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Ingleton

Age of Rocks

From a geologist's point of view, the Ingleton Waterfalls Trail superbly exposes Lower Palaeozoic basement rocks - Yorkshire's oldest rocks to date! The succession (right) identifies the age of rocks you are likely to come across during your walk (MA represents Millions of Years). Examining the rocks from a plate tectonic perspective may well shed some light on the lost ocean of 'Iapetus'! The enigmatic Ingletonian rocks were initially described by Leedal & Walker (1953) as Precambrian. Subsequent workers reassigned them to the Lower Ordovician (Arenig) time frame. At the time of writing (3 Sept. 2003), new research by Dr. N.J. Soper suggests that they may well be Precambrian after all!

This is an ideal excursion for studying a number of key geological concepts which include:

- a)** Structural geology: the Craven Faults, Synclines, Anticlines and Isoclinal folds;
- b)** Stratigraphy: the different geological periods; a classic unconformity;
- c)** Petrology: igneous, sedimentary and metamorphic rocks;
- d)** Quaternary glaciation: a classic terminal moraine.

It is worth noting that in Crummack Dale further in-sights into the Lower Palaeozoics can be seen at Nappa Scars (SD 768697) and Norber Erratics (SD 770704). In Ribblesdale superb outcrops of Silurian rocks can be seen in Arcow Quarry (permission required) and finally, Combes Quarry, Foredale (SD 800701), is another splendid locality to see another angular unconformity.

Ages of rocks seen in Ingleton Glens	CARBONIFEROUS 362.5 MA	Silesian	Stephanian
			Westphalian
			Namurian
		Dinantian	Visean
	DEVONIAN 570 MA		Tournaisian
		Upper	
		Middle	
	SILURIAN 408.5 MA	Lower	Dyke
			Pridoli
			Ludlow
		Wenlock	
		Llandovery	
ORDOVICIAN 510 MA		Ashgill	
		Caradoc	
		Llandeilo	
		Llanvirn	
		Arenig	
CAMBRIAN 570 MA		Tremadoc	
		Merioneth	
		St. David's	
PRECAMBRIAN		Comley	
		Ingletonian ?	

Swilla Glen

The Ingleton Glens are particularly important to the geologist with the key feature being the exposure of the Lower Palaeozoic basement rocks that lie below the Carboniferous Great Scar Limestone. As you can see from the photograph (left) the paths are well maintained.

The car park is built on an alluvial flat that covers Coal Measure sandstones on the down throw side of the South Craven Fault.

On entry to Swilla Glen you will have crossed the South Craven Fault. The only evidence for this is a wet ground to the left of the path.

The initial outcrop of limestone in Swilla Glen dips gently downstream forming the southern limb of an anticline. As you walk along the valley you should be able to see the limestone begin to exhibit a much more shallower dip. This indicates that you have (or are about to) reach the crest of the anticline. Later along the path the limestone will begin to dip gently to the north.

Limestone is made of almost soluble calcium carbonate. It's solubility is greatly increased by the presence of carbon dioxide (as found in rain water). The interaction of rain water and limestone leads to the formation of soluble calcium bicarbonate. When the carbon dioxide is later released from solution, (typically in flowing water and spray over a waterfall) the carbonate is reformed and deposited as tufa.

This is a typical feature found throughout the Yorkshire Dales limestone country. It is to be found in Malham at Janet's Foss.

The photo to the left shows the tufa screen in Swilla Glen. For the chemists amongst you this is chemical equation that defines the process.

Manor Bridge - *North Craven Fault*

When you cross Manor Bridge leaving Swilla Glen and the Great Scar Limestone anticline behind, you will eventually notice a change in lithology. On the right bank of the Twiss Upper Ordovician calcareous siltstones of the Norber Formation are exposed along the path. A little further on, the left bank becomes dominated by a steeply inclined limestone face. This is the fault plane of the North Craven Fault (footwall).

