The action of ice freezing on to rock and ripping it up as it moved, "plucked" rock from valley sides to create the massive vertical faces of limestone (like Kilnsey Crag in Wharfedale for example) and the countless scars which in some cases run for miles high on the fells. The same action produced the horizontal surfaces of limestone which have been developed by solution and chemical weathering (by acidified water), to create the huge variety of cracks and fissures seen in today's limestone pavements.

Eroded rocks and soils have been moved along by the ice over large distances and deposited as glacial till or boulder clay, now covering many of the valley floors. Classic examples of drumlins can be seen at Ribblehead and in Wensleydale. Drumlins are egg-shaped mounds of till which were formed under moving ice. Till dumped at the snout of melting glaciers forms terminal moraines, visible as very bumpy low barriers running across the dales. Eskers are gravel ridges shaped like sinuous railway embankments marking the courses of streams which ran beneath the ice. They can be seen in the Aysgarth area.

Small but significant examples of the ability of the ice to move large boulders and of water to dissolve limestone can be seen clearly in the Norber erratics. Some of these boulders, moved from Crummackdale during the last glaciation, now stand on limestone blocks as much as 30cm above the surrounding surface where they have protected the underlying rock from the dissolving action of rain water.

Gorges and classic V-shaped valleys have been cut into the landscape by glacial melt water. It is thought that the gorges were cut through frozen rock during glacial and immediately post glacial times. This accounts for their narrowness and sheer sides. In many cases these are now dry valleys, the sources of the rivers having disappeared with the vanishing ice.

13 000 YEARS AGO

Many of the Dales held lakes on the newly shaped valley floors in immediate post glacial times. The exit routes of the melt waters were blocked in many places by glacial deposits, such as terminal moraines formed by melting ice, and in some cases by glaciers themselves. Lake bed deposits are evidenced in places on the valley floors, though many have been washed out by the rivers flowing across them. Semerwater is the last remaining example of a glacial lake. Some of the tributary streams flowing into the moraine lakes formed deltas. These now provide slightly raised and therefore drier settlement sites like at Kettlewell and Buckden in Wharfedale.

Glacial melt waters, operating in much the same way as today's rivers, have washed deposits of gravel, sand, silt and clay in to many areas. At the same time they have cut through till deposits to wash out the river courses we see today. Rivers flooding year upon year, have built up extensive deposits of alluvial sands, silts and clays in many places on the valley floors.

THE LANDSCAPE OF TODAY

The foundations of the Dales scenery of today owe a great deal to the nature of the rocks from which the ground is made. The layering, low inclination and low levels of faulting of these surface rocks (notable exceptions to the west and south) reflect the stability of the underlying rigid block of granite. The details of the present day landscape have been immensely influenced by glaciation.

For the last 11000 years or so the rivers of the Dales have continued to re-work the bedrock and the glacial deposits of the valley bottoms. The process of washing out and re-depositing further down stream continues the landscape evolution which has been going on since these rivers began.

If people were present in the area during the Ice Ages then it is most likely that any evidence will have been erased by ice. The earliest evidence of people in the area is an antler harpoon point found in Victoria Cave near Settle, dated to about 11 000 years old. The evolution of the landscape since that time is very much the story of the developing relationship between people and the land.

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YORKSHIRE DALES
National Park Authority

Geology

foundations of natural beauty

AN OUTLINE GEOLOGY

By about 280 million years ago the base rocks of the Yorkshire Dales landscape had been laid in place. These rocks were created under seas and buried by deposits which themselves formed rocks. Since that time the whole of the area has been lifted above sea level and the over lying rocks worn away by natural processes.

The geology of the area is of sedimentary rocks between 350 and 280 million years old (Carboniferous age). These rocks lie almost flat over older more strongly folded rocks between 500 and 400 million years old (from Ordovician and Silurian times).

