

The Three Peaks of Yorkshire

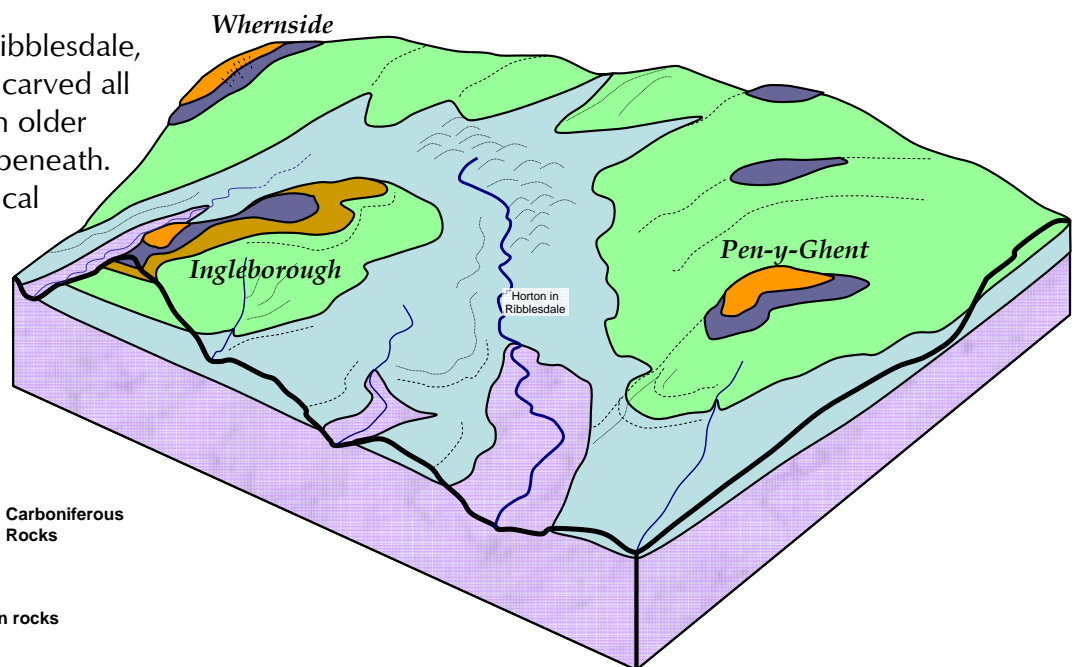
A Geological Guide.

Pen-y-Ghent from Ingleborough. © A. Thompson 2007

The Three peaks of Yorkshire (**Whernside** [736m], **Ingleborough** [723m] and **Pen-y-Ghent** [694m]), are prominent hills rising above the valley of Ribblesdale in the far west of the Yorkshire Dales National Park.

Whernside and Ingleborough are the two highest peaks in Yorkshire. Pen-y-Ghent, though a bit smaller, is one of the most striking in shape. All three are very similar, geologically, and the steps in their profiles (see photo of Pen-y-Ghent, above) pick out the various layers of '**Carboniferous**' rocks, formed between 350 and 320 million years ago, which once would have continued across the whole of the area in between the hills. The fact that they are now hills is because the valleys in between them have been carved out of that much earlier landscape by streams, rivers and glaciers over many millions of years.

At the southern end of Ribblesdale, that erosion has actually carved all the way through to much older and very different rocks beneath. This is where the geological story of the Three Peaks begins, almost 500 million years ago, in the '**Ordovician**' period of the Earth's history.



At that time, this area was part of a **deep ocean floor**. Underwater avalanches cascaded down into the deep water from the edge of a nearby continental shelf, carrying fine grained sands, silts and muds, which accumulated in layers on the bed of the ocean as dark grey 'turbidite' deposits (also known as '**grewackes**'). The fossils of tiny sea creatures from this period (known as '**graptolites**') became trapped in the layers of sediment. Conditions remained like this for around 80 million years, gradually building up a huge thickness of sediment throughout the Ordovician and into the following **Silurian** period. The sheer weight of overlying sediment gradually changed the sediments into rocks. Towards the end of the Silurian, around 400 million years ago, the deep ocean basin began to close, as the huge continental 'plates' on either side moved together, compressing the rocks even more and folding them into contorted shapes. In doing so, the rocks were pushed upward to form massive **fold mountains**, rising high above sea level. The same geological event, the '**Caledonian Orogeny**' created most of the Scottish mountains, but in Northern England, the hills were almost completely eroded away. The evidence for all of this can be seen in the quarries to the South of Horton in Ribblesdale(see next page).