The Ordovician calcareous siltstone (footwall) contrast nicely with the limestone. You can see that the calcareous siltstones are contorted

(deformed) and have yielded a sparse fossil fauna. Also you will notice a 'cave' or more likely a failed attempt to find lead mineralization. If you are eager for a closer inspection by crossing the Twiss you should look out for:

- a) Vertical grooving and oblique slickensiding on the fault plane.
- b) A lamprohyre dyke cutting the Ordovician siltstones. The volcanic rock is a medium grained crystalline rock rich in biotite and quartz.

More dramatic slickensides and a mineral breccia can be seen further along the Twiss but you will have to climb up a height to see it!



The Pecca Slates - Outline Geological History

- a) Late 19th Century Ingletonian Pecca Slates were assigned Lower Silurian, then shortly after, Ordovician.
- b) Early 1900's the Ingleton Series were assigned to the Precambrian.
- c) Green (1917) in Pecca Quarry placed the Ingletonian rocks as Ordovician.



d) The 1920's and onwards recognised that the angular unconformity between Carboniferous / Ingletonian was a significant feature.

e) In 1950 Leedal & Walker described the Ingleton rocks in terms of their sedimentary structures. The unfossiliferous nature and intense folding led to their reassignment to the Precambrian.



Current View

The Ingletonian strata all dip steeply to the SW and were originally thought to represent a continuous succession over 4km thick. A study by Leedal & Walker (1950, Geol. Mag. 87, 57-66) using way-up evidence from the fine beds reinterpreted the Ingletonian as isoclinally folded, and their inferred fold pattern has been adopted on the BGS 1:50 000 map and cross-section (Sheet 50, Hawes).



There are three lithofacies: sandgrade turbidite greywackes, green siltstones, mudstones and sandstones. A number of sedimentary features such as ripple cross lamination, flute casts, slump folds and intraformational breccias, have been used to aid their interpretation as turbidite deposits. The very coarse quartz-feldspar-rich greywackes are commonly referred to as 'Ingleton granite', particularly by the quarrymen.

The Ingletonian is devoid of fossils and was traditionally thought to be of Precambrian age. However, the Beckermonds Scar borehole yielded one sample of *Arenig acritarches*, so an early Ordovician age for the 'Ingleton Group' has been adopted by BGS.

The enigmatic Ingletonian strata still attract much interest from geologists today. Recent research by looking at sedimentary structures and cleavage are once again challenging the stratigraphical position of these fascinating rocks.

Thornton Force



This one of the most important waterfalls of the Yorkshire Dales National Park geologically speaking of course. Located on the River Twiss, the waterfall plunges off Carboniferous Great Scar Limestone that was laid down in a clear sub-tropical sea 330 million years ago. The water bounces onto rocks belonging to the Lower Ordovician (Arenig) Ingleton Group laid down some 500 million years ago. The time gap between the horizontally bedded limestone and the steeply dipping turbidite sandstones is about 170 million years.

Recently more research on the age of the Ingletonians suggest that they may be Precambrian after all! There are dark greenish-grey cobbles lying on the underside of the limestone outcrop. This is the classic Carboniferous basal conglomerate that marks an ancient land surface; probably representative of an early Carboniferous beach. The significance of this locality was first spotted by John Playfair at the end of the 18th century during his preparation of his book *Illustrations of the Huttonian Theory of the Earth* (1802). He described the section in terms of evidence to prove Hutton's theory that geological processes of the past were the same as those of today continued over immense periods of time.

Formation of Thornton Force

The diagrams show how the geological feature of Thornton Force was formed.

