Ingleborough Archaeology Group
A survey of the north-west flanks of Ingleborough 2007 -2011

Geology and topography: an overview

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Introduction

The dominant solid geology underlying the Ingleborough massif is of Carboniferous age: the top beds of Carboniferous limestone form the present land surface of the Terraces; the limestone is overlain by the Yoredale (or Wensleydale) Group with alternating beds of limestone and sandstone with shale bands interspersed that make up the bulk of the summit massif and of Simon Fell and Park Fell; and in turn these are overlain by Millstone Grit strata forming the uppermost layer of the actual summit plateau.

Carboniferous strata lie *unconformably* on Basement rocks of Ordovician and Silurian age (Figs.1 and 2).

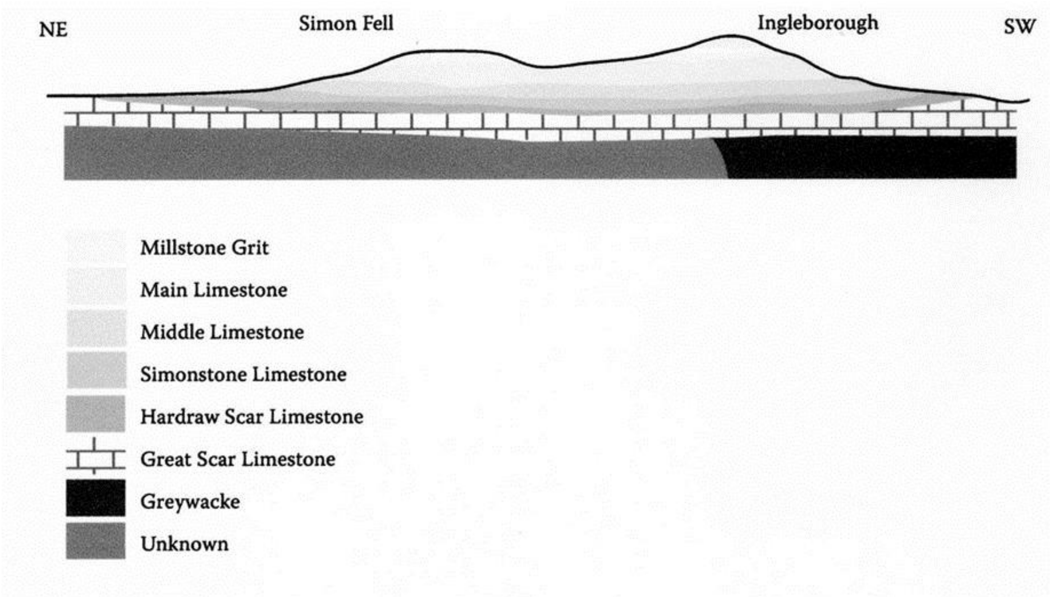

Fig.1 Geological section through Ingleborough, looking south

The intervening Devonian period is not represented within the Dales as the area lay above sea level during that time and there was no deposition of marine material. Basement rocks do not outcrop at the surface on the western or northern flanks of the massif but are found within the valleys of the Twiss and Doe where they have been commercially exploited over several centuries in the long-disused Ingleton 'Granite' Quarry (actually not granite at all) and smaller slate quarries along the two rivers, as well as in the still-operational Ingleton Quarry.

Various *geomorphological* processes have left their mark on these geological foundations, shaping the landscape that we see today. Weathering actions are slow and imperceptible.