This old quarry face near Horton in Ribblesdale reveals steeply dipping (tilted) layers of Ordovician rocks at the (the remnants of the Caledonian fold mountains) overlain by much younger, horizontally-bedded Carboniferous limestone. The junction between the two (known as an '**unconformity**') is an ancient land surface formed by the wearing down of the old mountain range. The unconformity represents a very long period of geological time: the whole of the **Devonian** period (from 417 to 354 Million years ago), during which the landscape was transformed into a hot desert and, in this area, intense erosion took place. Eventually, the surface became submerged beneath rising sea levels once again to allow the younger limestones to be deposited on top.

The **Carboniferous Limestones** are responsible for much of the character of the Yorkshire Dales landscape. They were formed in warm, shallow, tropical seas and represent the accumulated shells and skeletons of countless millions of sea creatures. Some of the limestone was formed as huge **coral reefs** and the fossilised remains of coral stems can be found in some of the limestone seen in the dry stone walls. Most of the limestone was formed, however, in shallow lagoons behind the coral reefs and is made up of horizontal layers of crushed shells from creatures such as **brachiopods** (a bit like modern day oysters).

One of the most spectacular landscape features formed by the Carboniferous limestones in this area are the **limestone 'pavements'**, seen especially on the flanks of Ingleborough. →



These are extensive, horizontal outcrops of limestone, which have been exposed by the wearing away of younger rocks from above, particularly by glacial erosion (see next page), and which have then been partially dissolved by

rainwater to create an amazing interlocking pattern of deep grooves, known as '**grykes**' with blocks of undissolved limestone (known as '**clints**') in between. The grykes pick out the natural pattern of joints in the limestone and often contain rare species of plants. All limestone pavements are protected by law as features of geological and biological conservation interest.



The photo above shows the horizontal layers of Carboniferous limestone to the west of Ingleborough, dissected by the valley of the River Doe. The top surface of each of the layers is a '**bedding plane**' in the rock: a surface of deposition when the rock was being formed under the sea. These surfaces have since been exploited as planes of weakness by glacial erosion, so that the landscape has been carved into a series of steps, with limestone pavements developing on the top surface of each step. In the bottom left corner of the photo, where the limestone is overlain by other deposits, the surface is 'pock-marked' by a series of conical depressions, known as '**shake holes**', formed by the collapse of these deposits into **dissolution cavities** in the limestone beneath.



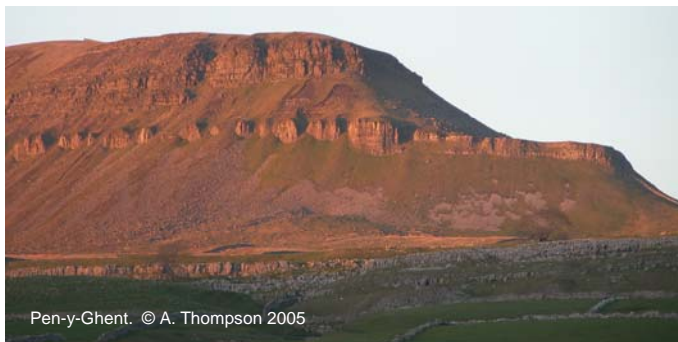
In addition to the intricate, small scale dissolution features of the limestone pavements, and the myriads of shake holes seen in areas where the limestone has a thin cover of younger deposits, there are occasional much larger features, both on the surface of the limestone and deep within the rock. At the surface there are **swallow holes** or **sink holes**, similar to shake holes but formed in the limestone itself, either through dissolution by rainwater draining into them and/or by the collapse of the surface layers of limestone into a large dissolution cavity in the rock beneath (see below). Some of these swallow holes, such as **Hunt Pot** (see photo below) which you will visit on the Pen-y-Ghent hike, have 'captured' the flow of streams so that these disappear underground into cave systems (see below).