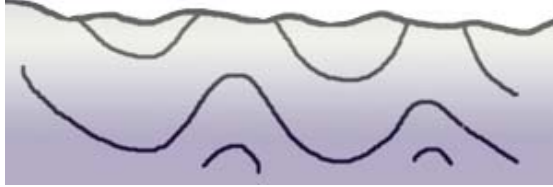


Diagram 1

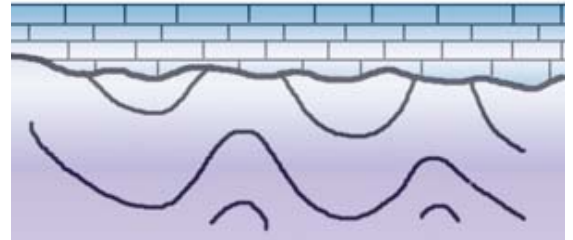


Diagram 2

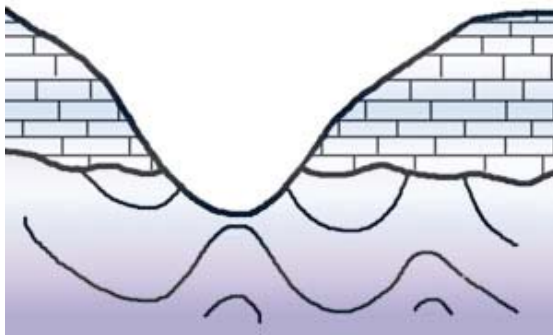


Diagram 3

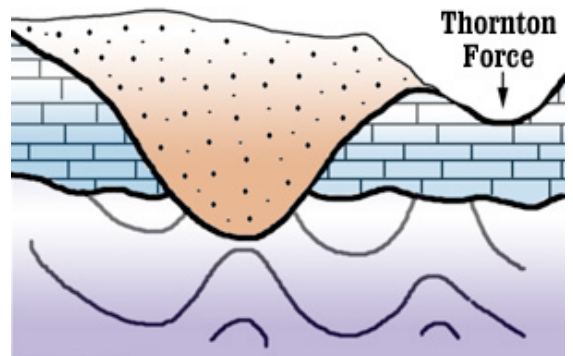


Diagram 4

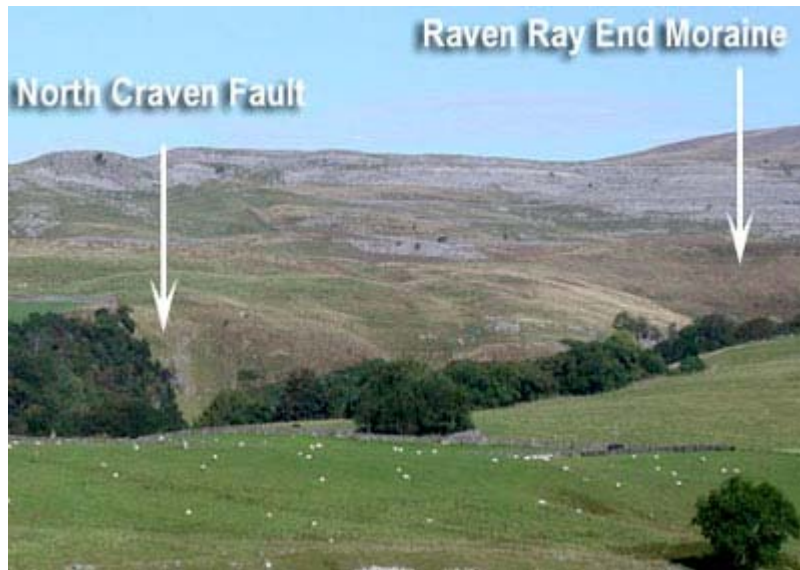
Diagram 1 represents a time when Ordovician (Precambrian?) mud and sand was deposited into a deep ocean. These sediments, often of a turbiditic nature, were uplifted and folded into mountains which were subsequently eroded down over millions of years.

Diagram 2 shows how the land was submerged beneath a warm shallow Carboniferous sea.

In Diagram 3 there has been some uplift of the Limestone and ice flowing down Kingsdale has further eroded Kingsdale valley.

Diagram 4 shows the end moraine at the head of Kingsdale - a major obstruction to the natural drainage. The River Twiss had to cut a new course in order to bypass the moraine. The right-hand edge of the moraine can be seen in the photograph at the top.

River Twiss Valley



The idea of an inlier is shown in the photograph. The Twiss Valley exposes the oldest rocks, the Lower Palaeozoics, while the Carboniferous limestones are clearly seen exposed on higher ground.

