
2 The Craven Fault Zone — Malham to Settle

David Mundy *Talisman Energy, Calgary* and Russell Arthurton formerly *British Geological Survey, Keyworth, Nottingham*

Purpose

This excursion observes Carboniferous (Dinantian and Namurian) stratigraphy and structural relations at the southern margin of the Askrigg Block along the line of the Middle Craven Fault (MCF) between Malham and Settle. Features relating to mineralization, Quaternary geology and geomorphology will also be addressed.

Logistics

The itinerary covers some 9 km, with an optional side trip to Victoria Cave (Locality 15). It may be tackled as a half-day or a full-day walk, starting at Gordale Bridge [SD 913 634], or for a shorter walk, from Malham itself [SD 990 636]

The excursion is entirely within the confines of the Yorkshire Dales National Park; *thus hammering of the exposures is strongly discouraged.*

There is a large pay-and-display car park adjoining the National Park information centre in Malham. There are several car parks in Settle; alternatively, a small number of vehicles can park on the roadside verge adjacent to the last Locality 18 [SD 836 630], thus avoiding a 1.5 km road walk to Settle.

Maps

O.S. 1:50 000 Sheet 98, Wensleydale & Upper Wharfedale; 1:25 000 Outdoor Leisure Map 10, Yorkshire Dales-Southern Area; B.G.S. 1:50 000 Sheet 60, Settle (Drift edition recommended for this traverse). B.G.S. Memoir, Settle (Arthurton *et al.*, 1988).

Geological background

The Carboniferous (Dinantian, Namurian) palaeogeography of the North of England was greatly influenced by structurally controlled blocks of Lower Palaeozoic basement, which under a regime of largely extensional rifting, produced depositional settings of ramp, rimmed shelf and basin. The Craven Faults, and in particular the Middle Craven Fault (MCF), defined the southern margin of the Askrigg Block, a northward-dipping tilt-block of isostatically buoyant (granite-cored) Lower Palaeozoic basement. This block formed a site suitable for shallow water limestone deposition, and contrasted markedly with the subsiding area to the south, where deeper water environments were formed, characterized by both mudstone and limestone deposition.

By late Dinantian times there was a clear differentiation between a rimmed carbonate shelf developed on the Askrigg Block, with marginal carbonate build-ups (the Cracoean 'reef' limestones), and the deeper water settings of the Craven Basin. These build-ups had a unique set of facies and supported a prolific invertebrate fauna. The dip of the Malham Formation in the hanging wall of the MCF is always greater than that on the adjacent footwall, and implies northward rotation of the hanging wall. The rotation is a reflection of a concavity in the MCF plane, with the fault plane flattening out with depth; such fault geometries are described as listric. In detail, the Visean (late Dinantian) depositional history of the shelf-edge was complex, and involved syndepositional (extensional) 'growth faulting' along the MCF, followed by a major erosive phase instigated by a strike-slip component on the Craven faults with localized compressional effects. Mudstones of the Bowland Shales progressively covered these disrupted Dinantian limestones, burying the 'reefs' and lapping over the MCF; the Bowland Shales passing up into the siltier and sandier Pendle Grit Formation. After further structural upheaval and erosion, widespread across the Askrigg Block, the deltaic, pebbly, coarse-grained sandstones of the Grassington Grit Formation extended southwards across the Block and into the Craven Basin.

Excursion details

Locality 1, Gordale Scar viewpoint [SD 913 634]

View from Gordale Bridge or proceed as a side trip into Gordale Scar. The spectacular gorge in the Malham Formation was probably carved as a meltwater channel beneath the Devensian ice-sheet. Upstream of the waterfall the gorge dog-legs abruptly to the northwest, where a series of minor extensional faults have controlled the erosive path of the meltwater channel. These faults are exposed just above the tufa screen and are part of the complex set of fractures between the North and Middle Craven faults. The superb Malham Formation section in Gordale Scar exposes 43 m of the Cove Limestone Member and 94 m of the overlying Gordale Limestone Member. This location is designated as the stratotype for the latter. The contact of the two formations is a strong bedding plane defining the top of the first persistent scar feature.

