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Introduction

Kingsdale is the most westerly of the classic Yorkshire Dales, lying between Whernside and Gragareth, near the southwestern tip of the Craven Uplands (Fig. 1). Its straight U-shaped glaciated trough is some 6 km long and about 700 m wide, cut through the Great Scar Limestone, so that its walls feature a succession of limestone scars. Wide limestone benches, largely covered with glacial deposits, stand above both rims. The floor of the dale is perched, so its outlet drainage cascades over Thornton Force and down the Ingleton Glens, in a total descent of 150 m to the Craven Lowlands.

These notes are largely abstracted from the leaders' recent paper on Kingsdale (Waltham *et al.*, 2010), with points of debate added. Further information on the caves will be available as a chapter (Brook, 2012) in the forthcoming BCRA book *Caves and Karst of the Yorkshire Dales*.

Caves beneath Kingsdale

The limestones of Kingsdale are drained by an extensive system of interconnected cave passages (Waltham *et al.*, 1981, 1997). Streams that drain off the shale-dominated Yoredale sequences, forming the higher slopes of both Whernside and Gragareth, all sink underground where they meet the top of the Great Scar Limestone (Fig. 2). The only significant surface flow across the limestone is in the flood channel along the axis of the valley, active when flows are too large to enter the sinks at Kingsdale Head.

Streams that sink on the high limestone benches have utilised the bedding planes, shale beds, joints and small faults to establish underground routes through to the single resurgence of Keld Head on the valley floor. Beneath the limestone bench of Gragareth, the West Kingsdale Cave System has dendritic, vadose, tributary caves descending from multiple sinks to converge on the short section of large vadose canyon passage known as the Kingsdale Master Cave. This carries drainage into long underwater passages that reaches through to Keld Head. Across the dale, similar stream caves descend northwards to converge on the East Kingsdale Master Cave. From there, the cave becomes a water-filled conduit that passes beneath the floor of Kingsdale to join the phreatic caves feeding out to Keld Head. This flooded passage crosses beneath the valley with about 10 m of solid rock above the cave roof and 18 m of limestone beneath the cave floor.

Stalagmites have been dated by decay of their uranium isotopes, but these indicate only when their host cave passages were above the water table, with a latest possible date for the formation of each passage that can be much older. They imply maximum levels of the contemporary local water table, and

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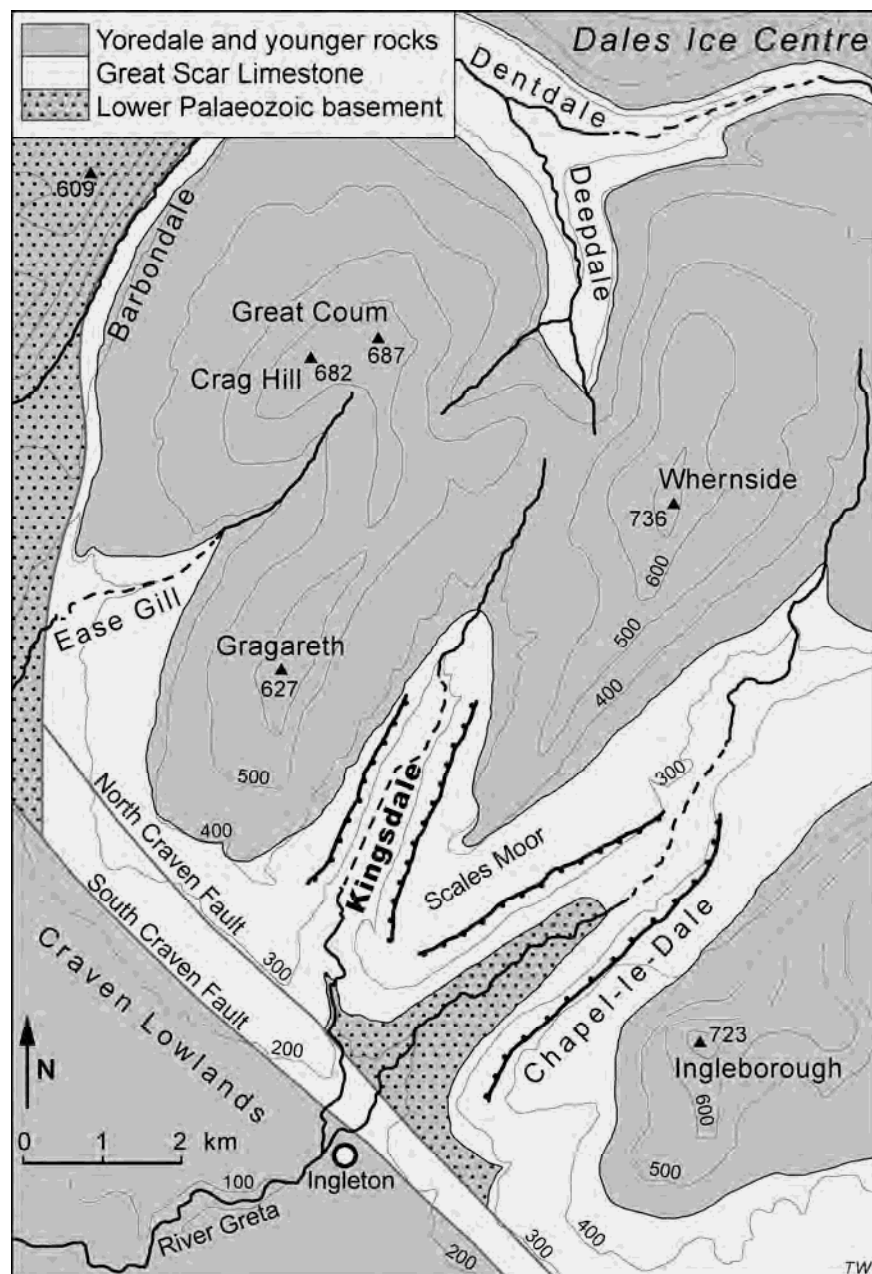