Of particular interest in the photograph of Kingsdale Valley is the Raven Ray End Moraine. This is a product of events related to the last ice age which had a major impact on shaping the valleys. The ice age was characterised by the repeated advance and retreat of ice sheets across the Yorkshire Dales. The Raven Ray glacial moraine had two major effects:

- a) It held back melt water thus creating a Lake Kingsdale.
- b) The moraine diverted the River Twiss away from its original course.

Tiddeman's Breccia



On crossing the valley to the River Doe section try to spot 'Tiddemans Breccia'. Tiddeman (along with McKhughes and Gunn) in 1870 did the first comprehensive study of the geology of Ingleton. The breccia is seen in one of a few isolated rocks in the farmer's field. The coarse clasts in the limestone

boulder are partially angular and rounded. This is evidence for the local unconformity of Dinantian limestone and Ingletonians in Chapel Le Dale. This extra locality allowed the party the chance to view Ingleborough and Skirwith Quarry. The geology of Ingleborough itself was explained as this extends into the famous Yoredale Cycles. Also the vast workings of the quarry could be seen and the term 'Ingleton Granite' was explained to the party.

Wood Anemone

It's also a good idea to make a note of the plant life that you encounter on your walk. Often the kind of plants you see reflect the underlying geology. In this case, in late April 2004 the Wood Anemone was in full flower. This is a member of the buttercup family. It is usually found in mixed deciduous woods often near damp calcareous soil.

River Doe Valley - Mapping the Ingletonian



The River Doe section is perhaps more geologically intriguing part of the walk than the text book geology of the Twiss section. The walk commences below Beezley Farm where you enter an oak woodland where the River Doe flows down from Chapel-le-Dale. Along this part of the walk you will see the following waterfalls:

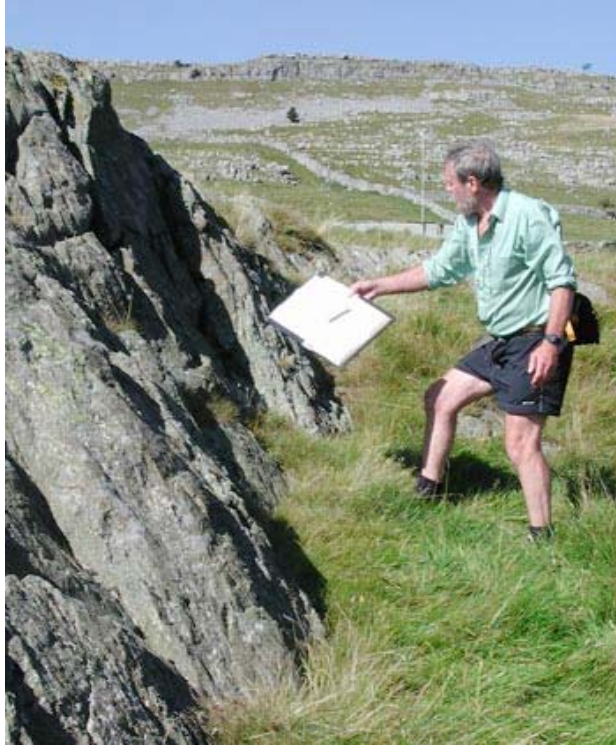
Beezley Falls

Triple Spout

Rival Falls

Baxenghyll Gorge

Snow Falls



The geology of the Doe is characterised by turbidite sandstones with some interbedded siltstones. As demonstrated on the River Twiss section, the waterfalls are formed from the turbidite sandstone posts with the siltstones / slates forming the plunge pools.

The Ingletonian rocks on close examination show a number of important sedimentary features such as graded bedding, isoclinal folding and cleavage - all key structures in determining the way-up of the strata.

The Ingletonian rocks have also been subjected to intense compression forming synclines and anticlines.

Sedimentary Structures

Sedimentary structures are an important feature in the Ingletonian rocks. They can be used to work out the conditions of deposition and the direction of currents. This is especially useful in areas like this where the rocks have been intensively folded. In view of the age of these rocks, interpreting these structures needs to be carefully applied in the field!

Isoclinal Folding



The top photograph shows small-scale isoclinal folding (a special case of overturned fold) in the Ingletonian turbidite. An isoclinal fold is where both the limbs of a fold dip towards the same direction. In a fold like this, one limb looks normal while the other limb appears to be overturned towards the other.

