology.

Logistics

Three half-day excursions, mostly on public rights of way, in the three valleys where Lower Palaeozoic rocks are exposed: Chapel le Dale, Crummack Dale and Ribblesdale. There are car parks, toilets and services in Ingleton, Clapham, Stainforth and Horton in Ribblesdale.

Note Access to Arcow Quarry must be agreed with the quarry manager beforehand (Tel: 01729 860202) and will require safety helmets, protective footwear and insurance cover.

Maps

O.S. 1:50 000 Sheet 98 Wensleydale & Wharfedale; 1:25 000 Outdoor Leisure Map 2, Yorkshire Dales (Western area); B.G.S. 1:50 000 Sheet 50 Hawes; and Sheet 60 Settle.

B.G.S. Memoir, Settle (Arthurton *et al.,* 1988).

Geological background

The Craven Inliers are found on the southern margin of the Askrigg Block, immediately north of the North Craven Fault (Figure 1.1). They provide windows into the Ordovician and Silurian rocks which underlie the western part of the county and probably form the basement at considerable depth elsewhere in Yorkshire. Their deposition, over at least 200 Ma, records the contemporary plate tectonic history on the margin of the Eastern Avalonian microcontinent, as it moved north from high southern latitudes, subducting Iapetus Ocean crust, before colliding with Baltica and Laurentia (see (Figure 3)a for the palaeogeographic terms of this time).

The oldest, Ingleton Group, is either Arenig or possibly Precambrian in age. The succession of grey-green turbidite sandstones, siltstones and conglomerates was probably derived from Eastern Avalonia and deposited in a deep marine environment on its northern margin. The group forms part of an arcuate ridge with a distinctive geophysical magnetic signature that extends from Furness in south Cumbria to Norfolk, beneath the cover of younger rocks.

The group was deformed and uplifted as Iapetus Ocean crust began to be subducted in the Early Ordovician. By the Late Llanvirn continued uplift resulted in the folded and cleaved rocks forming an island arc with subduction related volcanism. Subaerial volcanic rocks are preserved in the Lake District, but no Late Llanvirn or Caradoc rocks are present in the Craven Inliers.

Subsidence caused the island arc topography to be transgressed by an Ashgill sea. The upper Ordovician, a mixed carbonate clastic shelf sequence, rests unconformably on the Ingleton Group. Marine conditions persisted throughout the Silurian, with a gradual return to a deep marine environment and the deposition of silty graptolitic mudstones.

In the Wenlock, turbidite sandstones (Austwick Formation) derived from Eastern Avalonia entered the basin. Subsidence accelerated in the Ludlow and increasing rates of sedimentation and turbidite sandstones derived from Baltica indicate the near closure of the Iapetus Ocean.

The collision of Eastern Avalonia, Laurentia and Baltica produced folds, cleavage and minor thrusts in the early Devonian Acadian Orogeny. Granite plutons, generated at depth, were emplaced into the deformed sedimentary rocks that formed a continental fold mountain belt during the remainder of the Devonian. Crustal stretching early in the Carboniferous produced a series of rift basins and blocks across the British Isles. The Lower Palaeozoic rocks form part of the buoyant Askrigg Block, underpinned by the Wensleydale Granite. The Craven Faults define the southern margin of the block and separate it from the Craven (rift) Basin. The relief of the continental area gradually declined and subsidence during crustal stretching allowed the tropical Carboniferous seas to slowly transgress across the rifted Lower Palaeozoic terrain.

Excursion details

The stratigraphic names used are those on the Settle 1:50 000 geological map and in the accompanying memoir (Arthurton *et al.,* 1988).

Ingleton, Kingsdale and Chapel le Dale

Begin in the car park on the west side of the River Twiss [SD 693 733] and follow the popular Waterfalls walk, a well-laid and maintained footpath. The walking distance is 7 km. The excursion examines the Ingleton Group, the oldest rocks in Yorkshire, the unconformably overlying Carboniferous Limestone and the Craven faults that define the southern margin of the Askrigg Block (Figure 1.1).

The Ingleton Group is a turbidite sandstone and siltstone succession that has been isoclinally folded. The rocks are either Arenig or possibly Precambrian in age. Arenig microfossils have been found only in the Beckermonds Scar borehole, located 15 kilometres to the east. Structural evidence suggests that the group was deformed in a pre-Ordovician orogeny from which an end Precambrian (Ediacaran) depositional age of about 560 Ma is deduced. The Ingleton Group was uplifted and eroded in the Late Llanvirn before deposition of the Late Ordovician (Ashgill) marine succession.

