Chapter 3 Outlying karst areas of the northern Pennines

Introduction

The northern Pennines contain Britain's most extensive and spectacular karst landscapes, spread across a range of uplands formed in mixed sequences of sandstones and limestones interbedded with shales. Most of the region is dissected by deep glaciated valleys cut between numerous residual summits which rise to over 700 m. The karst is all formed on the Carboniferous limestones which form bands across the whole region (Figure 3.1). The best known and most extensive outcrops are in the southern Yorkshire Dales, and these are referred to in Chapter 2.

Outside the main Yorkshire Dales karst, the karst landforms of northern England are widely scattered on various Dinantian and Namurian limestones which exhibit considerable lithological and structural diversity (George *et al.,* 1976; Dunham and Wilson, 1985). Both the modern structures and the Carboniferous environments are best viewed as features of three positive areas and some intervening troughs. The Pennines form a massive escarpment; the Askrigg and Alston Blocks, separated by the shallow trough of Stainmore, both have limestones dipping gently east from their upper margins along the Dent and Pennine Faults respectively (Figure 3.1). The third positive area is the denuded dome of the Lake District, where the limestone survives as part of an annular escarpment facing the Lower Palaeozoic inner; these outcrops now lie on the edge of the Vale of Eden and around Morecambe Bay, where, though topographically outside the Pennines, they are geologically related.

The single most important limestone in the northern Pennines is the Great Scar, largely of Asbian and Holkerian age. This massive and pure facies forms most of the karst in the southern Dales (Chapter 2), and extends with very similar lithology into the faulted blocks just east of Morecambe Bay and also into the Stump Cross area just north of its bounding Craven Fault Zone. Northwards the Great Scar Limestone thins considerably, and thick shales occupy much of the Asbian succession. It forms the low escarpment with its many pavements between the Vale of Eden and the Lake District, but its extension onto the Alston Block, as the Melmerby Scar Limestone, has very little exposure beyond the pavements at Helbeck.

The Brigantian rocks are dominated by the Yoredale facies of cyclic shales, sandstones and limestones; these form the Wensleydale Group on the Askrigg Block, and the Alston Group on the block of the same name. The cave systems of Nidderdale are cut in the Middle Limestone, and are the largest karst landforms in the many limestones within these sequences (Figure 1.9). Cyclic sedimentary sequences continue with little change into the Namurian, where the lowest unit is a limestone. Known as the Main Limestone on the Askrigg Block, and as the Great Limestone on the Alston Block, this contains all the largest caves and karst landforms in the Pennines north of Wensleydale. All the Carboniferous limestones are very similar with respect to their karstic erosion; they are strong and generally massively bedded and are broken by thin shale partings; the Brigantian and Namurian limestones are generally darker than the Asbian Great Scar.

Lower Palaeozoic rocks underlie the unconfor-mity which occurs throughout the region at the base of the Dinantian, but have almost no direct influence on the limestone aquifers and their karst morphology. In the Vale of Eden, the Dinantian limestones are underlain by the Holkerian Orton Group of mainly clastic sediments, which were deposited in the contemporary Ravenstonedale Trough.

Most of the limestones in the Pennines are structurally uncomplicated, with dips of 1–3°, widely spaced faults and generally two, well developed, conjugate joint systems. The notable exception is along the major fault zones bounding the Pennine blocks; the Stump Cross and Short Gill caves and the Clouds and Helbeck pavements all owe their character to strong folding of the limestone within these disturbance zones (Figure 3.1). Dips of 10–20° are common in the limestones around the fringes of the Lake District, and block faulting dictates the overall morphology of the hills east of Morecambe Bay.

The karst

Pleistocene ice sheets repeatedly scoured the northern Pennines, and the Devensian ice covered the entire area. The limestone landscapes are therefore dominantly glaciokarsts, except where glacial till totally blankets the outcrops or where landforms on the thinner limestones are lost in a broader topography of glaciated features. Ice sheets flowed south from Scotland, east and south off the Lake District, and almost radially from centres of ice accumulation on both the Pennine blocks, near the head of Wensleydale and over Cross Fell (King, 1976). The Stainmore Gap was a major iceway across the Pennines, and all the Dales were modified to some extent, so that the glaciated troughs now epitomize the Pennine landscape. Scouring of the shale and soil cover and plucking of the limestone beds occurred across all the limestone outcrops, with varying intensity related to aspect and exposure to the flow of the glaciers and ice sheets.