Locality 2, Janet's Foss, Gordale Beck [SD 912 633]

Take the footpath which leads south from Gordale Lane into Gordale Beck. The footpath enters a wooded valley where the stream is interrupted by a small waterfall (Janet's Foss) below which is a moss-covered tufa screen. This exposure of Gordale Limestone forms the northern part of the hanging wall block of Wedber Brow. These limestones dip east-northeast at 25° towards a fault defining the eastern margin of the Wedber block. The middle and southern parts of Wedber Brow are formed by 'reef' limestones. The small cave known as Janet's Cave was, according to records, inhabited in the late 17th century by smelters working the copper mines at Pikedaw to the west. The exposed Gordale Limestone above the waterfall is notably mottled as a result of the burrowing activities of bottom-dwelling organisms. This burrow-mottling can be seen in exposures in the path on the return to Gordale Lane.

Locality 3, Gordale Lane, at the base of Cawden Hill [SD 904 629]

View the 'reef' limestones on the southern flank of Cawden from a position just west of the bend in Gordale Lane. These carbonate build-ups, first recognized by R. H. Tiddeman, were largely constructed by organisms, and had depositional topographies of over 100 m. They are not, however, analogous to present-day coral-algal framework reefs. Three principal subfacies make up the build-ups *bank*, *flank*, and *framework* (Figure 2.3). The bank is the poorly bedded core of the build-ups, while the flank facies formed the basin-facing palaeoslope, with depositional dips up to 35°. These subfacies contained a diverse and locally prolific biota dominated by brachiopods, molluscs, crinoids, bryozoans and corals. The lower southern slope of Cawden here consists largely of flank beds dipping southwards at about 300 (clearly seen in the old quarries just beyond the wall), whilst the middle slopes consist of flank and bank facies. The small raised feature visible at the top of the hill is a good example of the stromatolitic framework facies, which developed locally in the shallowest-water setting of the build-up. The present-day topography on this slope is a reflection of the original profile of the build-up. Proceed to Malham village.

Locality 4 (optional), Malham Cove viewpoint [SD 897 633]

Follow the road northwards through the village to the footpath gate leading to the Cove. View the geology of this spectacular section from here, or if you have the time and the energy inspect it at closer range. Malham Beck resurges from the base of the cliff. This stream receives only a small component of water from the Malham Tarn 'Water Sinks', a sink at the head of the Watlowes dry valley (which terminates at the Cove), taking the overflow water from Malham Tarn. This water source, although seemingly the obvious candidate for the Cove resurgence, does in fact flow at a deeper level and rises south of Malham as the Airehead Springs. The majority of the Malham Beck resurgence is derived from the 'Smelt Mill Sink' 1.2 km west of the Water Sinks.

Malham Cove is the stratotype of the Cove Limestone which is here 72 m thick. The top of the member is the bedding plane some 5 m above a prominent overhang (compare Gordale Scar). The basal 10 m of the overlying Gordale Limestone forms the remainder of the Cove cliff, with a well-developed limestone pavement on its top. A small inlier of dark grey grainstone referable to the Kilnsey Limestone Member of the Kilnsey Formation occurs in the valley bottom

below the Cove. While you are at this locality, take the opportunity to view the western side of Cawden, where bedded Malham Formation in the hanging wall of the MCF can be seen dipping northwards at about 20°. Return to Malham.

Locality 5, Burns Barn (Field Barns) [SD 893 632]

Take the footpath from Malham heading to Field Barns and Pikedaw. The footpath crosses 'reef' limestone belonging to the Malham Formation. Small exposures in this tract show shelly limestones referable to the *bank* subfacies. The contact of the Bowland Shales on the reef limestones occurs 100 m west of Field Barns, and is defined by the rising ground east of Sell Gill. Although both the limestone and Bowland Shales are covered by a veneer of till, the ill-drained ground associated with the shales is conspicuous. Proceed westwards, up Pikedaw Gill, picking up the line of the MCF defined by the Malham Formation escarpment of Pikedaw to the north. Review the course of the fault eastwards from Malham.