Underground, the rainwater draining down through the surface layers of rock collects together into underground streams which are then capable of dissolving and eroding extensive cave systems, such as the **White Scar Cave** system near Ingleton (www.whitescercave.co.uk) and the nearby **Ingleborough Cave** (www.ingleboroughcave.co.uk). Please note that any suggested connections to the once famous **Crowborough Caves** (www.crowborough-caves.org.uk) are purely conjectural. Water that disappears down into these cave systems eventually reappears further downstream, either at the base of the limestone where it meets the impermeable Ordovician and Silurian rocks beneath, or at higher levels after long periods of rain, when the water table is higher. The places where this **groundwater** comes back to the surface are shown on maps as **springs** or '**rises**'.



Hunt Pot
© A. Thompson 2006

Around 330 million years ago, the warm shallow lagoons in which the limestone had been laid down began to be filled in by river deltas, bringing coarse-grained sediments down from an ancient land mass in the area to the north and east. For at least 10 million years, conditions altered between shallow marine, deltaic and tropical swamp environments as sea levels fluctuated, giving rise to a repeated sequence of thin limestones, sandstones, shales and occasional coal seams, together known as the **Yoredale Series**. These rocks generally form the main slopes of the hills rising above the limestone pavements, and the differences in strength between the various layers gives rise to the characteristic stepped appearance of these slopes, with hard limestones and sandstones standing out as distinct crags or 'scars'.



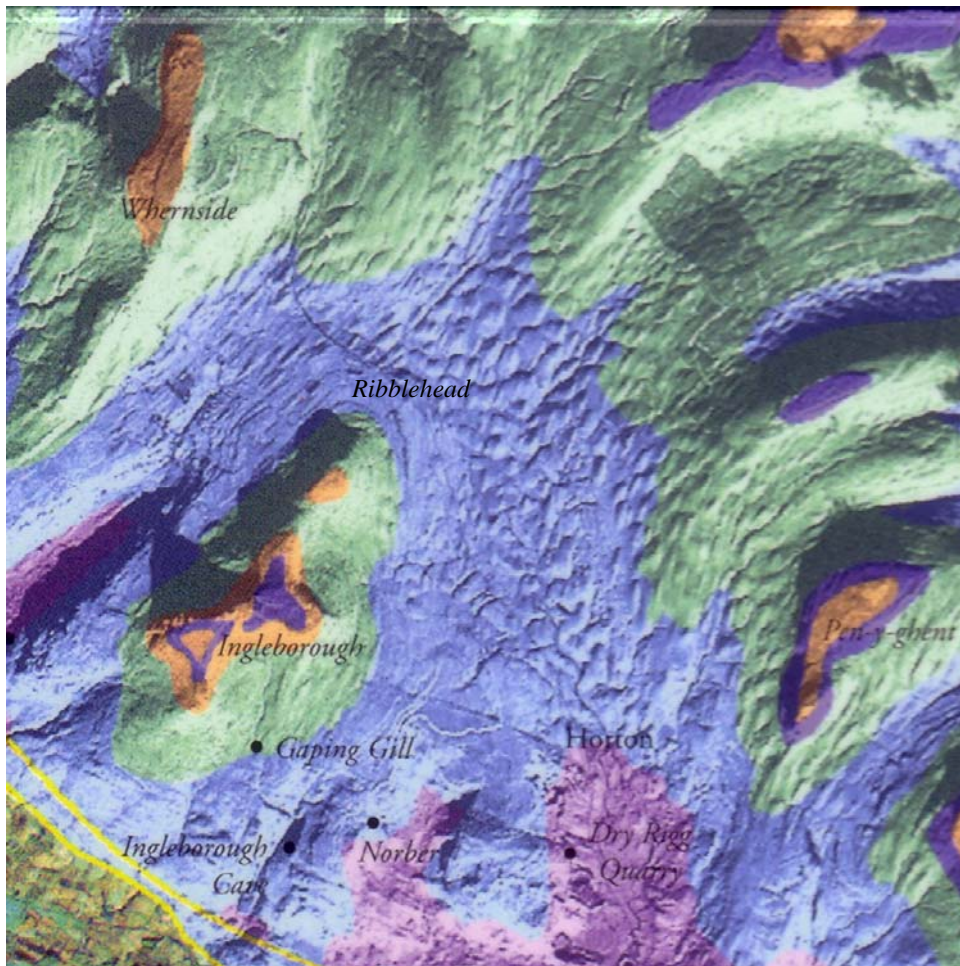
Pen-y-Ghent. © A. Thompson 2005

Towards the end of the Carboniferous period, around 320 million years ago, the area became dominated by vast river deltas which deposited thick layers of coarse, gritty sandstone known as the **Millstone Grit** (so named because it was often used, in the past, to make huge millstones for grinding flour). Today, all that is left of the Millstone Grit in this area is a capping of rock on the summits of the hills such as Pen-y-Ghent (see photo, left, and also the block diagram on page 1).