Locality 1, Swilla Glen

Follow the footpath that leads north from the car park on the alluvial flat that overlies Coal Measures rocks on the downthrow side of the South Craven Fault. The fault is crossed at [SD 693 737], near the entrance to Swilla Glen, where thick bedded Carboniferous Limestone is exposed in the stream, dipping 20° south-southwest. The limestone forms the walls of the glen, the dip decreasing northeastwards into the core of an anticline, on the other side of which it dips up to 10° northeast near the North Craven Fault.

The River Twiss follows the fault line for a short distance near Manor Bridge [SD 695 745], upstream of which limestone forms the cliffs on the left bank. On the right bank Upper Ordovician calcareous siltstones (Norber Formation) are exposed. About 100 m beyond the bridge the North Craven Fault is exposed on the far bank of the river. An exploratory tunnel for lead mineralization has been driven in the limestone of the hanging wall; sheared Norber Formation is present in the footwall. Continue upstream to where the Norber FormationIngleton Group boundary is crossed before Pecca Bridge. It is unclear whether the boundary is a fault or an unconformity.

Locality 2, Pecca Falls and Quarry

Cross Pecca Bridge [SD 695 748] and examine the rocks in the slate quarry. The cleaved siltstone is typical of fine-grained lithologies within the Ingleton Group. In the left-hand (southwest) face, sandy laminae indicate subvertical bedding coincident with the cleavage. In the right-hand corner, a slump-fold and its basal dislocation plane reveal that the beds young to the northeast.

At the first viewpoint to Pecca Falls, medium and thick beds of turbidite sandstone are present in the siltstone, marking the gradational passage into the overlying sandstone unit. Near the top of the waterfall, some beds have irregular sole structures and a few 0.3–0.4 m thick beds fine upwards with laminated tops. The sedimentary structures confirm that the beds dip and young northeastwards.

A synclinal axis is present immediately above the waterfall. A further 60 m along the path thick sandstone beds with laminated tops and siltstone interbeds dip 30–40° southwards and towards Thornton Force the dip gradually steepens.

Locality 3, Thornton Force (see cover photograph)

The path continues on the Ingleton Group with Carboniferous Limestone a few metres above it on the left. The unconformity represents a time gap of about 150 Ma and is exposed in the waterfall, beneath the limestone overhang. The basal few metres of limestone are sandy and contain layers of Lower Palaeozoic pebbles. The subhorizontal limestone rests on laminated siltstone dipping 70° southeast which passes up into turbidite sandstones, the basal beds forming a ridge in the river, 10 m downstream from the plunge pool.

Continue on the path over limestone via Twisleton Hall towards the River Doe. Exposures of turbidite sandstone are seen near Beezleys.

Locality 4, Beezley Falls

The falls are in subvertical Ingleton Group turbidite sandstones with some interbedded siltstone; the succession youngs southwestwards. Thick bedded sandstones form each cascade, with plunge pools developed on the siltstone units. If the river is not in spate, the beds can be examined in the river bank above the second cascade by scrambling down from the path. There bedding is clearly defined and on polished surfaces sedimentary structures are revealed, e.g. small-scale slump folds in a 0.1 m thick siltstone interbed. Rejoin the main path to the foot of the falls, where the sandstone passes up into siltstone. Baxengill Gorge is cut in isoclinally folded siltstone. A syncline and anticline are crossed on the way to Snow Falls.

Locality 5, Snow Falls

The cleaved siltstones of the Ingleton Group can be examined in the quarry floor between the path and the river. In the southwest quarry face two north–south trending basic dykes, 7 to 8 m apart, cut obliquely through the siltstones. The eastern dyke is most obvious; the western one, in the corner of the quarry, is overgrown. The dykes are also exposed in the river at the downstream extremity of the quarry. About 60 m southwest of the quarry, the siltstone passes gradationally upwards into sandstone.

Locality 6, Twisleton Glen

The Ingleton Group sandstone in Twisleton Glen is deformed in an isoclinal syncline. Inverted beds on the southwest limb, dipping 70° southwest, are exposed alongside the footpath between the bridge [SD 702 742] and quarry 50 m further downstream. Slump folds are present in a 2–3 m wide zone in the siltstones between the path where it enters the quarry and the river. In the quarry, the planar laminated siltstones are subvertical. South of it, towards the North Craven Fault, the outcrop is drift covered.

