

Map of Gaping Gill and Ingleborough Cave in relation to surface features.

<u>ERA</u>	<u>PERIOD</u>	<u>TIME SCALE</u> (Millions of years)
QUATERNARY	Holocene	0.01
	Pleistocene	1
TERTIARY	Pliocene	10
	Miocene	25
	Oligocene	40
	Eocene	60
	Paleocene	70
MESOZOIC (SECONDARY)	Cretaceous	135
	Jurassic	180
	Triassic	225
PALAEOZOIC (PRIMARY)	Permian	270
	Carboniferous	350
	Devonian	400
	Silurian	440
	Ordovician	500
	Cambrian	600
PRE - CAMBRIAN		2000

**GEOLOGICAL
TIME SCALE**



The Main Chamber of Gaping Gill

The invasion of the cave system by each successive ice age destroyed many, but not all, of the cave formations. When new cave systems were developed, after each retreat of an ice cap, then new cave formations grew. Research in the Ingleborough Cave and Gaping Gill system has dated some of the stalactites and stalagmites using a radioactive technique. The measurements for one group have yielded dates of between 90,000 and 150,000 years indicating they started to grow during the last interglacial of the Pleistocene period. Another formation from Old East Passage in Gaping Gill measured 280,000 years old. Further samples from Ingleborough Cave and Gaping Gill gave dates of less than 15,000 years indicating they have all developed since the last Ice Age ended.

The Present Cave System

Fell Beck gathers on the higher slopes of Ingleborough Mountain. It runs down the mountain, reaches the limestone plateau at an altitude of 400 m and then drops 98 m into the Main Chamber of Gaping Gill, Britain's highest unbroken waterfall. The Main Chamber, England's largest underground natural cavern, is formed along an East -West fault line in the limestone and measures some 145 m long by 25 m wide and up to 35 m high (excluding the inlet shaft). From here and many other similar but smaller stream entrances, a network of over 15 km of underground passages links the drainage of the area to the resurgence at Beck Head, at an altitude of 240 m. Some of the stream 'sinks' on the limestone have developed cave passages large enough to be explored by man. Many are far too small and lines of these small sinks, called **shakeholes** or **dolines**, can be seen along joints in the limestone on the plateau around Gaping Gill

In the Main Chamber of Gaping Gill, Fell Beck disappears through the boulder clay and gravel on the floor not to be seen again as a running stream until it flows out of the Terminal Lake in Ingleborough Cave. Downstream from Terminal Lake the passages are very wide low bedding planes only partially drained and passing under Trow Gill Gorge. Then a pronounced joint in the limestone guides Fell Beck in a South Easterly direction into Lake Avernus and Pluto before it turns and runs parallel with the dry valley of Clapdale through large phreatic passages, finally emerging into daylight at Beck Head alongside the entrance to Ingleborough Cave.

Life in Ingleborough Cave

Ancient man often made use of caves but Ingleborough Cave is subject to occasional flooding and this, along with the pools of water at the entrance, made it unsuitable as a dwelling. However, a short distance up the valley towards Trow Gill is a cave called Foxholes. This is a dry cave which connects with passages in Ingleborough Cave and the remains of ancient animals, wild ox, elk and red deer, and evidence of Neolithic man's occupation have been found.

Within the Cave there is no sunlight (the normal energy source trapped by plants to start food chains). The cave temperature is constant at about 9 degrees centigrade and there are no seasons underground. Nevertheless, where Fell Beck flows through the Cave, there are some small blind trout. There are also small blind colourless shrimps in some of the pools of water in the Cave. Fell Beck must carry sufficient food material to sustain the blind fish and the occasional floods replenish the pools to maintain the shrimp population. Sometimes a bat is seen in the Cave they, of course, can fly out for their food. Inside and near to the entrance of the Cave, there is some insect life and where electric lights are positioned in the Cave algae growth occurs. The floodlights are switched on only briefly therefore, to minimise growth of the algae. A study of species found in the Cave is in the Transactions of the British Cave Research Association Vol.2, No.3 Oct.1975 (Authors T.G.Pearce & C.Gidman).

Conclusions

Although Ingleborough Cave and Gaping Gill is a classic example of a cave system, it is difficult to state an exact chronology for its development. What we see today is the end result of events stretching back almost 30 million years since the limestone rock became exposed. We are currently in an interglacial period and an ice age may return again. Once more the cave system will be affected and the landscape modified so as to trigger further cave development. The essential mechanisms for developing caves and cave formations have remained unchanged though and continue to the present day.

