Chapter 2 The Yorkshire Dales karst

Introduction

The main part of the Yorkshire Dales karst lies on the largest outcrop of the Great Scar Limestone across the southern dales. The finest of the karst landscapes are around Ingleborough and Malham, but many of the major caves lie to the east and west, and the karst is continuous from the Dent Fault, in the west, to the eastern watershed of Wharfedale — a distance of 40 km (Figure 2.1). The topography is dominated by the massive unit of nearly horizontal limestone, whose top surface forms a series of plateaus and benches at around the 400 m level. Outliers, formed largely of shale, rise to summits at around 700 m, and the glaciated troughs of the Dales cut through the limestone to expose basement inliers. The limestone landscapes are the most spectacular in Britain, and have the country's finest glaciokarst landforms, while the geology has proved ideal for the development of large caves.

The Great Scar Limestone Group is the unit of strong Dinantian carbonates that is so conspicuous in the topography of the Yorkshire Dales karst. It consists of limestone beds of massive facies, formed through the Arundian, Holkerian and Asbian stages, locally subdivided into the Kilnsey, Cove and Gordale Formations (Arthurton *et al.,* 1988). The facies includes the Hawes Limestone of the lower Brigantian (Figure 1.9). The Great Scar Limestone is mainly formed of very pure, cream or pale grey, thickly bedded, bioclas-tic, sparites and micrites; these were a shallow water facies formed on the Askrigg Block, a shelf area partly bounded by faults and surrounded by deep water in the Dinantian sea (Ramsbottom, 1973, 1974). The Porcellanous Band is a fine, cream micrite at the Holkerian/Asbian boundary at the top of the Cove Formation; it is generally only 1 m thick, but may split into multiple units. Thin shale beds throughout the limestone succession greatly influence the cave development (Waltham, 1971b), but reef facies at Malham and in lower Wharfedale are of little significance to the wider karst geomorphology. The limestone is 160–220 m thick, and the variation is almost entirely due to transgression across over 50 m of local relief on the basal unconformity. Beneath the limestone, Lower Palaeozoic greywackes and slates are totally impermeable, and are exposed in the floors of most of the dales; their buried ridges provided the clastic debris for the discontinuous conglomerates at and near the base of the limestone.

The basement inliers in the dale floors are truncated to the south by the North Craven Fault (Figure 2.1). The southern limit of the karst is along the South and Middle Craven Faults, which downthrow to the south by many hundreds of metres. The slice of limestone between the faults is widest where it forms the splendid karst above Malham. The Dent Fault bounds basement rocks to the west, and forms the western edge of the karst. Both the northern and eastern limits of the main karst are formed where the Great Scar Limestone dips gently beneath its cover rocks. The regional dip is just a few degrees north, splaying to the north-west and north-east off the axis of the Pennine anticline. Minor faults occur all across the limestone outcrop.

Above the Great Scar Limestone, an alternating series of thin shales, limestones and sandstones forms the Brigantian Wensleydale Group (Figure 1.9). These were formerly known as the Yoredale Series (Hicks, 1959), but are now described as the Yoredale facies of the Brigantian. They are up to 300 m thick, and have considerable lateral variation; all the limestones have some karstic features, mostly on a small scale. The clastic units between the five lower limestones are locally absent, and the Gayle and Hawes Limestones are inseparable from the Great Scar across much of the Dales area. The Girvanella Band is a nodular, algal limestone about 1 m thick within the Hawes Limestone; it is often regarded as the top of the Great Scar facies. The entrance bedding passages of some of the major caves are within the Hawes Limestone, and east of Wharfedale, the Mossdale and Langcliffe caves in the Middle Limestone drain underground right through to the Great Scar. More significant to the karst than the local stratigraphy is the ubiquitous situation, where the higher slopes of the Yoredale shales provide surface streams that drain onto the main limestone benches.

The karst

Ice sheets scoured the entire Yorkshire Dales karst, during at least four of the Pleistocene cold stages. They interrupted the karstic processes of warmer climates, and their phases of glacial ero sion alternated with those of fluvial erosion to impose a sequence of rejuvenations on the pattern of geomorphic evolution. The effects of the Devensian glaciation are most conspicuous within the present landforms. At its maximum, Devensian ice covered the entire area; during its retreat, summit nunataks appeared while the ice still swept over the limestone plateaus, and the final retreat stage saw only shrinking valley glaciers in the dales beneath the limestone benches. Ice flowed from the north, and its impact on the dales varied with the ice catchment as defined by the topography; Wharfedale and Ribblesdale carried the largest glaciers, but the Ease Gill and Malham valleys were both sheltered from major ice scour (Figure 2.1). Except for those two valleys, all the dales are deep glaciated troughs flanked by limestone scars.