Locality 6, Pikedaw Gill [SD 882 636]

The stream runs close to the margin of an extensive landslip, involving the Namurian formations to the south. Stop at the portal of the Pikedaw lead level beside the footpath. The portal has a stone-built arch with a keystone dated 1872, and is one of several entrances to the mine workings exploiting galena-bearing veins of the Pikedaw area. Most of the lead veins trend northwest-southeast, coincident with the general fault trend between the NCF and MCF. The Pikedaw area has a long history of mining probably dating from the 17th century, with copper, zinc and lead minerals extracted.

Locality 7, Pikedaw [SD 881 638]

Follow the footpath 200 m northeast of Locality 6 to limestone exposures bordering the footpath. Here the Gordale Limestone, close to the contact of the Hawes Limestone, is partially silicified. Brown quartz-rock has replaced limestone in irregular zones which stand proud of the limestone surface due to their greater resistance to weathering. Analogous silicified limestone forms northwest-trending replacement zones within the Hawes Limestone just to the north. These replacement bodies, clearly visible east of the footpath, weather as raised ribs carrying a more acid-tolerant flora than the limestone. The landslip on the eastern slopes of Kirkby Fell is well seen from here. The failure occurred in two episodes, each postdating the Devensian glaciation, with the Pendle Grit Formation and the lower leaf of the overlying Grassington Grit Formation collapsing to leave jumbled debris extending downslope onto the Bowland Shales.

Locality 8, Calamine Mine 'New Shaft' [SD 876 640]

A concrete cap with a metal door covers a 21 m deep shaft, dug in 1806 for access to the mine, which yielded smithsonite (calamine) from a Quaternary cavern system some 70 m in length. The mineral occurs as a sediment flooring the caverns, and was discovered during copper mining in 1788. The calamine was originally brought to surface via the difficult access of the copper mine to the west (see Locality 9). The New Shaft (rediscovered in 1944) was constructed to ease the handling of the mineral. It is estimated that up to 5000 tons of calamine, used largely in brass-making, were extracted before the mine was closed in 1830.

Locality 9, Pikedaw Head Gate [SD 875 640]

Proceed westward from the New Shaft through the gate in the wall. The disturbed ground immediately west of the wall is the result of copper workings and consists of shafts, bell-pits and their spoil. The copper deposits were in poorly differentiated veins and impregnations and were very difficult to work. The heap of limestone debris to the west of the gate is that from the 'principal copper shaft', and it was by this exit that calamine was initially brought to surface. Continuing westwards, observe the ground to the south (eg 200 m west of Locality 9). Here a line of shake holes defines the contact of the Upper Bowland Shales on the Hawes Limestone. The Namurian shales overlap an eroded limestone surface north of the MCF, a manifestation of a substantial throw in the MCF and subsequent erosion of the footwall scarp before the deposition of the shales. This buried fault-scarp is an example of the pre-Namurian topography.

Locality 10, Kirkby Fell viewpoint [SD 870 638]

The MCF crops out about 100 m south of the path, the rising ground of Kirkby Fell beyond being Pendle Grit Formation capped by Grassington Grit. To the southwest, two leaves of Grassington Grit form the prominent Rye Loaf Hill. To the west the path descends and crosses a narrow north-northwest-trending dry valley, developed along another of the subsidiary extensional faults which cross the ground between the MCF and NCF. This subsidiary fault is linked with several others to the north, forming a complex zone of westward down-stepped slices. Silicified limestone analogous to that seen at Locality 7 is exposed adjacent to the path, and a line of small mineral workings follows the fault. Spoils have yielded sphalerite, galena, malachite, azurite and baryte.