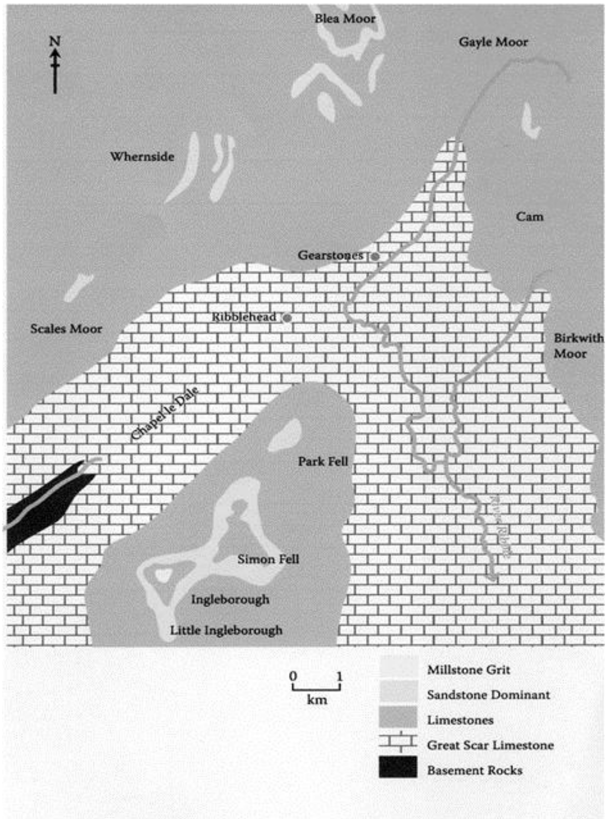

Fig.2 Solid geology of Ribblehead, based on British Geological Survey mapping

Frost action opens up vertical and horizontal joints within rock strata leading to fracturing of blocks of rock into smaller fragments that form the expanses of scree and block fields such as on The Arks and above Black Shiver. Wind and rainwater action physically wears away and shapes exposed rock surfaces, while chemical reactions between the natural carbonic acid in rain and the calcium carbonate content of limestone lead to the slow dissolution of limestone along weakened joints and mineral veins as can be seen so dramatically on the expanses of limestone pavement along the western terraces between Black Shiver and Tatham Wife Mosses and Raven Scar. Ingleborough contains the most spectacular upland limestone pavement in the entire country with its classic *karst* landforms.

Palaeo (ancient) landscapes have also been modified over millennia by more dramatic geomorphological processes with glaciation having been the most obvious. Indeed, the impact of ice on limestone surfaces has led to this type of karst landscape being referred to as a *glaciokarst* landscape, dominated by limestone pavement and cave systems. The very existence of the wet and acidic mosses below the summit massif is due to the laying down of a veneer of glacial *till* that masked the limestone bedrock.

At the end of the most recent glacial episode events of a much more sudden or perceptible nature have not only left their mark on the present day landscape but have also had a direct impact on earlier people's ability to exploit landscape. The former is represented by the massive landslips (rotational slumps or debris slides) to be seen at Falls Foot and on Black Shiver; the latter by pockets of wind-blown *loess* silts that have survived within natural depressions and proved to our ancestors to be fertile and easily workable thereby attracting human occupancy.

The action of ice

During successive glaciations much of Ingleborough would have been covered in ice and would have been an ice *growth pole* in its own right – its great bulk and height were sufficient to lead to the development and build up of ice that flowed under gravity onto the fells below. In addition, the area was affected by major ice flows from the north, spilling over from Mallerstang and the Howgills to merge with ice coming down from Cam Fell and Whernside to flow down the textbook glacial trough of the Chapel-le-Dale valley. However, it is now understood that a single Dales Ice Centre covered most of the area under an ice sheet and that even the summits of the major hills, including Ingleborough, were submerged beneath the ice (Mitchell 2013, 48).

Glacial deposition and till

Where existing topography – or convergence of ice flows – caused moving ice to lose momentum it also lost its capacity to transport material leading to the laying down of *moraine* deposits in the form of till which consists of an unsorted mix of boulders and clay.

It was not laid down evenly but in hummocky form. This uneven nature was further modified by meltwater once the ice had gone. Being mainly clay, till is sticky and cold and highly acidic. Whatever soil is able to develop on till is itself acidic and of low potential and able to support only a limited range of plant species such as sphagnum moss (*Sphagnum* spp.), heather (*Calluna vulgaris*), cross-leaved heath (*Erica tetralix*) with a range of grasses and rushes.

Glacial erosion and limestone pavement

Within the research area, more or less continuous expanses of bare limestone pavement stretch all the way from Scar Close in the north to White Scars above Crina Bottom in the south, lying between the areas of moss directly beneath the summit massif and the cascading limestone scars that form the Terraces above the valley of Chapel le Dale. In places the pavement is interrupted by patches covered with glacial till or by *solutional hollows* some of which are themselves infilled by till, but most of it lies bare. This was subjected to the erosive power of ice but it is too simplistic to hold on to the traditional view that glaciers swept (or sandpapered) away loose material and scraped bare what we now see as pavement. In reality there are quite different types of limestone pavement on the terraces, each created in a different way and in different eras.

Fig.3 Palaeokarst clints showing well-rounded clints and deep grykes

One type was formed as pavement during the Carboniferous period: this is a palaeokarst feature (Fig.3).

Such pavements have massive blocks, or *clints*, with relatively few joints or cracks but what joints, or *grykes*, they do have are very deep. Since the last retreat of the ice there has simply been insufficient time for such deep cracks to have developed. The clints tend to have surface depressions and runnels, as seen above Keld Bank.

Some of the clints on the terraces are many metres in length and have a general absence of depressions and *runnels.* These were scoured by the sandpapering effect of ice during the Devensian period so they, too, are a palaeo feature. The pavement to the north-east of Harry Hallam's Fold has a spectacular expanse of this type of pavement.