On the large scale, the main valleys are all influenced by geological structure. The Vale of Eden is a major structural low, the Dent Fault has glaciated troughs along most of its length, and all the main valleys north of Wharfedale drain east with the dip, though at lower gradients. Nearly all the glaciated Dales have low longitudinal gradients, and most of them contain permanent surface rivers. Nidderdale and Dentdale have sections of limestone floor where the drainage is underground except for flood flows. Wensleydale may have an unmeasured underflow through its limestone floor, but this route offers no significant hydraulic advantage and a permanent surface flow is therefore maintained over a long limestone outcrop. The northern Dales cross only narrow outcrops of limestone, and only the River Greta goes underground for a few metres at God's Bridge (Figure 3.1). There are no long dry valleys, but How Stean Gorge in Nidderdale and Hell Gill are two of the more spectacular karst gorges cut through the narrower limestone outcrops by streams in valleys tributary to the main dales.

Limestone scars and pavements form the most conspicuous elements of the northern Pennine karst regions. Low white scars, plucked clean by the glaciers, fringe narrow rock terraces which almost trace the contours in most of the northern Dales, but they are overshadowed by the larger scars in the Great Scar Limestone of the southern Dales. The limestone pavements are much more dramatic, and form huge expanses of bare rock wherever the stronger limestone beds lay in the right attitudes to be stripped clean by Pleistocene ice. The pavements of Morecambe Bay and the Lake District fringe constitute some of the finest glaciokarst landforms in northern Europe (Goldie, 1981, 1993).

Where the Pennine limestones are covered by glacial till, they are distinguished by huge numbers of subsidence dolines. Locally known as shakeholes, these are classic karst features formed by suffosion and ravelling where percolation water washes the unconsolidated till into underlying limestone fissures. Each shakehole is typically 2–10 m across, with sloping sides and a depth limited by the till thickness. Almost all the Pennine limestone outcrops are marked by either zones of shakeholes in a till cover, or strips of pavement on scoured rock surfaces. Even the thinnest of the Yoredale limestones is commonly defined by a line of shakeholes round a hillside. Some larger dolines swallow allogenic stream flows, with open cave entrances or shafts descending into solid limestone, and there are innumerable risings on all the Dales hillsides. The larger are resurgences of sinking streams, many draining from open cave passages, but most are small flows of percolation water emerging from impenetrable fissures.

The caves

Nearly all the Carboniferous limestones have underground drainage; they are massively bedded, strong limestones whose high mass permeability is entirely due to fissure flow with secondary, solutional enlargement along tectonic joints. Most of the limestones are ideal hosts for karstic development, and caves are widespread at favourable sites; a few units of thinly bedded and heavily fractured limestones behave as diffuse aquifers and have no accessible caves.

The relatively thin scatter of known caves across the northern Pennines, in contrast to the very cavernous karst around Ingleborough (Chapter 2), is a function of both geology and drainage patterns. Most of the northern Pennine limestones form units less than 50 m thick and lie almost horizontally, thereby precluding the development of deep caves. Convergence of the underground drainage, or the sinking of large allogenic streams, is necessary to create stream caves of humanly accessible dimensions, and these criteria are generally not fulfilled within the thin limestones of the region. The typical situation has narrow hillside outcrops of the thin limestones, which swallow innumerable tiny streams; each flows underground for a very short distance to a rising at the base of the limestone directly down the hillside, forming one of many, roughly parallel, very small caves. Furthermore, most of the large areas of limestone pavement lie on high ground so that they receive no input of allogenic drainage; rainfall drains into all their fissures and emerges from numerous small risings fed by seepage flows and inaccessibly small cave passages.

Where the geology, topography and drainage are favourable, significant caves are formed, and this region houses three very distinctive and very different cave environments, each almost restricted to its own unit of geological structure.