Locality 11, Great Scar viewpoint [SD 866 639]

Continue westwards for some 400 m. The slopes and gullies to the northwest display the stratigraphy of the lower part of the Wensleydale Group (formerly called the Yoredales). This succession represents a continuation of shelf carbonate deposition, but with periodic interruption by mud-stones in this area, but mudstones and sandstones (some with coals) north of the NCF. These siliciclastics were deposited during the southward progradation of a deltaic complex.

Compared with the underlying Malham Formation, the Wensleydale Group limestones are typically darker grey and contain more visually conspicuous fossils (particularly crinoids, corals, brachiopods and algae). The Wensleydale Group section exposed in the Great Scar escarpment includes, in ascending order, the Hawes Limestone (27 m), Gayle Limestone (16 m) and Hardraw Scar Limestone (14 m); the latter forming the skyline. The stepped topography is controlled by the mudstone bands separating the limestones. The top of the Lower Hawes Limestone contains several prominent fossil markers including algal (oncolite) beds ('*Girvanella* Band'), a *Gigantoproductus* brachiopod bed, and a coral biostrome dominated by colonies of *Siphonodendron* and *Lithostrotion*.

Locality 12, Stockdale viewpoint [SD 863 639]

Follow the footpath to the head of Stockdale. The Gordale Limestone produces continuous scars in the footwall fault scarp of the MCF. The position of the contact with the underlying Cove Limestone Member, on the top of the lowest scar-former, is clearly discernible and analogous to that at Malham. Northwest-trending fractures of little throw have influenced erosion, producing nicks in the escarpment. The MCF runs south of the whale-back ridge in the valley bottom. The ridge is defined to the north by the more northerly of two westerly-diverging fractures which here characterize the MCF; the other fracture, with most of the throw, occurs some 100 m to the south, concealed by Bowland Shales.

High South Bank, south of the main valley, is an inlier of Dinantian limestones forming a northward-dipping hanging wall dip-slope. This inlier is analogous to that at Malham, and is almost certainly fault-defined on its eastern and western margins. Bowland Shales are banked against the limestone. Prior to burial by these mudstones, the limestone of this hanging wall block had undergone significant erosion. A small outcrop of 'reef' limestones forms the southernmost part of the inlier (on the skyline), while the main dip-slope (locally dipping up to 30°) is formed of Malham Formation and Wensleydale Group. The latter includes the Hawes to Hardraw Scar limestones, but these have been attenuated to a 5 m interval, and contain conglomeratic units. Quarries on the northern end of the inlier expose cross-bedded grainstones, correlatives of the Middle Limestone (Brigantian) of Fountains Fell. Small mineral workings occur in the Wensleydale Group limestones, with galena, malachite and baryte in the spoils, while a large area of quartz-rock has replaced the Malham Formation. Attenuation of the early Wensleydale Group limestones and succeeding erosion of the shelf margin, suggests a slight compressional regime on the previously extensional fault line (a process known as fault inversion) before collapse of the hanging wall into a series of downthrown fault-blocks in late Dinantian times. The subsidiary faults (mostly northwest-trending) both north and south of the MCF were formed at this time, and reflect a component of right-lateral movement on the Craven fault system.

Locality 13, Stockdale Lane corner [SD 848 638]

Proceed westward to Stockdale Lane, then to the footpath gate at the bend in the lane 500 m ahead. The viewpoint, immediately north of the MCF, gives a good perspective of the High Hill hanging wall block relative to the Malham Formation footwall escarpment that includes Attermire Scar. The High Hill fault block contains 'reef' limestone exposures on the southern scarp-face and Malham Formation with overlying Wensleydale Group on the main dip slope, with dips