All the streams and rivers have dry sections in their surface courses across the limestone. The Ribble and Wharfe maintain their surface flows in all but very dry weather, while most small streams off the shale outliers sink into caves and potholes under all conditions. The limestone high ground is therefore normally streamless. Its fine glaciokarst is best developed on the wider plateaus south-east of Ingleborough and north-east of Malham. The bare outcrops of limestone have great expanses of pavement, deeply incised by solution runnels. Where the fissured limestone is veneered with glacial till, doline fields with thousands of subsidence dolines (locally known as shakeholes) have formed, and are still active. Fluvial erosion of the mature karst has been limited to short periods of periglacial conditions, most significantly during the Devensian ice retreat. There are few dry valleys, but some were formed by subglacial and proglacial meltwater, and include the spectacular gorges of Gordale and Trow Gill, whose walls are now largely dry and therefore preserved. Malham Cove has a more complex origin, but the evolution and survival of its great limestone cliff are further consequences of the changing karstic processes. The large solutional dolines of High Mark (Figure 2.1) are probably the largest relics of interglacial karstic development in the region.

The Yorkshire Dales karst owes its spectacular geomorphology to the combination of so many landforms: the sinks which take all the drainage, the expanses of pavement, the long scars, the deep gorges and the innumerable dolines. The area is strictly a glaciokarst, but Ingleborough and Malham provide the finest limestone landscapes in Britain.

The caves

Nearly half of all Britain's known caves lie in the Yorkshire Dales karst (Table 1.1). This is because the geology presents an ideal cavernous environment: allogenic streams from the shale cover provide input to the top of the limestone, and this drains through to resurgences at or near the base of the limestone exposed in the dale floors (Waltham, 1974a). Most underground stream routes therefore have a simple staircase profile. Shafts are formed on joints or faults which are close to vertical, and nearly horizontal caves lie along the bedding planes and shale horizons within the limestone. Vadose canyons follow the bedding down the gentle dips, while phreatic routes are directed towards the available resurgence sites, regardless of geological structure. Hence looping cave plans are created where passage directions change in response to the hydrology, and patterns are further complicated where faults divert the underground drainage by overriding the bedding influence.

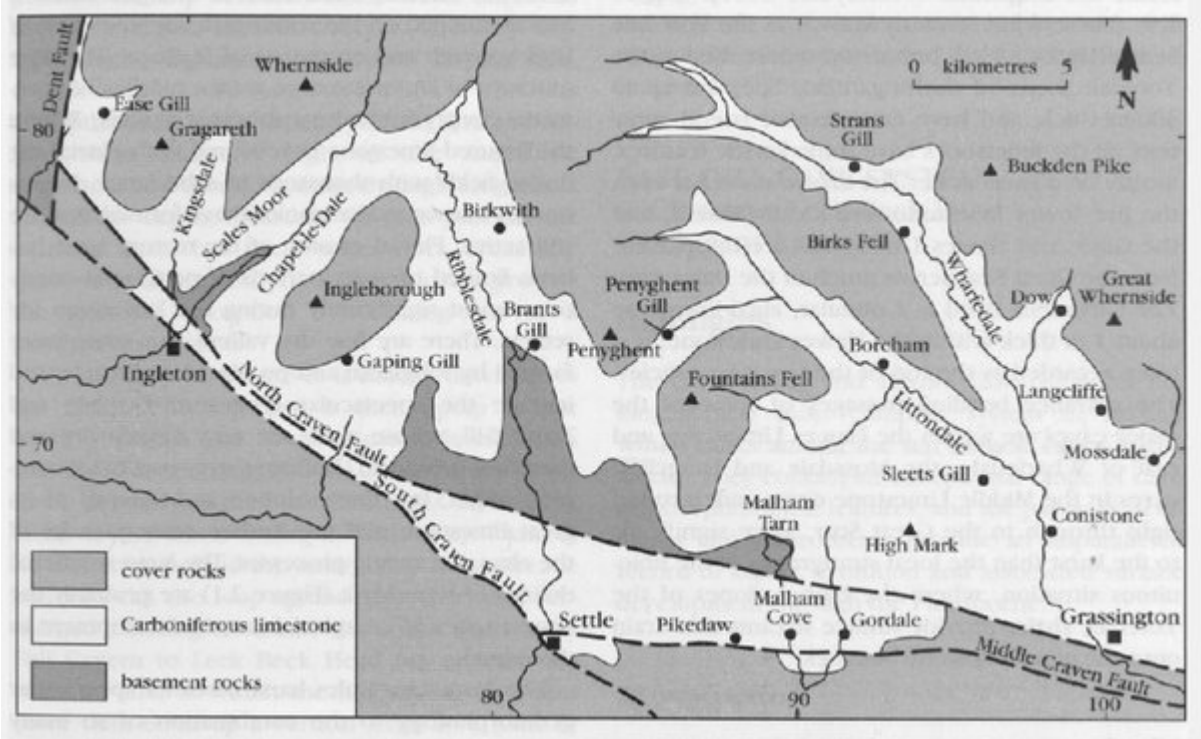
The geology imposes local detail on cave profiles, notably because vadose water descends the first available tectonic fracture. The deep daylight shafts, including the famous Gaping Gill, therefore drain into long sub-horizontal conduits at depth. Many other sinking streams find and follow shale horizons high in the limestone sequence, and therefore drain through long caves at shallow depth; Mossdale Caverns provide the extreme case, but their water does eventually descend to depth, and the Birkwith caves provide the grandest exception by draining out of a perched resurgence.