This publication is limited in its scope. For a more comprehensive analysis of the area the student should refer to other publications such as "Exploring the Limestone Landscapes of the Three Peaks and Malham" by Phillip J Murphy (ISBN 0-900-265-30-02); "Caves and Karst of the Yorkshire Dales", a field guide by A.C.Waltham and M.Davies (ISBN 0 900265 04 3) and "Karst & Caves in the Y.D.N.P." by Tony Waltham (ISBN 0 905455 22 3) all published jointly by the Yorkshire Dales National Park and the B.C.R.A.

When the percolation water enters a cave passage natural ventilation removes carbon dioxide and precipitation of **calcium carbonate** occurs in the form of **calcite** crystals. It is these tiny crystals which slowly grow together to create the cave formations. The very varied shapes of the formations add interest for the visitor. **Stalactites** hang from the roof along the joints or minor cracks; **stalagmites** grow upwards from the floor or ledges underneath drips of water. **Flowstones** form as the water flows over a surface; hollow and very fragile **straw stalactites** develop where the precipitation occurs on the surface of a water drip. The rate of growth of a formation may vary significantly over periods of time. The major factors being the amount of dissolved limestone in the percolation water in the form of calcium hydrogen carbonate, the rate of carbon dioxide loss, the water flow rate, rainfall and cave temperature. Water emerging from a cave may have a typical pH 7.8 and a dissolved limestone load between 50 and 200 p.p.m. calcium carbonate. However, as the water emerges, then evaporation may lead to significant deposits of calcium carbonate near a cave mouth. This forms a weak, crumbly material called **tufa**. Pools of water in the cave may be subject to evaporation if there is a strong draught. Carbon dioxide is discharged and the precipitation of calcium carbonate forms the knobbly underwater deposits seen in the Cave called **cave coral**, a form of tufa.

The early Victorian explorers gave names to the major formations in the Cave such as the **Mushroom Bed**, a large flowstone with an obvious mushroom shape. The **Sword of Damocles** describes a huge stalactite hanging from the roof. A big stalagmite on the floor is called the **Jockey's Cap** which, from measurements and analysis of the calcite, started growing some 4500 years ago, about the time Stonehenge was being built. Other formations though are significantly older than this. The **Pillar** is a tall column where stalactites and stalagmites have merged. Ever since 1837 the public have enjoyed visiting the



Cave and it must be preserved for future generations. Fortunately, increasing awareness of conservation and preservation makes this task a little easier.

A similar chemical weathering process lead to the development of **limestone pavement** on the surface. The acidic rain water enlarged the cracks and joints on the surface of the limestone, which had been denuded of vegetation by glacial action. The enlarged joints are called '**grikes**' whilst the near horizontal blocks between are called '**clints**'.