from 15° to 25° towards the MCF. The throw on the fault using the datum of the base of the Hawes Limestone is calculated to be of the order of 170 m, much less than at Stockdale, but analogous to that at Wedber Brow, Malham. The High Hill block is truncated on its eastern margin by a fault, with Bowland Shales forming the low, poorly drained ground on the downside. The trace of this fault is not, however, shown on the B.G.S. map because the Bowland Shales overlap the fault plane (i.e. the fault is pre-Bowland Shales). This relationship clearly demonstrates the separation into blocks of the hanging wall geology by the subsidiary faults south of the MCF and also demonstrates the variation of throw of these isolated fault blocks relative to the main fault. The small roadside exposures near this viewpoint are dark grey grainstones of the Kilnsey Limestone. These are the oldest Dinantian rocks observed on this excursion; they crop out along the base of the slope (Little Banks), but are truncated by a fault east of Attermire Scar.

Locality 14, Attermire Scar–Warrendale Knotts viewpoint [SD 840 641]

Follow the footpath westward to the gate in the wall below Attermire Scar. The Malham Formation produces magnificent exposures in the fault scarp of the MCF. This escarpment is cut by northwest-trending faults which have produced zones of weakness along which narrow gullies have been eroded. These faults are part of the complex of minor fractures of very late Dinantian age which characterizes the ground between the NCF and MCF. As at Pikedaw and near Kirkby Fell, some are mineralized.

Locality 15 (optional), Victoria Cave [SD 838 650]

Take the footpath between Attermire Scar and Warrendale Knotts northwards for some 850 m. *En route* consider the fault-controlled topography to the west. The fault bordering Langcliffe Scars has a throw of up to 100 m. Climb the scree-strewn slope to the entrance of Victoria Cave. The cliff gives an opportunity for viewing the Gordale Limestone at close quarters. Four emergent (palaeokarstic) surfaces occur over a 17 m section of the cliff. The cave is an important site for cave archaeology and Pleistocene geology. Discovered in 1837 (the year of Queen Victoria's coronation) the cave was excavated intermittently over many years, but a major excavation was carried out between 1870 and 1878. Two distinct cave earths were found. The 'Upper' contained Neolithic cultural remains with Romano-British artifacts scattered on the surface, and the 'Lower', separated by a laminated clay and truncated by till at the mouth of the cave, was a Last Interglacial (Ipswichian) bone bed with the remains of nine large mammals including brown bear, spotted hyaena, lion, hippopotamus and narrow-nosed rhinoceros, indicating a use alternating between hyaena den and bear cave. Calcite speleothems enclosing the bones have been dated using the $^{230}\text{Th}/^{234}\text{U}$ method and give an age for the fauna in the cave vicinity at or just before 120 000 (± 6000) yrs BP. Return to Locality 14.

Locality 16, Sugar Loaf Hill [SD 836 638]

Cross the wall and continue east for 100 m to steps providing access to the footpath leading to Sugar Loaf Hill, in the High Hill fault block. Proceed 350 m southwards to the base of the conical shaped Sugar Loaf Hill. The dark grey limestones dipping at 18° immediately to the west are Lower Hawes Limestone. The base of this limestone provides a reliable datum on which the throw of the MCF can be calculated (here 170 m). Please note that this area of Hawes Limestone has been inadvertently shaded as Cove Limestone on the solid edition of the Settle 1:50 000 geological map, but corrected on the drift edition. The strata forming Sugar Loaf Hill are early Namurian (Pendleian) in age and unconformably overlie the limestones of the lower part of the Wensleydale Group. Most of the hill is composed of intercalated mudstone, siltstone and thin cherty limestone (30 m in all), collectively named the Sugar Loaf Shales, while the top of the hill is capped by 5 m of shelly (brachiopod) wackestone, the lower third of the Sugar Loaf Limestone. The local names reflect the unique character of these units, which are correlatives of the nearby Upper Bowland Shales, but more analogous in lithology to the Namurian part of the Wensleydale Group (the Main Limestone and underlying siltstones as found, for example, on Fountains Fell). The Sugar Loaf succession represents the localized deposition of a late Wensleydale Group facies on an isolated fault block, when the adjacent tract was typically characterized by the deeper water deposits of Bowland Shales. These stratigraphic relations indicate the relative independence and variable subsidence rates of the isolated blocks forming the hanging wall of the MCF.