The geological structure is dominated by the Askrigg Block. This is a raised section of the earth's crust, bounded by the Dent Fault to the west and the Craven Faults to the south, which tilts downwards to the north and north east.

For much of the last 65 million years, the land mass which includes Yorkshire has probably been above sea level. A combination of natural forces including rivers, rain water and ice age glaciers has been at work on the ground to produce the scenery of today.

500 TO 400 MILLION YEARS AGO

The oldest rocks of the Dales were formed when what was to become Yorkshire, was an ocean bed lying south of the Equator. Under water avalanches sent mud and sand to the floor of an ocean trough (Fig 1.). During calmer periods finer muds settled over the coarser muds and sands. The alternation of calm periods with more turbulent times led to the building of alternate layers.

Fig 1. Underwater avalanche

These sediments were later compressed to become sandstones and shales. As the land masses of what would later become Europe and North America collided, the layers were folded and raised above the surface of the sea to form the Caledonian Mountains. The friction generated by the collision produced great heat which cooked the rocks while extreme pressure transformed the shales into slate. A core of molten rock penetrated the layers and solidified to form a granite plug under the area that is now Wensleydale.

410 TO 350 MILLION YEARS AGO

These mountains were eventually eroded away (during the Devonian period (Fig 2.)) in a hot dry desert climate leaving behind a gently undulating land surface.

Conglomerates full of cobbles and pebbles of likely Devonian age are seen near Sedbergh.

This surface with its underlying core of granite formed a rigid platform. Faulting along the Mid-Craven Fault began the formation of the Askrigg Block.

It was this platform which sank beneath the surface of the sea to form the base upon which the Carboniferous rocks were laid.

LOWER CARBONIFEROUS, 350 MILLION YEARS AGO

In early Carboniferous times (Fig 3.) the area lay under a shallow warm tropical sea, about 5 degrees south of the Equator, in which a succession of flat lying layers, or beds, of limestone were laid down.

A reef belt was situated in deeper water to the south, fringing the block along the developing mid-Craven Fault. Shales and limestones were laid down in the deeper water to the south in the Craven Basin.

The Carboniferous limestone stretches in a wide belt across the south of the park roughly between Grassington and Ingleton. Limestone pavement, scars, sink holes and dry valleys are all classic features of the area.

MIDDLE CARBONIFEROUS, 330 MILLION YEARS AGO

Above the limestones were laid the Yoredale Series (Fig 4.), repeating layers of limestone, shale and sandstone, along with some thin coal and earth seams. The sequence is repeated about eight times. The alternation of these layers may be due to changes in sea level. It has also been suggested that these layers were formed by flow deep within the molten material of the earth's mantle, causing uplifting in some areas and sinking in others.

A great river delta draining off the eroding mountains to the north spread deposits on the limestone of the sea floor filling up the basin. Silts deposited in deeper water later became shale. The advance of the shoreline southwards meant that the silts were covered by sandy deposits which later became sandstone. Thin coal seams topping the sandstones are evidence of the swamp vegetation which developed here, while some of these layers were covered by soil in places which is thought to have formed on dry land.

The changing shape of the delta, and the changing course of the channels flowing across it caused great variation in the depth of water, and this accounts in part for the nature, extent and thickness of the sediment layers. The Bowland Shales were being laid down at this time in the Craven Basin.

The resistant limestones and weaker sandstones and shales of the Yoredales have produced the stepped landform and waterfalls typical of present day Wensleydale and Upper Wharfedale.

UPPER CARBONIFEROUS, 320 MILLION YEARS AGO

The Upper Carboniferous rocks contain massive sandstones and gritstones and are known collectively as the Millstone Grit (Fig 5.). These rocks were laid down in a river delta covering most of Yorkshire and form the main building blocks of the Pennines.

As erosion of the mountains to the north released the weight of the land, the land mass rose, supplying more material to be eroded. At the same time the weight of materials deposited on the sea bed caused this part of the land mass to sink. The Earth's crust was behaving like a see-saw.