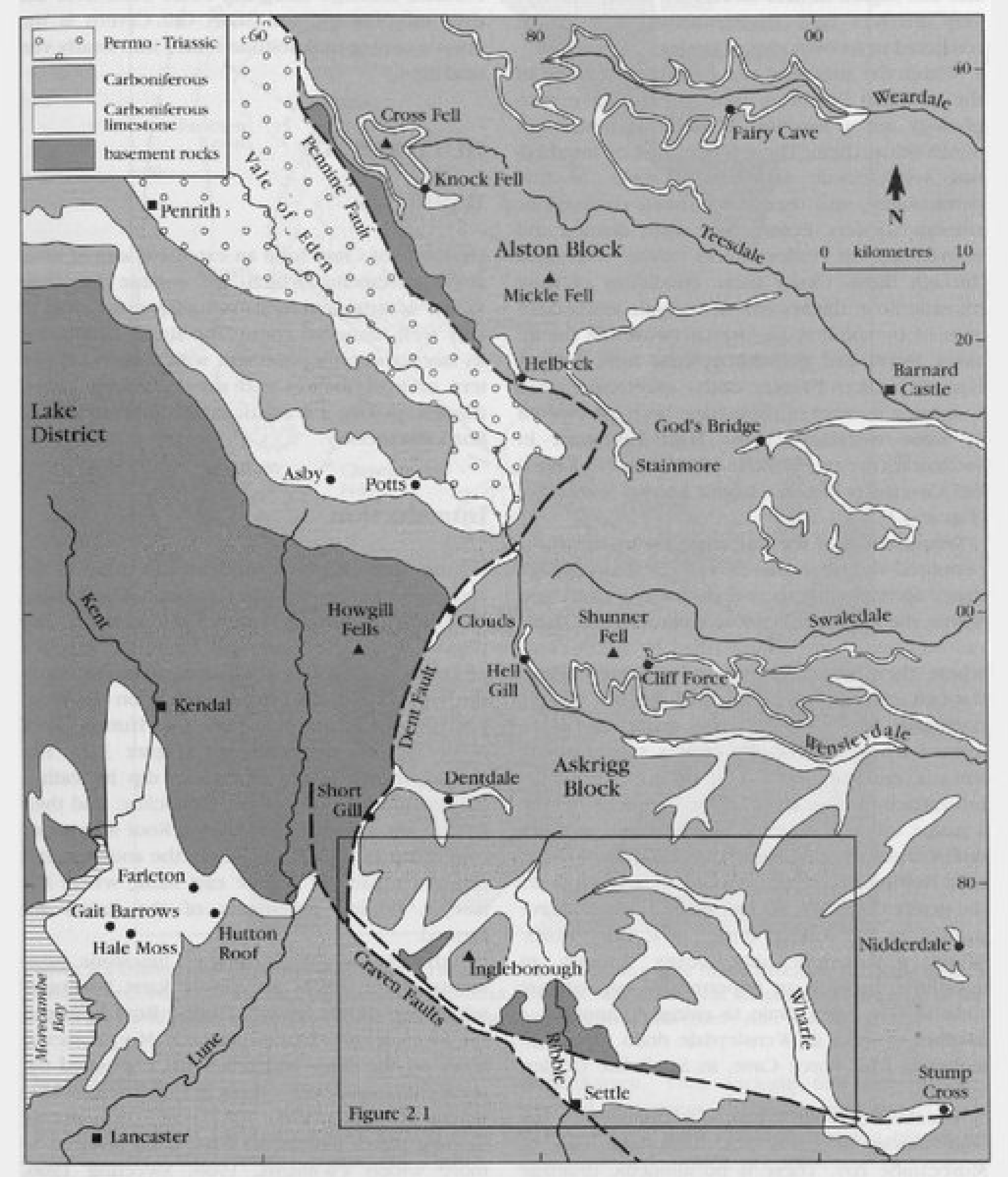
Within the structural and environmental unit of the northern Pennines, two types of cave morphology are a function of the thin limestones which house them. These limestones are interbedded with clastic sedimentary rocks of low permeability, and therefore formed confined or artesian aquifers, before they were drained and rejuvenated as valley floors were excavated through them. Under these conditions of slow phreatic flow, the systems of tectonic joints were opened by solution to form networks of fissure caves. Developed to maturity, these form the first type of northern Pennine cave — spectacular maze systems; a number of these have been intersected by mine workings in the Main Limestone in Swaledale (Ryder, 1975), and further north Knock Fell Caverns is Britain's largest known maze cave (Figure 3.1).

Rejuvenation of the immature fissure networks permitted vadose stream caves to develop though them, forming the second distinctive cave type within the northern Pennine environment. These vadose canyons are distinguished by zigzag plans where they have followed and enlarged routes through existing interconnected fissures on the conjugate joint systems. The major caves are formed where topography creates a stream sink site at a significant distance updip from a potential resurgence site — in any of three situations. Where a major valley floor exposes limestone, its river drains underground beneath a surface flood route, as in Nidderdale. Where a hillside outcrop follows the gentle dip, a stream can drain through a cave parallel to the surface slope, as at Fairy Holes. Where a limestone dips gently through an interfluve, beneath an impermeable cap, stream sinks in one valley drain to risings in another; a number of sinks in Wensleydale drain to risings, including Cliff Force Cave, in Swaledale (Ryder, 1975).