Continue on the footpath to return to the car park in Ingleton. In Meal Bank Quarry [SD 698 737], on the opposite side of the river, there is an impressive section of Carboniferous Limestone that lies between the North and South Craven Faults.

Crummack Dale

Begin at the Crummack and Thwaite Lane crossroad [SD 759 692], 300 m north of Austwick Town Head, accessible from either Clapham or Austwick. The walking distance is 7–12 km.

The excursion examines stratigraphy and structure of the Ashgill to Wenlock parts of the Windermere Group, the Sub-Carboniferous unconformity, and effects of the Pleistocene glaciation (Figure 1.1).

Locality 7, Nappa Scars [SD 768 697]

The footpath 50 m west of the crossroads leads to Nappa Scars where the Sub-Carboniferous unconformity is exposed. Pebbly limestone and conglomerate onlap a palaeocliff in cleaved calcareous siltstone of the Upper Ordovician (Ashgill) Norber Formation. Springs a few metres above the base of the limestone indicate diversion of the groundwater flow by the impermeable Ordovician rocks. Follow the footpath to the stile at [SD 768 697], cross the wall and scramble down to the base of the cliff to find exposures of the Norber Formation and the unconformity.

The prominent planes in the calcareous siltstone that dip 60–70° south-southwest are the Acadian cleavage. Bedding is ill-defined but a few laminae dip northwards at about 40°. A sparse brachiopod and trilobite fauna indicates the Rawtheyan Stage of the Ashgill.

The unconformity lies in the undercut part of the cliff. The basal few metres of the Carboniferous consist of clast-supported boulder beds and conglomerate. Many of the larger boulders are Austwick Formation sandstone. This is overlain by matrix-supported conglomerate in which abundant Lower Palaeozoic pebbles and a few reworked Carboniferous limestone clasts are cemented together by a limestone matrix. Higher up, the limestones gradually become pebble-free.

On the cliff top look east-southeast, along the prominent scarp of Norber Brow, an exhumed palaeocliff, its form today closely resembling that in Carboniferous times. The limestones abut and eventually onlap the cliff, indicating the marine transgression onto the irregular topography of the Askrigg Block. Return to the stile at [SD 768 697] and head for Locality 8.

Locality 8, Norber [SD 767 700]

The limestone pavement is strewn with blocks of dark Austwick Formation sandstone and laminated siltstone. The blocks were plucked by the ice from outcrops [SD 770 704] I km to the north in Crummack Dale. The pillars of limestone beneath the erratics have been used to gauge the rate of limestone dissolution in post glacial times.

Again return to the stile at [SD 768 697], take the footpath along Norber Brow and head northwards on Crummack Lane. The source of the erratic blocks can be seen in the small crags on the left-hand side of the lane before the junction at [SD 772 706]. Take the footpath northeastwards to Locality 9.

Locality 9, Central Crummack Dale [SD 773 708]

Follow the footpath northeast for 250 m, to where it crosses a stream that is coincident with the axis of the Studrigg–Studfold Syncline. Look west-northwest towards the unconformity on the west side of the valley, up the plunge direction of the fold; the strike of the sandstone beds (Austwick Formation) can be seen to swing round in the fold closure. The erosion-resistant sandstones form a palaeotopographic high point on the Sub-Carboniferous unconformity which has risen more than 100 m from Nappa Scars. About Soo m northeastwards along the footpath, the thick-bedded turbidite sandstones on the northern limb of the syncline can be examined. Towards Austwick Beck [SD 778 715], the ground is extensively drift covered, but to the east on Hunterstye, another major fold, the Crummack Anticline, can be seen. Join the lane and continue northwards to Locality 10.

Locality 10, Moughton Whetstone Hole [SD 784 719]

Where the footpath leaves the enclosed farmland is Moughton Whetstone Hole. Adjacent to the stream, the ground is littered with fragments of dark red and green banded rock, the remnants of a bygone enterprise that worked the Austwick Formation sandstone for whet, or sharpening, stones. The dark red and green banding phenomenon, known as liesegang rings, results from the weathering of iron oxides in the sandstone. This occurred during the Devonian and early Carboniferous when the deformed Lower Palaeozoic rocks were part of a continental area and subjected to subaerial erosion. In some fragments laminae (bedding) are preserved, crosscut by the younger liesegang rings. The colour banded rock can be seen *in situ* on Capple Bank, in small exposures north of the footpath, next to the wall.