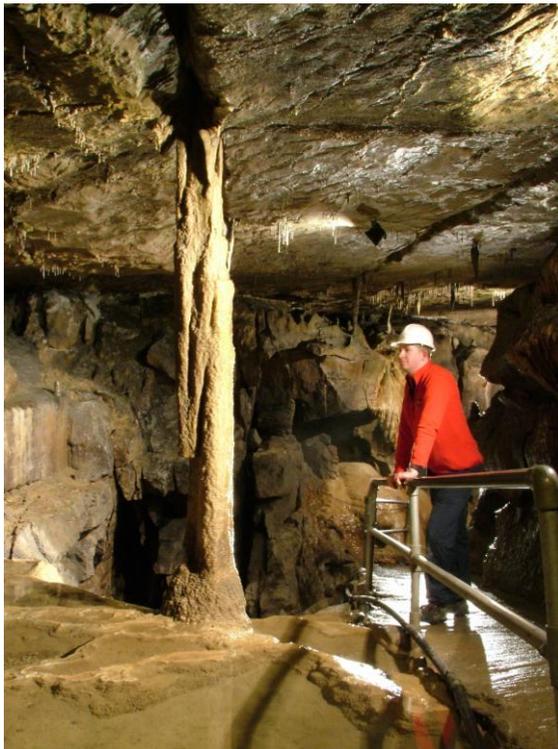
Limestone pavement

The Ice Ages

Climatic change, commencing during the **Pleistocene** period, some one million years ago, led to the formation of glaciers in the more northern parts of Europe. Temperatures dropped and snow accumulated forming thick sheets of ice. The mass of ice increased and flowed south across the land towards warmer regions where it eventually melted. The advancing ice sheet pushed in front of it large accumulations of debris scoured or swept from the land surface. Some of this debris, known as **boulder clay**, was washed into the cave systems by seasonal melt water and huge amounts were deposited underground, effectively sealing the underground water courses. The land was scoured and deep north - south aligned valleys formed on the surface. At the end of an Ice Age the retreating ice sheet released vast quantities of melt water. New surface features were cut into the limestone landscape, such as Trow Gill Gorge. New cave systems were developed, this time at a lower level than previous ones, because the local water table level had been lowered by the deepening of the valleys. Sometimes the earlier, original cave passages were utilised again. The melt water entering the passages and washing the glacial debris out from them. This is demonstrated in Long Gallery, the final section of the tourist path in Ingleborough Cave. Remnants of boulder clay remain 'cemented' to the walls by calcite and at the end the earlier cave passage, developed before the last ice age, continues straight ahead entirely filled and choked with boulders, clay, sand etc.. Some digging operations here in 2001 revealed the tooth of a woolly rhinoceros buried in the boulder clay. These animals became extinct 22,000 years ago! The 'new' cave passage, formed since the last ice age, enters the earlier one from the side and melt water has cleared out much of the glacial debris between here and the Cave entrance. The new passage, Cellar Gallery, has no boulder clay in it at all, indicating it developed after the last ice age. This mix of passages developed at different periods provides an intriguing record of past major events. It is generally believed there have been at least three advances and subsequent retreats of an ice sheet over Ingleborough (Anglian, Wolstonian and Devensian stages). Each has contributed to the formation of the present landscape and the development of the underground cave systems in their present form. "Erosion Cycles and Limestone Caverns in the Ingleborough District", a paper published by Dr.M.M.Sweeting in the Geographical Journal Vol.XCV, Jan/Mar 1950, shows the larger chambers and passages in the limestone of the Gaping Gill - Ingleborough Cave system occupy three general levels, each one corresponding to a major advance of the ice and subsequent deepening of the valley. Because of the last deepening of Clapdale valley, Fell Beck now emerges at Beck Head Cave, some 10 m below its previous resurgence from Ingleborough Cave.

From the vantage point of the Cave entrance area a number of interesting features can be observed. Looking up and down the valley the former glaciated 'U' shape of the valley can be visualised along with the later notch cut into the valley floor by melt water. The face of the cliff overhanging the entrance to the Cave shows the horizontal bedding of the limestone along with a pronounced vertical joint. The present resurgence at Beck Head is some 10 m lower than the former resurgence from Ingleborough Cave due to deepening of the valley.

Over many years the system of cave passages, both at Gaping Gill and Ingleborough Cave was explored and more passages were discovered. As each new discovery was made and the passages were surveyed, then the map of the system took shape. Glancing at the map (inside front cover) the major high and narrow 'vertical' passages in the system can be seen to correspond to the strong jointing and faulting of the limestone. They tend to be more or less parallel with each other in a N.N.W. direction and some of the surface features, such as Trow Gill Gorge, are also aligned in a similar way.



The 'Pillar' with the 'Abyss' in the background

3

Cave Systems

Surface streams draining off the peat are mildly acidic in nature with a typical pH 4.9. Atmospheric carbon dioxide, surface vegetation, peat and similar organic material give rise to the acidic waters which dissolve the limestone rock. The primary permeability of the limestone rock is very low but the cracks and fissures in the limestone allow the water to penetrate. Initially the water seeped into the vertical joints or fault fissures, dropping down to the water table level and then along the weakness or '**bedding plane**' between the beds of submerged limestone. A slow dissolving of the limestone followed to form elliptical shaped submerged passages. This period of cave development is known as **phreatic** development. Drainage routes through the limestone became established and the cave passages were slowly enlarged. As progressive deepening of the valleys lowered the water table in an area, the submerged phreatic passages were drained. Water could now flow through the underground passages as a running stream, cutting into the floor of the original elliptical passage by abrasive action to form a trench or canyon in the floor. This period of cave enlargement is known as **vadose** development. The phreatic and vadose phases of development result in the classical 'T' shape of many cave passages. This can be seen in Ingleborough Cave where there are expanses of flat roof with narrower passages at floor level.

Cave Formations

The major water flows in the limestone carved out the cave passages and the



The "Sword of Damocles" (right) & "Beehive" flowstone (left)

minor flows or **percolation water** resulting from general rainfall on the surface, lead to the development of cave formations. The dissolving of the limestone by the acidic percolation water, as it descends through numerous fissures in the rock, forms a solution of **calcium hydrogen carbonate**.