Vadose flow in the caves is mainly downdip to the north. Phreatic flow is then updip to the south, towards the lower surface levels. This accounts for the long flooded zones in the lower levels of nearly all the Yorkshire Dales caves; Keld Head is the finest example with over 7 km of flooded cave behind the resurgence. The phreatic conduits can also loop up and down between submerged bedding horizons; the route from Ireby Fell Cavern to Leck Beck Head has at least five phreatic lifts, of which the highest carries water more than 60 m up a vertical shaft on a joint or minor fault. The only long vadose streamway out to a resurgence is White Scar Cave, draining downdip into Chapel-le-Dale.

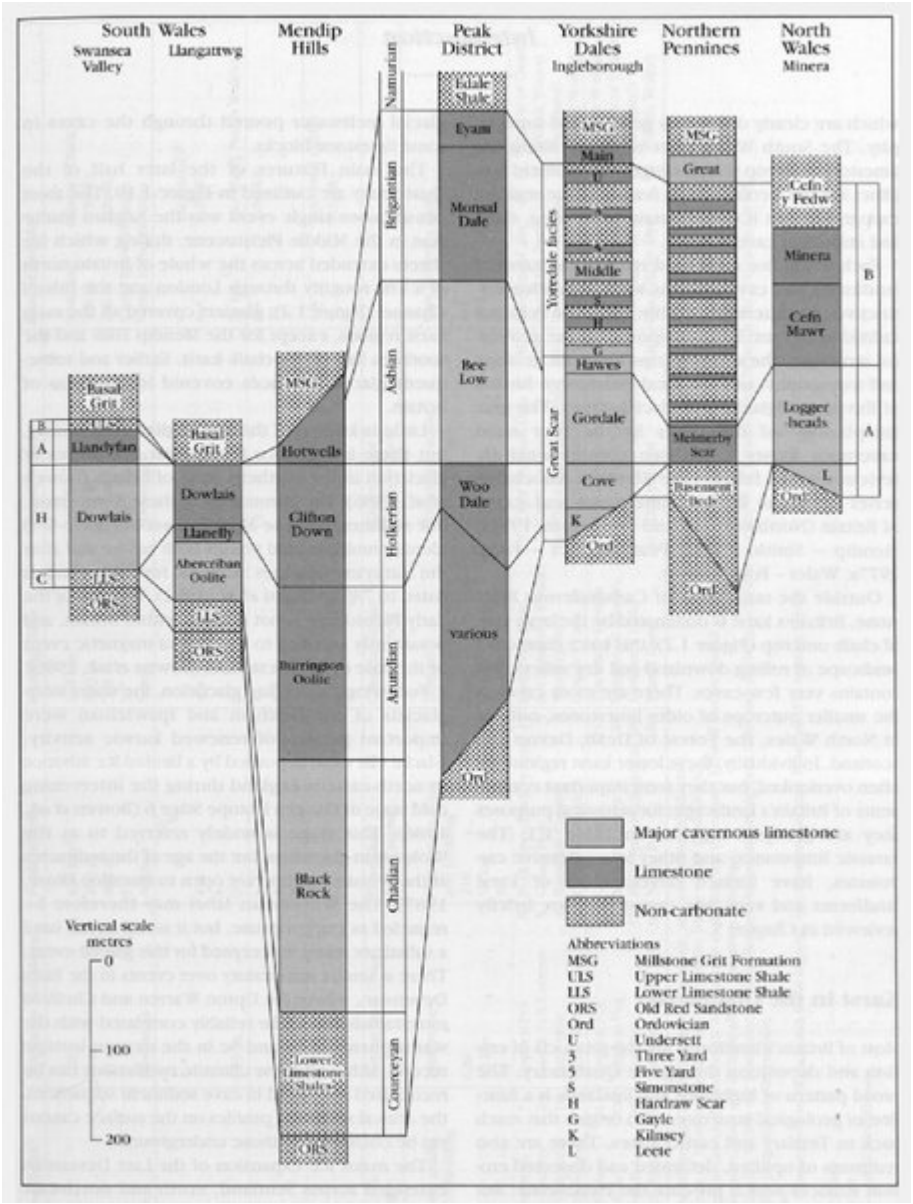
Previous to successive rejuvenations and surface lowering during the Pleistocene, higher levels of phreatic caves developed where the aquifer was impounded behind the impermeable rocks south of the Craven Faults. These caves were then abandoned as the entrenching dales created new resurgence sites, close to where they breached the fault barrier. The old phreatic caves were also developed largely along the bedding, and now form the high-levels, abandoned, invaded or intercepted by the modern, rejuvenated stream caves. The Gaping Gill Cave System has a long system of old sub-horizontal caves at depth beneath the famous daylight shaft, and Sleets Gill Cave has the best examples of abandoned phreatic lifts. These old caves contain extensive calcite and clastic sediment sequences, which record the Pleistocene environments and rejuvenations, but dating of the material has so far been on a modest scale, and much remains to be evaluated (Atkinson *et al.,* 1978; Gascoyne *et al.,* 1983a, b).