Return down the lane towards Wharfe. Southward-dipping Austwick Formation can be seen below the unconformity on Studrigg [SD 781 708] The axis of the Studrigg–Studfold Syncline is crossed where the lane turns sharply to the right [SD

777 705]

Northward-dipping rocks can be seen next to the ford in Austwick Beck where Silurian 'flags' have been used to construct a clapper bridge. The lane to Wharfe follows the foot of the escarpment formed by northward-dipping Austwick Formation sandstone. There is a choice of footpaths to return to Austwick and Clapham.

Ribblesdale

Younger parts of the Silurian succession are preserved in Ribblesdale because the main synclinal axis plunges east-southeast.

The stratigraphy, sedimentology and structure of the Wenlock and Ludlow parts of the Windermere Group and the Sub-Carboniferous unconformity are superby exposed in two quarries less than 1 km apart (Figure 1.1).

Locality 11, Arcow Quarry [SD 802 705]

Access to the quarry should have been arranged beforehand (see logistics).

The roadstone quarry is in the Austwick, Arcow and Horton Formations on the southward-dipping, northern limb of the StudriggStudfold Syncline. The structure is most clearly seen from the east side ofthe quarry [SD 804 705]

On the north side there is an east-southeast plunging anticline, a parasitic fold on the limb of the main syncline. The anticline and most of the quarry are in the Austwick Formation, an interbedded succession of turbidite sandstone and siltstone. On the south side of the quarry the overlying Arcow and Horton Formations are present. The succession can be examined in detail on one of the benches part way up the west side of the quarry.

The sandstone units consist of parallel-bedded fine to medium grained turbidites up to 2 m thick. Some of the thicker beds have coarse bases, consisting of ill-sorted quartz, feldspar and rock fragments with a clay matrix. Sole structures, mostly flute casts, on the base of some beds indicate turbidity currents flowing from an east-southeast direction. Ripple marks on the top of the sandstones, however, show current reworking from the west-southwest. The sandstones pass gradationally upwards into overlying dark-grey, parallel-laminated siltstones containing a few thin mudstone and siltstone turbidites. Graptolites of Wenlock age are present. Approximately 20 m of siltstone separate the youngest sandstone unit from the overlying Arcow Formation.

The Arcow Formation comprises 9 m of medium to light-grey, weakly bedded, calcareous siltstone. The basal metre is thin bedded and some beds are ripple cross-laminated. Extensive bioturbation has destroyed most of the bedding. It contains a sparse shelly fauna dominated by orthocones. Benthonic fauna and bioturbation indicate an oxygenated depositional environment, contrasting with anoxic conditions for the beds above and below. There is a 2 m gradational passage into the overlying Horton Formation.

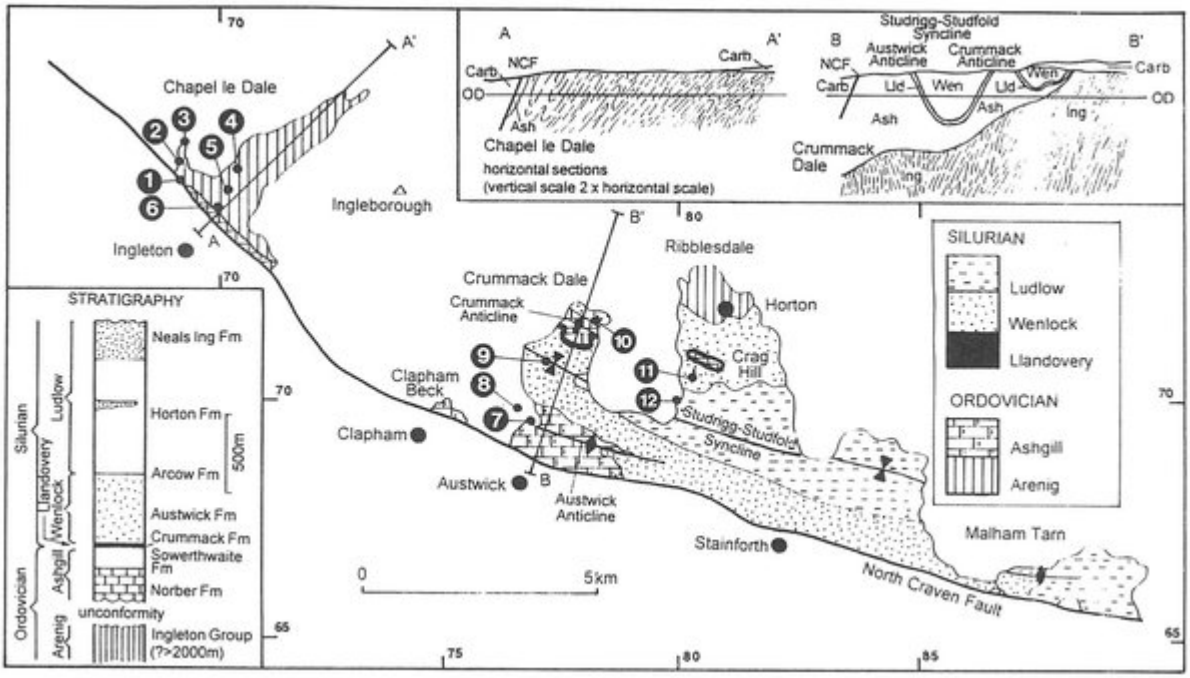
The Horton Formation consists of dark-grey, parallel-laminated siltstone that is sandy and calcareous in part. Calcareous nodules occur near the base, often in layers. Only the oldest part of the 700 m thick succession, with poorly preserved Ludlow graptolites, is exposed in the quarry.