These rocks, in places 240m deep, form many of the moorland areas and the higher parts of the peaks of the Yorkshire Dales, particularly to the north in Swaledale. On top of the grit stone in some places lie coal measures, formed from plants growing 300 m years ago, in conditions similar to the Amazon delta and Florida Everglades.

280 MILLION YEARS AGO

The South Craven and Dent Faults were active at this time and the Askrigg Half Dome was formed, a process which created many faults and fissures in the rocks. Hot saline liquids forced their way through these cracks to form mineral veins as they cooled and their contents crystallised out (Fig 6.).

The mineral deposits (mainly of galena, calcite and fluorite) vary a great deal in their make up and distribution, making them difficult to locate and unreliable to exploit, so making lead mining a very risky business.

Since these times the area has again been flooded by seas, and covered by more sedimentary deposits. These younger rocks have been uplifted and eroded away leaving behind no trace of their existence in the Dales.

65 MILLION YEARS AGO

At around this time, the land masses that were to become Europe and North America began to move away from each other, causing rifting in the Earth's crust and producing faults and folds. Many of the old lines of weakness became active again (Fig 7.).

It is from this foundation that the current landform has been carved.

2 MILLION YEARS AGO

The present landform of the Dales has been widely influenced by glaciation. During the last 2 million years ice sheets thought to have been 1000 m deep in places have covered the area. There have been 3 glacial periods in the last half million years, the first two began 450 000 and 190 000 years ago respectively. The effects of each glaciation tended to add to and obscure those of previous periods.

80 000 YEARS AGO

The most widespread effects of glaciation visible in the landscape of today result from the latest glacial period (the Devensian). This period is thought to have begun about 80 000 years ago and ended about 13 000 years ago. The glaciation was not constant, the extreme cold was broken by milder periods (interstadials) during which the ice cover was reduced only to return again with the returning cold. The whole of the Yorkshire Dales was covered with ice at times, apart from the highest peaks which stood out as "islands".

Prior to these periods of glaciation it is thought that the modern dales were already in existence as winding V-shaped river valleys (Fig 8.). The movement of ice spreading from the north and west and the erosive material it carried, both widened and straightened out the existing valleys to produce the glacial troughs of today's Dales.