The combination of large dendritic systems of active cave passages and intercepted networks of abandoned conduits produces very long caves. The Ease Gill Cave System is the longest in Britain, and its links through to the Kingsdale caves are known to exist. It is only a matter of time and exploration effort before these links are found, and a single cave system over 100 km long will extend the whole way round the southern flank of Gragareth (Figure 2.1).

References



(Figure 2.1) Outline map of the Yorkshire Dales karst, with locations referred to in the text. The Carboniferous limestone shown includes all the Great Scar Limestone (Kilnsey, Cove and Gordale Formations) and also the lower Yoredale limestones (of the Wensleydale Group) where they are hydrologically linked to the Great Scar and are therefore part of the same karst unit. Higher limestones within the Yoredale Series are not marked. Basement rocks are Palaeozoic slates and greywackes. Cover rocks are the Yoredale facies of the middle and late Brigantian Wensleydale Formation and various Upper Carboniferous and Permian clastic formations.



(Figure 1.9) The main limestone units of the Lower Carboniferous within the major karst region of Britain. Thicknesses are generalized as there are considerable lateral variations. All the limestones are Dinantian, except for the Namurian Main and Great Limestones of the Pennines. In the Yorkshire Dales karst, the Great Scar Limestone is the massive carbonate facies developed on the Askrigg Block, and the Yoredale facies belongs to the Brigantian Wensleydale Group. In South Wales the Abercriban Oolite Group includes the Blaen Onneu Oolite. The main cover and basement rocks are identified; the Cefn y Fedw Sandstone extends across thp Brigantian/Namurian boundary. All the named limestones are karstified to some extent, but the major cavernous units are distinguished. (Largely after George et al., 1976; Arthurton et al., 1988; Lowe, 1989a.)