Fig. 1. Location of Kingsdale and adjacent dales, cut into the western corner of the Craven Uplands.

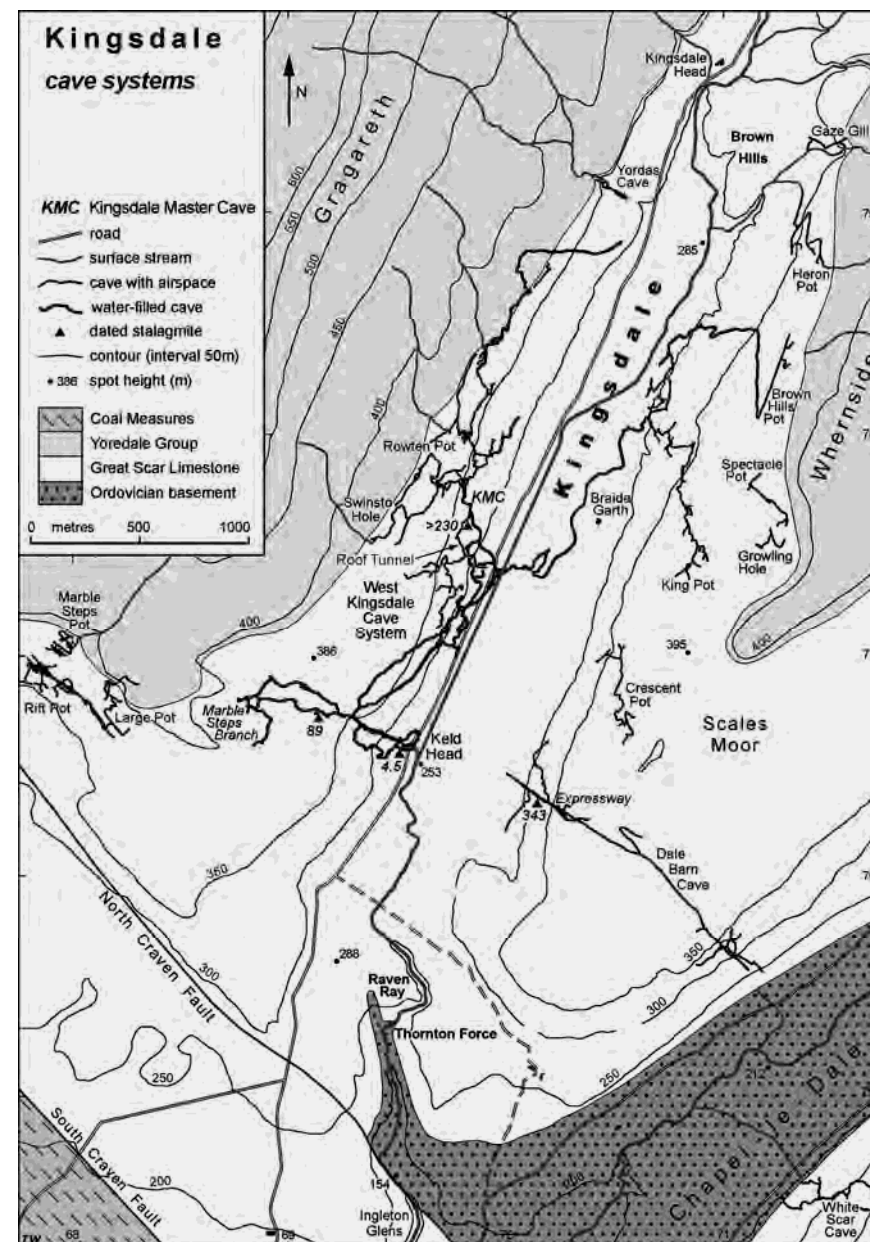


Fig. 2. The caves passages beneath and beside Kingsdale; the stalagmite dates are given as ka BP.

therefore the resurgence level, and thereby indicate maximum altitudes of the contemporary valley floors (there are obvious complications with perched conduits, stepped water tables, unknown resurgences and drainage routes out to other valleys). Declining levels of the radio-isotopes over time limited the early U/Th dating of stalagmites to about 350 ka. Thermal ionisation mass spectrometers have extended the range back to 600 ka, and Al/Be dating of quartz in clastic cave sediments can reach back to about 2 Ma, but dates from these newer methods have not yet been obtained for the Kingsdale caves.

Within the West Kingsdale Cave System, Roof Tunnel is an abandoned section of trunk passage, now truncated by the glaciated trough of Kingsdale, where it is partly obscured by glacial till at Valley Entrance. Calcite flowstones from within Roof Tunnel have yielded ages more than 230 ka (all dates and their associated errors are listed in Waltham *et al.* (2010)). These indicate that the cave passage was essentially dry during the interglacials after rejuvenation of the valley; this was probably by Anglian glaciers in MIS 12, but the presence or role of any glaciers in MIS 10 and 8 remains uncertain. The cave passage then lay above a water table that stood at an altitude no higher than about 260 m.

While the modern karst drainage of Kingsdale is largely mapped, little is clear about most of the earlier phases of drainage. Isolated segments of large, abandoned, phreatic trunk passage are known inside the limestone hills on both sides of Kingsdale; their continuations are choked with clastic sediment. They carried flow either to or from both Chapel-le-Dale and the Ease Gill valley when water tables and thalwegs lay at altitudes well above those of today, suggesting that most are pre-Anglian. Beneath the eastern flank of Kingsdale, a large cave passage carried a major flow beneath a contemporary water table. Calcite flowstone dated to 343 ka coats the upper walls of the passage. This indicates the draining of an old phreatic route to Chapel-le-Dale prior to MIS 9.

The early glaciations of Kingsdale

The glaciated trough of Kingsdale has a U-shaped profile only slightly modified by post-glacial alluviation. It is perfectly straight, but there is no firm evidence of any fault guidance. The splendid U-profile owes part of its origin and much of its preservation to the strength and stability of the limestone, especially with its slight increase in thicker and stronger beds near the top of the succession to define a sharp rim to the trough.

During each Pleistocene glaciation, a Kingsdale glacier was fed by ice from a Dales Ice Centre to the north (Mitchell, 1991e; Evans *et al.*, 2005), with significant flow coming southward from Dentdale, up Deepdale and over the saddle west of Whernside. Through most of the cold stages, all or most of the Askrigg Block was covered by ice, and Kingsdale was occupied by an ice stream that carried a significant flow between sheets of ice that were either cold-based and static or were moving only much more slowly across the high limestone benches and over the higher hills. Kingsdale was occupied by a

valley glacier between its limestone walls only just after (and probably just before) these phases of total ice cover. Certainly this was the case in the retreat phases of the Devensian glaciation.