Ripple Marks



The Ingletonian show evidence of ripple marks. Both wind and water can displace sediment to make ripples. In the case of the Ingletonian greywackes, these ripples are formed in marine waters and are therefore wave-formed or current ripples. They are of value in determining the way-up of the beds.

Tool Marks



These form when objects being carried along in the current come into contact with the sediment surface. There are a number of different ways that geologists' describe them i.e. prod, roll, brush, bounce marks. They can be used to determine the direction of current flow. Usually the sharp end marks the direction in which the current was travelling.

Flute Casts



These can be elongate or triangular (heel-shaped) with either a rounded or pointed upstream end, flaring in downstream direction. Often they form through local scouring by eddies in currents and are typically found throughout turbidite sequences. Geologists' generally find that flute casts are reliable means of determining palaeocurrent direction.

Dyke Intrusion - Ingletonian Dyke



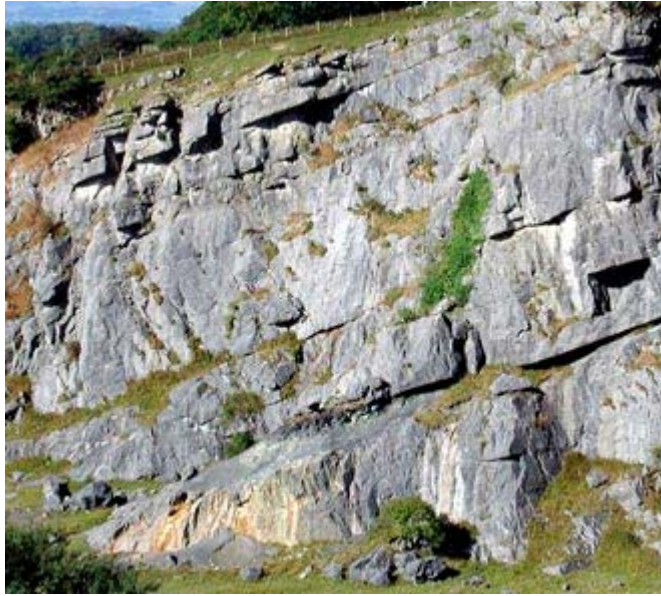
This outcrop is located on the River Doe section of the walk. The dyke can just be picked out by the diagonal mineralization making it about a metre thick. On close inspection it looks not unlike the surrounding Ingletonian strata. This similarity has been compounded by the fact that once intruded, the dyke has been subjected to a fair degree of metamorphism.

There are other dykes cutting through the rocks of the Ingleton Glens. Some are smaller and similar in appearance to the one shown in the photograph.

There is however, a lamprophyre dyke just before you reach Meal Bank Quarry further along the River Doe. This dyke is much younger (probably early Devonian) and is likely to be related to the main Lake District intrusions (such as the Shap Granite). It makes a splendid feature as it partially cuts across the River Doe.

You do have to leave the path and care must be taken when descending the hillside. Please return to the path afterwards and do not cross-over into Meal Bank Quarry as access to Ingleton via the gate is extremely difficult!

Meal Bank Quarry - Carboniferous Limestone



From the elevated position of Storrs Common there is a good view across to the disused Meal Bank limestone quarry. This impressive quarry is situated between the South Craven Fault and the North Craven fault.

The north end of the quarry is relatively unfossiliferous. As you pass south along the quarry face a shaley coal seam is exposed. This is seen just above the iron staining in the associated fireclay. It indicates a basin-wide lowering of sea level (palaeokarstic surface). There was sufficient time for colonisation by plants before the sea flooded in once more. There is a nodular bed enriched in pyrite 15 metres above coal seam. The palaeogeographical setting for this sequence of limestones is perhaps that of an atoll where the nodular bed is some kind of turbidite slumping on the flanks of the atoll.

Fossils can be found in the south end of the quarry and include typical Lower Carboniferous corals and brachiopods. It's also extremely popular with rabbits!