4

INGLEBOROUGH CAVE and GAPING GILL

Introduction

Ingleborough Mountain, one of the famous Three Peaks of the Yorkshire Dales National Park, is renowned for its caves and potholes. The Ingleborough area contains a labyrinth of underground passages and watercourses, hollowed out of the limestone rock over the last million years. The glaciers of the **ice ages** have advanced over the area during the **Pleistocene** period and carved out the valleys and surface features of the land, leaving behind a unique and picturesque landscape of high visual, recreational and educational value. The effects of the ice ages can also be observed underground. The development of the cave systems has been strongly influenced by each advance and retreat of the ice. Underground, some of the evidence is preserved for the visitor to see and realise the profound influence of an ice age.

On the south side of Ingleborough are some of the most famous caves in the British Isles. The Gaping Gill to Ingleborough Cave system, with the huge underground Main Chamber of Gaping Gill and the large and beautifully decorated passages of Ingleborough Cave, has attracted visitors for many years. Fell Beck, gathering on the higher southern slopes of Ingleborough Mountain, plunges into Gaping Gill pothole (alt. 400 m) with a dramatic single drop waterfall, 98 m high, to re-emerge into daylight, 144 m lower down in Clapdale Valley, at Ingleborough Cave some 2.5 km away.

At first it was only a belief that Gaping Gill and Ingleborough Cave were connected. Here was a large stream or beck going underground high up on the limestone plateau at Gaping Gill and a similar sized stream emerging into daylight, lower down in the valley, at Ingleborough Cave. Surely the two were connected? The connection was established in 1900 using ammonium salts emptied into Fell Beck, enabling it to be traced from the '**sink**' or '**swallow hole**' at Gaping Gill to the '**rising**' or '**resurgence**' at Beck Head alongside Ingleborough Cave. Exploration, commencing at Ingleborough Cave in 1837 and later at Gaping Gill in 1895, discovered a network of underground cave passages. Finally, in 1983, after 146 years of exploration, cave divers made the actual connection by entering Gaping Gill and emerging at Ingleborough Cave. The total length of passages discovered exceeds 15 km. and observations and measurements have revealed the complex history and development of the system.

Geology

The Ingleborough area is part of a limestone region which lies on the S.W. edge of the Askrigg Block, an uplifted area bounded by the Dent Fault to the West and the Craven Fault to the South West and dipping at just a few degrees to the N.N.E.. The rock, known as '**The Great Scar Limestone**', is a **sedimentary** rock. It was laid down as a sediment, almost 200 m. thick, in a warm tropical sea, about 350 million years ago during the **Lower Carboniferous** period when Europe and the British Isles lay somewhere near the Equator. The remains of sea creatures formed the sediment, of typically 95% pure calcium carbonate, deposited on a sea floor comprised of impermeable, strongly folded slates and greywackes of **Lower Palaeozoic Age**. The base of the limestone is much younger than the slaty rocks it lays on and this junction is called an **unconformity**. The sediments accumulated in successive layers or beds, varying from 50 cm to 5 m in thickness, with thin partings of shale between the beds. The limestone formed in this manner also contains the remains of some larger life forms such as corals, brachiopods, crinoids and fish skeletons, these can be seen as **fossils** in the rock.

Further deposits, known as the **Yoredale Series**, also of Lower Carboniferous age, were deposited on top of the underlying limestone sediments. The Yoredale Series is a repetitive cyclic series of limestones, shales and sandstones and some 300 m thick. Overlying this is the Millstone Grit capping the summit of Ingleborough (723 m).

Drifting of the continents (plate tectonics) and vertical movement of the land mass during the later **Tertiary** and **Quaternary** eras, commencing some 30 million years ago, resulted in the limestone being uplifted above the ancient sea and the origins of our present landscape were formed. Elsewhere in Europe these same earth movements created large mountain ranges such as the Alps. Although the whole limestone mass was only very slightly tilted during the upheaval process, the earth movements caused the rock to crack and fissure. Sometimes there was significant movement between adjacent blocks of limestone and **fault** fissures were formed but, more usually, simple cracking of the limestone formed vertical and roughly parallel **joints** in the rock. The faults and joints produced in the rock at this stage had a strong influence on the direction and manner in which the underground cave passages later developed. Earth movements continue, albeit in a much more subdued manner, right through to the present day! Earthquakes occurred in the area in 1947 and 1970.

Limestone scenery on the surface has a special beauty underground in Ingleborough Cave it is spectacular!