The third variation to be found on this part of Ingleborough is markedly more shattered and broken up with clints that are difficult to separate one from the other. These have been plucked by ice rather than scraped clean and their evolution is much more recent than the two preceding forms.

Solutional hollows and cave systems

Limestone dissolves in rainwater and this action is concentrated along lines of weakness – in other words along joints. This is how grykes develop but dissolution can lead to the development of much grander landscape features or hollows. These can be just a few metres in diameter and only a metre or two deep: they pepper the areas where a thin layer of till covers the limestone beneath. Limestone at depth has been dissolved away and the till collapses into the void, thereby creating the hollows or *shakeholes*. They tend to occur in clusters or linear belts and many examples, of varying size and shape, are to be seen on Harry Hallam and Tatham Wife Mosses.

Occasionally these shakeholes excel themselves in size forming very deep depressions or *dolines*. Braithwaite Wife Hole is the most impressive example on this side of the mountain.

If water is able to percolate downwards from one of these shakeholes or dolines, dissolution will continue to open up the vertical joints to form potholes and cave systems. Some reach a prodigious depth and scale. Great Douk Cave is not deep but runs for over 900m under Douk High Pasture; Hardrawkin Pot, at the western end of this enclosure, drops 60m and runs for about 240m; Tatham Wife Hole caps both with a depth of 155m and a length of 1220m; but far in excess of any of them is Meregill Hole with its 180m-drop and staggering length of 4.6km.

Landslips

Millstone Grit beds are solid and massive, limestone and sandstone beds within the Yoredale Group are generally solid and resistant to erosion, but the shale bands within the Yoredales are anything but. They are thin, weak and very friable (Fig.4). They weather rapidly and are prone to crumble away. They are also easily waterlogged. It does not take much to cause the shales to succumb and start to slide downhill, well lubricated and under gravity. Whatever beds lie immediately above such a failed shale band will also fail: as they are more massive and solid they fail in a spectacular manner. In places, as can be seen on The Arks and Black Shiver, linear gullies are formed where the shales have been flushed downslope.

Fig.4 Yoredale Shales exposed in Mere Gill

Fig.5 Post-glacial landslip at Falls Foot

Elsewhere a massive volume of rock has slumped downhill, as near the top of The Arks, and it is easy to see how the slumped rock has taken a rotational path as it failed, ending up with a raised rock lip along the lower edges with a chaotic jumble of rock blocks above. The most impressive of Ingleborough's slumps and rock falls lies above Falls Foot, clearly visible from below the summit plateau (Fig.5).

Glossary

Clint — a flat-topped block of limestone separated from surrounding blocks by cracks opened up by dissolution along vertical joints in the rock.

Doline — a large-scale hollow found in limestone country formed by underground dissolution of limestone leading to collapse. They can vary in diameter from tens of metres to hundreds of metres.

Geomorphology — the study of landforms and the processes that cause them to develop.

Glaciokarst — a limestone landscape, with karst features (*qv*) that have been physically affected by ice action during glacial periods.

Growth pole — a high area where fresh snow and ice accumulated during glacial periods often leading to ice flowing downhill under gravity as a mountain glacier.

Gryke — a deep groove across limestone pavement, separating one clint from another, opened up by dissolution.

Karst — a technical term for areas where limestone is the dominant rock and where limestone pavement, cave systems and other limestone features occur.

Loess — fine silt blown from the edge of a recent or present glacier by wind and deposited elsewhere. Much of the loess found in the Ingleborough area originated in what is now south Cumbria.

Palaeo	ancient, in terms of geological rather than historical time.
Runnels	a shallow channel on the top surface of a clint caused by dissolution of the limestone by rainwater running across the clint.
Shakehole	a smaller and shallower type of doline (*qv*) caused by underground limestone dissolving away with surface deposits of till sinking into the void. Diameter and depth are just a few metres.
Solutional hollow	a surface depression that may once have been a shakehole or doline but has been infilled with till, or a deep rock-lined hollow within a limestone pavement.
Till	a mixture of rock and stones in a clay or sand mixture deposited by a glacier either at its base or along its front edge or sides. Alternatively referred to as boulder clay.
Unconformity	a natural break or gap in the sequence of layers of rock of different ages. For example, on Ingleborough, Carboniferous limestone sits directly on much older Silurian or Ordovician rocks and the intervening Devonian is missing from the sequence because “Britain” lay above sea level during the Devonian when no new deposits were laid down here.

Further reading

There are several technical works on aspects of the geology of the Yorkshire Dales but *Ingleborough. Landscape and* history, 2008, by David Johnson (Lancaster: Carnegie Publishing) offers a relevant and readable account of geological processes in Chapters 2 and 3 and of landforms in Chapter 4.