Multiple glaciations successively modified the geomorphology of Kingsdale during the cold stages of the Pleistocene. Though the early stages of this proto-Kingsdale were excavated within the Yoredale rocks, the Great Scar Limestone was eventually exposed across the valley floor, and much or all of the drainage then sank into newly developing caves. Most of these caves were destroyed by excavation of the glacial trough, but various fragments of high-level passages are known at altitudes around 325 m under both benches; these suggest a contemporary water table at a level not far above 325 m, but the contemporary dale morphology, the location of the resurgence and the absolute age are unknown.

The drainage of Roof Tunnel by MIS 9 indicates that the contemporary resurgence lay about 100 m below the main limestone benches. If that resurgence was in Kingsdale, at or close to its floor level and somewhere near the present site of Raven Ray and Thornton Force, the glaciated trough of Kingsdale was already about 100 m deep by the end of the Anglian glaciation, and Roof Tunnel had been truncated by the Anglian glacier. Any link from Roof Tunnel to that resurgence has been removed by valley erosion, and it may be that the Kingsdale floor was at a higher level with underground drainage through Dale Barn Cave and out to Chapel-le-Dale (implying that that valley was already then entrenched to 100 m below the limestone benches).

The Roof Tunnel cave passage lost its role as the West Kingsdale trunk drain when its flow was captured by a lower route towards Keld Head. Cave drainage and passage development were minimal during the Anglian, and during each glaciation, when much of the ground was frozen and most cave entrances were blocked by ice plugs. Enlargement of the passages southward towards Keld Head accelerated after the Anglian rejuvenation, so that Roof Tunnel was left dry, probably early in the Hoxnian at MIS 11. The position of the contemporary resurgence, in either Kingsdale or Chapel-le-Dale, is unknown, as the passage to it has been truncated at Keld Head.

Whereas the altitude of the post-Anglian floor of Kingsdale remains uncertain, Wolstonian ice appears to have excavated the dale to a level below 248 m, as stalagmite dated to around 89 ka has been recorded at that level within the passages of Keld Head. This glacial re-excavation of Kingsdale would appear to have been during MIS 6, when there was a marked cessation of stalagmite deposition within the caves (Gascoyne *et al.*, 1983a). Cave passages behind Keld Head are now flooded because they lie at levels below that of their resurgence onto the floor of Kingsdale.