Nothing at all is left, in this area, of the rocks which were formed after the Millstone Grit: Upper Carboniferous **coal measures**, such as those found extensively on either side of the Pennine hills, may once have covered this area as well, but have long since been eroded away. Much younger **Jurassic limestones** and **Cretaceous Chalk** deposits would also once have extended over the tops of the Three Peaks but no vestige of them remains. Those periods saw the evolution of many thousands of different life forms, including the **dinosaurs**, almost all of which became extinct at the end of the Cretaceous period, just 60 Million years ago. *To get some idea of the scale of things, the equivalent of the entire geology of Sussex, from the Jurassic rocks beneath the core of Ashdown Forest to the Chalk at the very top of the South Downs, has been eroded from above the Three Peaks of Yorkshire in the last 60 Million years!*



Ingleborough Hill. © A. Thompson 2006



Within the last 2 Million years, ice ages have left their mark on the landscape of the Three Peaks, both in the form of deep **glacial erosion** which has carved out the valleys between the hills, accentuating the steep scars such as that on the eastern face of Whernside and the western face of Pen-y-Ghent. There has also been extensive **glacial deposition** however, most obviously in the form of streamlined, egg-shaped hills known as **drumlins**. These can be seen on the photograph below and in this satellite image, on which colours representing the underlying 'solid' geology have been superimposed.

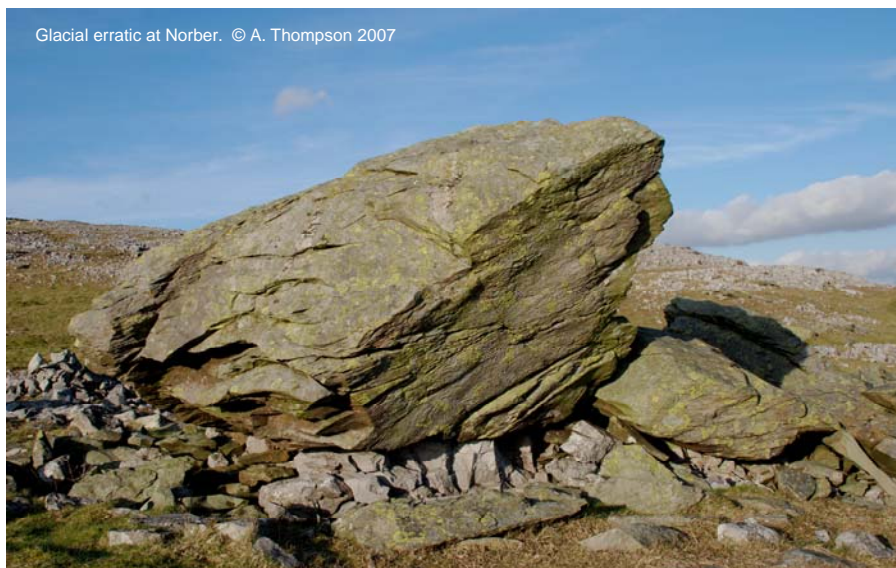


Image produced by the British Geological Survey © NERC

The drumlins, which are best displayed to the north and east of Ribblehead, were formed beneath slowly moving ice-streams within a huge **ice sheet** that covered the entire landscape around 18,000 years ago. They are formed of **glacial till** (sometimes known as 'boulder clay') which has been molded into these shapes by the flowing ice. Such deposits are mainly found along the valley floors.



Drumlins at Ribblehead. © A. Thompson 2006



Glacial erratic at Norber. © A. Thompson 2007

An intriguing exception to this are the deposits of large grey boulders (eroded by glaciers from the Ordovician rocks exposed in Crummack Dale), which have been 'dumped' by the ice at a higher level on top of Carboniferous Limestone at Norber (see satellite map for location). One such boulder, approximately 3 metres in diameter, is seen in this photo. Boulders like this, which are formed of a different rock type to the ones they are resting on, as a result of glacial transportation, are known as **glacial erratics**.