Fig 2. Devonian desert

Fig 3. Carboniferous reef

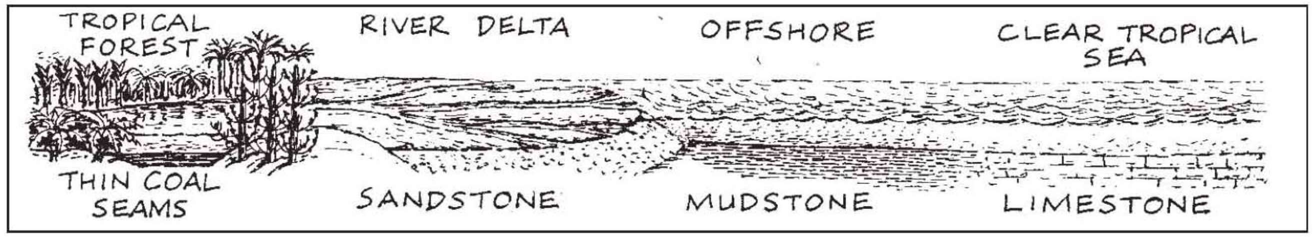

Fig 4. Yoredale sedimentary environments

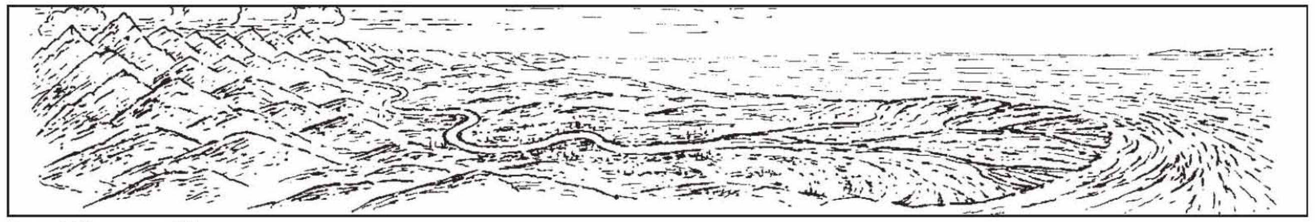

Fig 5. Millstone grit delta

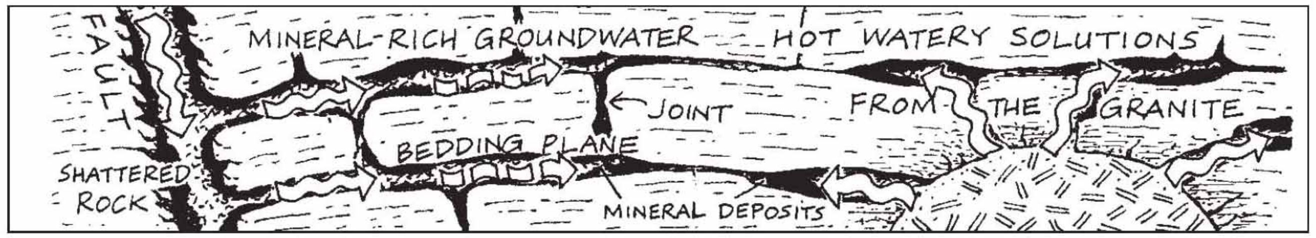

Fig 6. Mineralisation

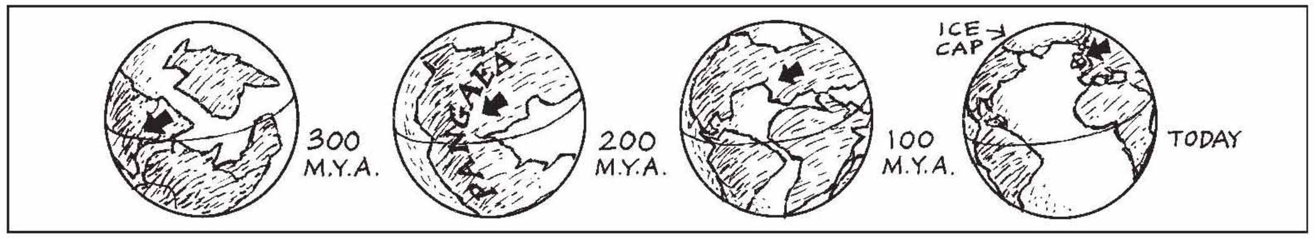

Fig 7. The break-up of Pangaea

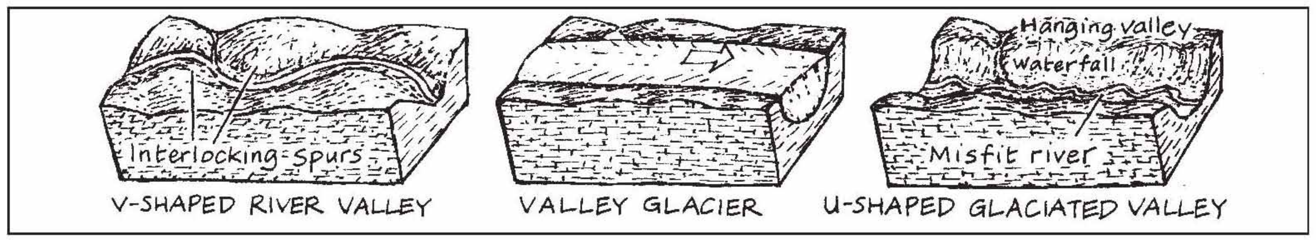

Fig 8. Valley glaciation