Region	Yorkshire Dales[1]	Northern Pennines[2]	Peak District	Mendip Hills	South Wales	Rest of Britain[3]
Geology						
Karst area[4]	320 km²	220	420 km²	110 km²	220 km²	9000 km² (mostly chalk)
Karst relief[5]	270 m	70 m	260 m	260 m	550 m	200 m (chalk)
Limestone thickness[6]	200 m	40 m	400 m	700 m	150 m	200 m (chalk)
Typical dip	1°	1°	5°	30°	10°	Varies between areas
Last glaciation	Devensian	Devensian	Anglian[7]	None	Devensian	Varies between areas
Karst[8]						
Glaciokarst	• • •	• •				• (Scotland)[9]
Fluviokarst			• •	• •		• • (chalk)
Interstratal karst			•		• •	
Pavement area[10]	677 ha	613 ha	0	0	8 ha	28 ha (Scotland, North Wales)
Dry valleys	•		• •	•	•	• • (chalk)
Karst gorges	• •	•	•	• •		
Collapse features	•		•			
Doline fields	• •				• •	• • (covered chalk)
Ephemeral lakes					•	• (chalk)
Polygonal karst	•			•		
Famous sites	Malham Cove Gaping Gill	Hutton Roof Crags	Dove Dale Peak Cavern	Cheddar Gorge Wookey Hole	Dan-yr-Ogof Porth-yr-Ogof	
Caves						
Major passage types	Vadose joint shafts, phreatic on bedding	Joint mazes	Phreatic on veins and bedding	Downdip phreatic loops	Downdip vadose, strike phreatic	Vary between areas
Number of caves[11]	1420	620	210	220	270	410
Total cave length[11]	325 km	65 km	50 km	55 km	195 km	45 km
Caves over 1 km long	50	9	9	10	12	6
Longest caves[12] (km)	Ease Gill System 71 Kingsdale System 24 Gaping Gill System 18 Ireby-Notts System 12	Goyden Pot 6 Knock Fell Caverns 5 Fairy Hole 4 Devis Hole 2	Peak-Speedwell System 14 Giants Hole 5 Bagshaw Cavern 4 Carlswark Cavern 2	Swildon's Hole 9 St Cuthbert's Swallet 7 Wookey Hole 4 Gough's Cave 2	Ogof Ffynnon Ddu 50 Ogof Draenen 48 Ogof Agen Allwedd 34 Ogof Daren Cilau 30	Slaughter Cave 11 (Forest of Dean) Ogof Llyn Parc 4 (North Wales) Uamh an Claonaite 3 (Scotland) Ogof Llyn Du 2 (North Wales)
Deepest caves[12] (m)	Ease Gill System 211 Meregill Hole 206 Pen y ghent Pot 196 Gaping Gill System 195	Goyden Pot 61 Scrafton Pot 44 Pate Hole 33 Aylebarn Mine Cave 30	Giants Hole 214 Masson Cavern 1 90 Peak-Speedwell System 184 Nettle Pot 180	Eastwater Cavern 180 Longwood Swallet 175 Swildon's Hole 167 Manor Farm 151	Ogof Ffynnon Ddu 308 Ogof Daren Cilau 217 Ogof Agen Allwedd 177 Dan-yr-Ogof 140	Ogof Llyn Parc 115 (North Wales) Slaughter Cave 99 (Forest of Dean) Cnoc nan Uamh 90 (Scotland) Ogof Hesp Alyn 90 (North Wales)

1 The main southern Dales area on the Askrigg Block, including Dentdale, and excluding Nidderdale.
2 Including Nidderdale, the karst east of Morecambe Bay, and the eastern fringe of the Lake District.
3 Mostly the weakly cavernous karst of the chalk and oolitic limestones; including the cavernous karst of Devon, Forest of Dean, North Wales and Scotland.
4 Approximate area of karstic landscapes; does not include all the limestone outcrops.
5 Approximate values for the local relief within the limestone, which dictates the maximum descent from sink to rising, added to any depth of karstification beneath the resurgence level.
6 Geological data are generalized for purposes of comparison.
7 Or possibly Wolstonian – see text.
8 Most karst features are found to some extent in all the main karst regions, but their importance is assessed in relative terms:
• = significant, but minor;
• • = important and widespread;
• • • = internationally important.
9 Location of the major features noted in parentheses.
10 From Ward and Evans (1976).
11 Recorded caves longer or deeper than 5 m; figures rounded to nearest 10 caves and 5 km of passage; from unpublished database of Limestone Research Group, University of Huddersfield.
12 Subject to continuous revision, as lengths (and less frequently depths) are increased by newly discovered passages or by links found between known caves.

(Table 1.1) A comparison of the major features which give the individual character to each main karst region of Britain