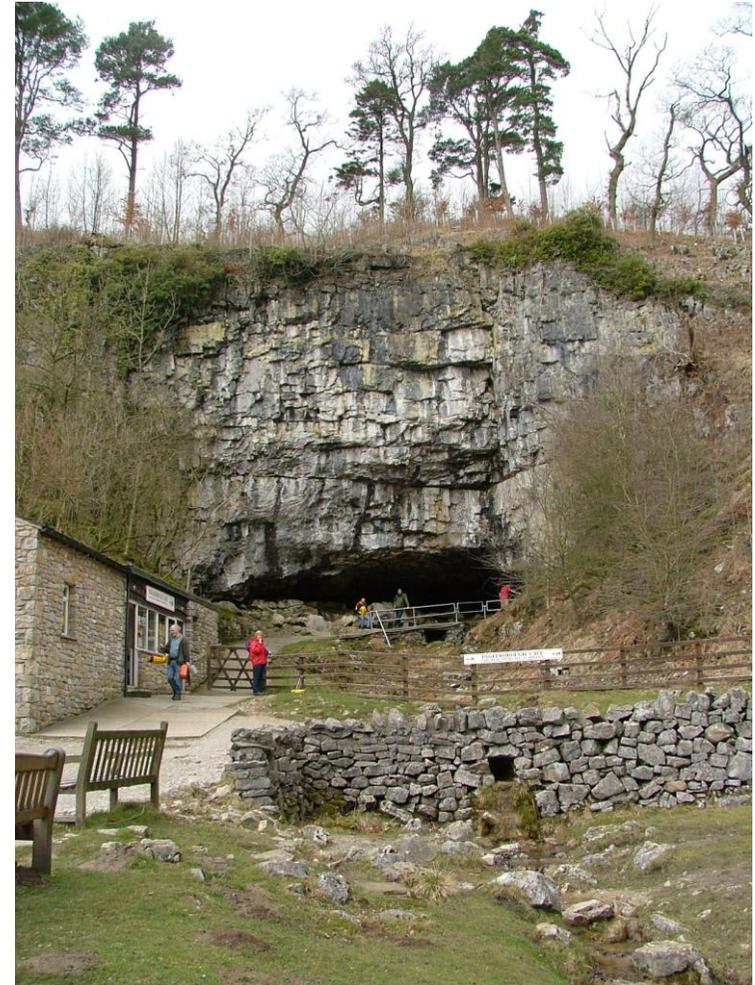
How to reach the Cave. Clapham Village is on the A65 Leeds - Skipton - Kendal road and in the Yorkshire Dales National Park. In the centre of the village, on its eastern side, there is a Y.D.N.P. car park with information boards where you leave your vehicle and start the **Nature Trail** walk which leads to the Cave (about 1.5 mile / 2 km). The Village nestles on either side of Clapham Beck which runs down Clapdale valley from the Cave. Leaving the car park by its western entrance, cross over the road diagonally to the right and proceed across the beck by the footbridge then turn right and simply follow the beck upstream, passing the church and waterfall to reach the old sawmill, which used to supply bobbins for the textile mills. The sawmill, powered by water turbine, is still in use, so don't be deterred by the piles of timber but enter the yard and obtain your **Grounds** ticket from the machine round the back of the Sawmill. Nature trail leaflets are also available here. The path leads on into woodland and by the lakeside where Reginald Farrer (1880 - 1920), the famous botanist, introduced many new plants into Europe from the Far East. If you are observant you will see rhododendron, bamboo and other unusual plants. The lake is artificial and provides power to the turbine at the sawmill. It also used to provide the village with its water supply.

Not far beyond the Grounds is the Cave where, after obtaining an admission ticket (pay by cash, cheque or card), your underground experience begins! Typically, tours of the Cave start on the hour every hour from 10am until the last tour at 4pm (3pm during winter months) but additional tours operate during busy periods. The tour takes almost an hour after which, if you wish, there is more exploring to do in the surrounding countryside. Limestone gorges, beautiful Dales scenery and deep potholes such as Gaping Gill where Fell Beck goes underground on its way to the Cave. The beck drops 98 m vertically from the surface into Gaping Gill, so beware! This is England's highest unbroken waterfall into England's largest natural cavern, although only the entrance can be observed!

The Cave is open daily with conducted tours at regular intervals during the period February half-term through to October half-term. During the winter months it is open at weekends or by appointment midweek. Special 'field work' tours can be arranged for students if required. No special clothing is needed and dogs are allowed on a lead. It is only rarely affected by wet weather so visits can be arranged with confidence. In fact, the wetter the weather, the more spectacular is the Cave! There are special rates for parties. The Cave cannot be accessed by wheelchair users except when accompanied by trained carers. Light refreshments are available at the Cave shop and there is ample picnic space. There are toilet facilities at the Cave for Cave Tour visitors.

Ingleborough Cave, Clapham, via Lancaster LA2 8EE.
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INGLEBOROUGH CAVE & GAPING GILL



A STUDENT'S GUIDE TO THE LIMESTONE & CAVES