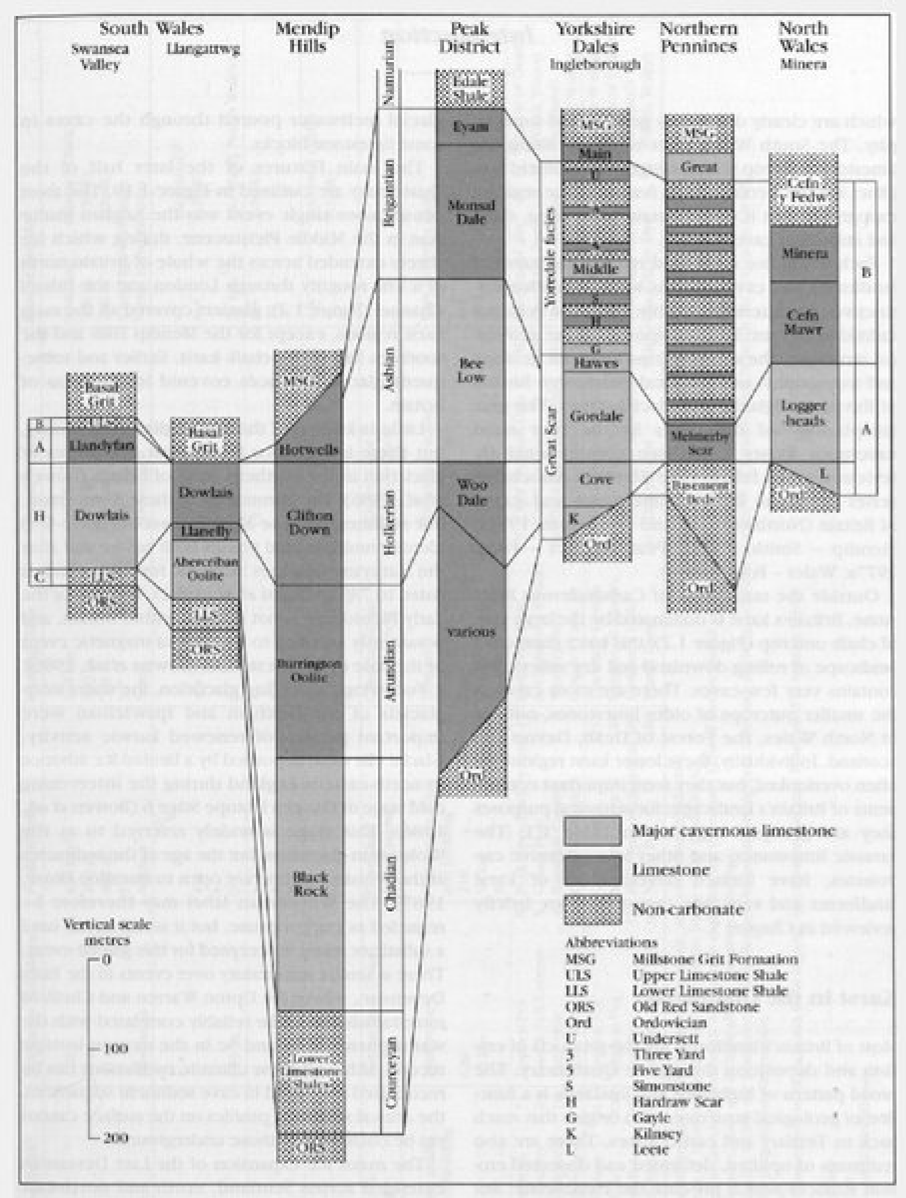
A second cave environment is provided by the fault blocks of Great Scar Limestone east of Morecambe Bay. There is no allogenic drainage onto the limestone hills, but shallow phreatic flow has created horizontal caves in the hill margins adjacent to Pleistocene lake flats, including Hale Moss (Ashmead, 1969).

The third cave environment is within the strongly folded limestones in the disturbance zones along the major Pennine block faults. Phreatic drainage along the strike dominates the cave morphology, and Short Gill Cavern is the finest example in limestone folded into nearly vertical dips.

References



(Figure 3.1) Outline map of the karst regions in the northern Pennines, with locations referred to in the text. The other Carboniferous rocks are the non-carbonates of the Orton Group and Yoredale facies of the Dinantian, and the Namurian, but they include thin bands of limestone with lesser karst features not shown on this map. The Carboniferous limestone includes the Dinantian Great Scar Limestone, the Yoredale limestones with significant karst, and the Main or Great Limestone of Namurian age. The basement rocks are Lower Palaeozoic non-carbonates. Details and locations in the southern Dales are shown in (Figure 2.1).



(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.)