Locality 12, Combs Quarry, Foredale [SD 800 701]

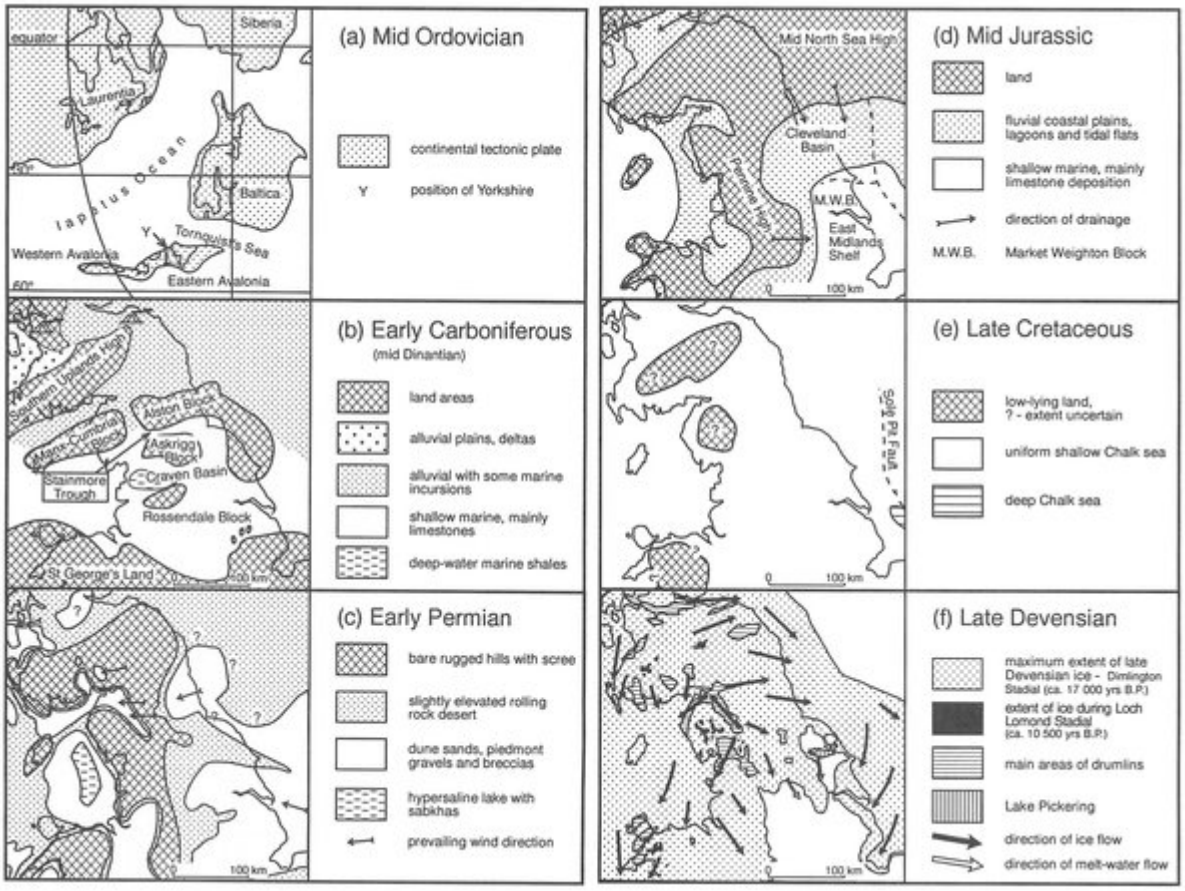
Follow the road from Foredale to the terrace of cottages on the hillside above. A path leads to the quarry.