The Devensian glaciation of Kingsdale

The early Devensian date of the Keld Head stalagmite at the 248 m level

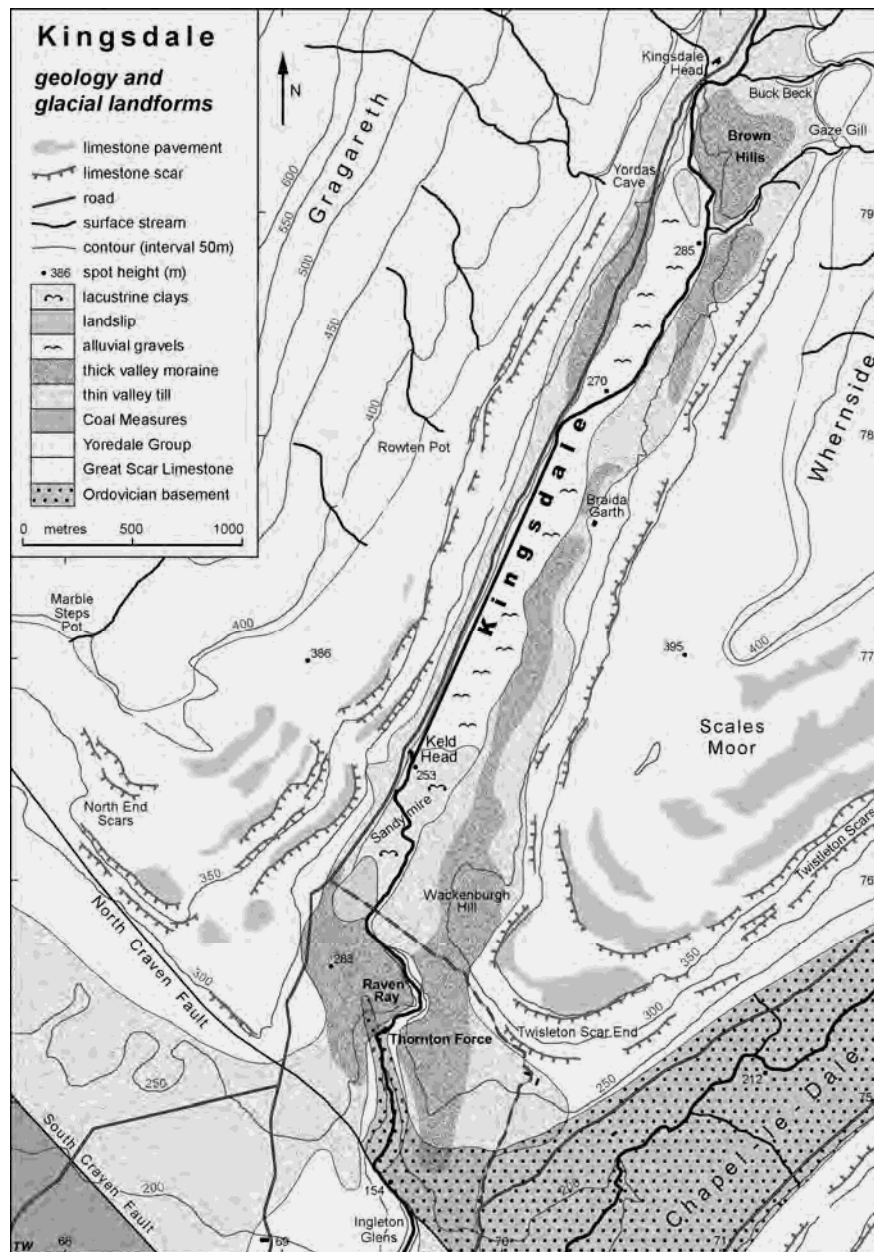


Fig. 3. Glacial and post-glacial sediments in Kingsdale.

suggests that the Ipswichian Kingsdale had a depth profile close to that of today. A subsequent exploration in Keld Head has revealed more calcite flowstone at a depth of 6.7 m below the current water level. This indicates that the cave was drained to a resurgence below an altitude of 246 m, almost certainly on the floor of Kingsdale, and probably also during MIS 5e. The modern rock floor, beneath the sediments of Kingsdale, appears to slope gently downstream from an altitude (known from unpublished geophysical soundings) of about 239 m at Keld Head, to about 210 m where it is exposed immediately downstream of Thornton Force; there the glacial fill within the buried valley reaches down to stream level about 70 m west of the waterfall.