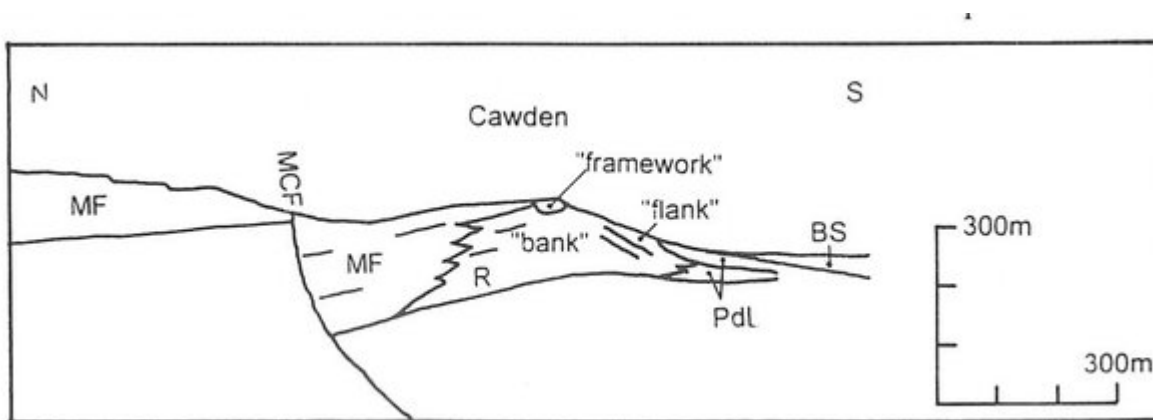
Locality 17, High Hill, eastern side [SD 837 634]

Continue southwards for a further 300 m to where the footpath runs close to the wall, following the line of a northwest-trending subsidiary fault, to the west of which are large replacive dolostone bodies in the Gordale Limestone. Observe the Gordale Limestone immediately to the west where well-bedded limestones are dipping at about 15°. Proceed southwards to the remains of a limekiln just west of the path. The quarried limestone section adjacent to the kiln exposes unbedded bank facies of the marginal 'reef' limestones. Notice that the bedded Gordale Limestone (previously viewed) overlaps these 'reef' limestones. The Gordale Limestone in this vicinity thus formed at the very edge of the original shelf, and would have passed into or lapped onto the marginal build-ups somewhere out of the exposure to the south; the present juxtaposition of beds reflecting erosion on the front of the shelf margin build-up.

Locality 18, Corner of High Hill Lane and Stockdale Lane [SD 836 630]

From this location, view the steep southern slope of High Hill, formed in 'reef' limestones. This topography is a pre-Namurian surface exhumed from a cover of Upper Bowland Shales, and gives an impression of the original bathymetry of the shelf margin. The extensive late Dinantian erosion on the front of the build-up has all but removed the basinward-dipping flank beds (as seen at Cawden, Malham), revealing mostly the unbedded 'core' of bank facies. Debris from this erosional episode was deposited to the south as conglomerates and boulder beds of the Pendleside Limestone and Lower Bowland Shales (as exposed nearby at Scaleber). This erosion surface has cut down progressively southwards, through the northward-dipping succession in the fault block defined by the South Craven Fault, intercepting the pre-'reef' Holkerian and Arundian succession of the Scaleber Quarry and Scaleber Force limestones (correlatives of the Kilnsey Formation). This deep erosion on the downside of the MCF (well exposed at Scaleber Beck and Scaleber Force some 600 m to the southwest) is associated with the minor compressional episode that preceded the major collapse on the faults. Continue west back to Settle via High Hill Lane (1.5 km) or rejoin vehicles parked adjacent to this locality.

[Bibliography](#)



(Figure 2.3) Geological section across the Middle Craven Fault near Malham. Abbreviations as in (Figure 2.1).