The quarry worked the dark-grey, laminated siltstone of the Horton Formation for flagstones. The siltstones dip steeply south and are lithologically similar to those in Arcow Quarry. Thin interbeds of bentonite (off-white volcanic clay from large, distant, subaerial eruptions) are present in the siltstone succession. They are much softer than the siltstone, forming recesses and prominent bedding planes. The Sub-Carboniferous unconformity is exposed at the top of the quarry face; bedding in the Carboniferous limestone above is subhorizontal.

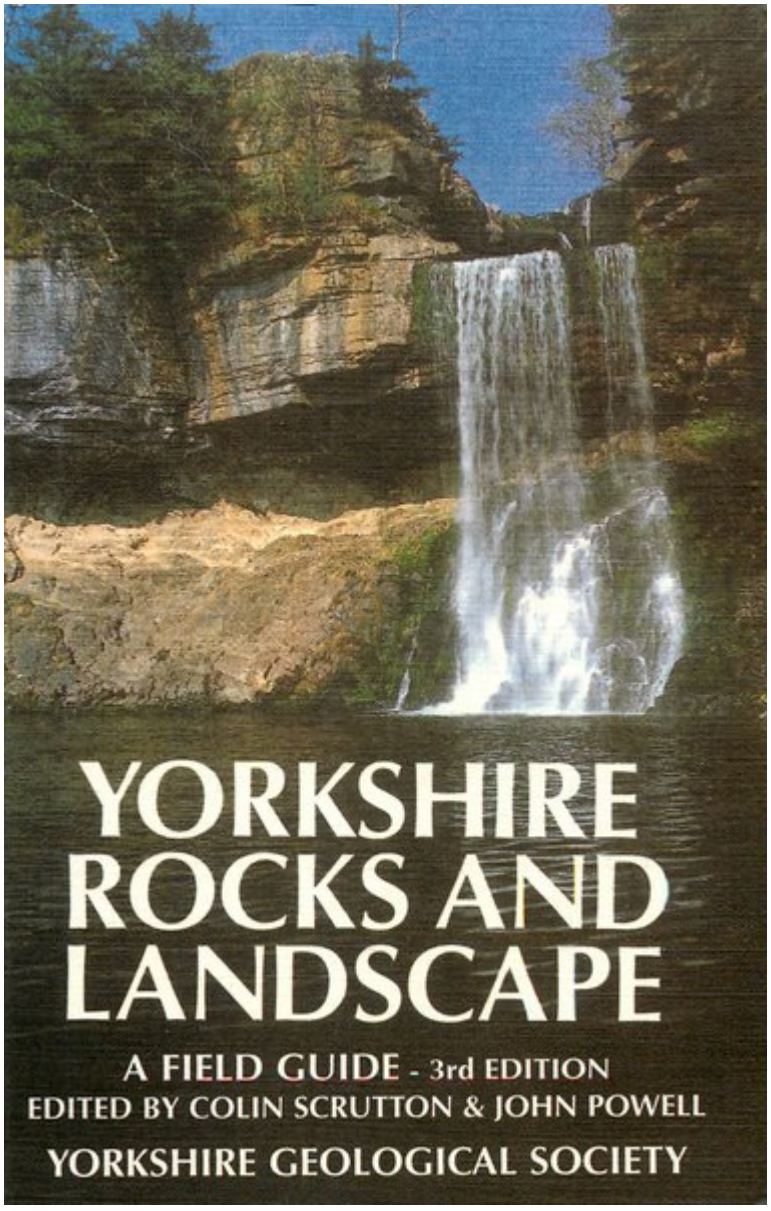
Bibliography



(Figure 1.1) Geological map of the Lower Palaeozoic Craven Inliers. Younger, Carboniferous rocks are not ornamented.



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