The Raven Ray ridge, across the mouth of Kingsdale immediately above Thornton Force, is interpreted as a recessional moraine that buries the original valley and is breached by a post-glacial channel offset to the east (Fig. 3). The limited exposures indicate that the lower part of the pre-Devensian valley, buried beneath the moraine, has a narrower profile that is more V-shaped in comparison with the wider U-shaped profile within the main dale (Fig. 4). This may be due to ice cutting down into the weaker materials of the thinly-bedded Kilnsey Formation and the underlying slate, or it may reflect more entrenchment by proglacial or subglacial meltwater.

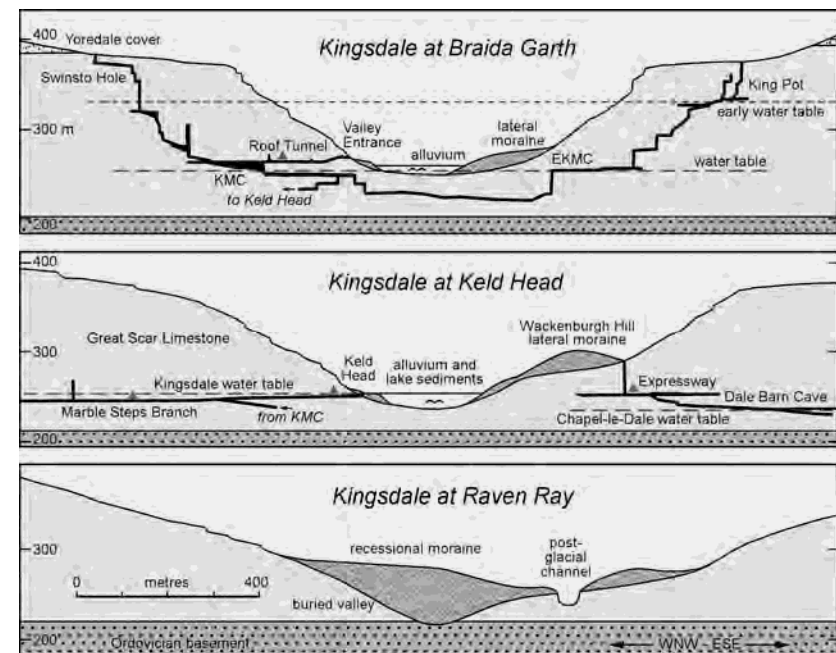


Fig. 4. West-east profiles across Kingsdale.

The Devensian glaciation (or glaciations) may have been responsible for as little as 9 m of dale floor deepening at Keld Head. At the same time, the ice trimmed the walls of Kingsdale to leave the lines of fresh scars along the stronger limestone beds. During the Devensian, the ice did spread over the limestone benches on each side of Kingsdale, but there was minimal scour of the pavements, followed by widespread burial of them beneath veneers of till. Both features indicate a relatively weak ice stream down Kingsdale when compared to the more powerful Chapel-le-Dale ice stream that left wide, scoured, bare, limestone benches on each side of its main trough.

Between Yordas Cave and Kingsdale Head, the rounded banks known as Brown Hills are interpreted as the eroded remains of a second recessional moraine within the dale, younger than Raven Ray and left further up the dale by an interlude of stability or re-advance during the retreat of the glacier. These hills lack the sharp ridge of the Raven Ray barrier, and may be just Rogen moraines or drumlinoid mounds of basal till that do not mark a second event. A spread of thicker till was left by the wasting glacier further up-valley, though Buck Beck cuts down into limestone just behind Brown Hills.

It is assumed that these moraines and glacial landforms in Kingsdale were left by retreat of the glacier of the Last Glacial Maximum, but there is no evidence yet recognised within Kingsdale as to exactly when that was. There is scope for debate on the relative roles of any ice during the cold stages of MIS 5d through to LGM1 within MIS 2. Current modelling suggests that the uplands of the Yorkshire Dales were probably clear of ice by about 16.5 ka (Telfer *et al.*, 2009), though valley glaciers may have survived for slightly longer into the Windermere Interstadial. No glacier re-occupied Kingsdale during the Loch Lomond Stadial (Younger Dryas), when high level-cirque glaciers were all that developed within the Yorkshire Dales; the nearest to Kingsdale were on the northeast slopes of both Great Coum and Whernside (Mitchell, 1996).

The Raven Ray moraines

The visible glacial landforms of Kingsdale are all products of the retreat phase of the Devensian ice, probably at the end of the Last Glacial Maximum (see above). Across the mouth of Kingsdale, the Raven Ray recessional moraine forms a barrier across the glaciated trough (Fig. 5). Lateral moraines continue down the valley from it on both sides, before merging into the till-mantled slopes that constitute the degraded scarp on the Craven Faults. An alternative scenario is that all the till around Raven Ray may be a part of a much larger left-bank lateral moraine left by the ice stream moving southeast along the Craven Lowlands, and subsequent erosion by the Kingsdale outflow has dissected this to create the isolated ridges. The writers do not favour this explanation, as the moraines fit too well with the topography of Kingsdale and its interpreted glacier, but the concept is open to debate.

Up-valley from the Raven Ray recessional moraine, Wackenburgh Hill is

interpreted as a high-point along the large lateral moraine on the eastern flank, which forms most of the terrace either side of Braida Garth (though the farm itself stands on bedrock). The hill is cored by a shoulder of bedrock limestone, which is exposed in some of the caves that descend through the till. It could be that the shape of Wackenburgh Hill indicates its origin as a drumlinoid mass of basal lodgement till, and not as a moraine of ablation till; this concept remains open to debate.

The west bank lateral moraine is a very modest feature barely large enough to carry the minor road along most of the length of Kingsdale, though it widens at the upper end of the valley. It is possible that this may be no more than a kame terrace, but there has been no exposure nor examination of its material to resolve this possibility.

Between these moraines, alluvial sediments form the broad valley floor with a low longitudinal gradient. Braided and meandering channels score the alluvium and have cut a cusped margin into the upper end of the western lateral moraine; all these channels are normally dry since artificial straightening of the beck. Beneath the fields in front of Keld Head, depths to rockhead reach about 15 m, though these may have missed a slightly deeper centreline of the valley.

A profile of the buried valley beneath the Raven Ray terminal moraine is revealed west of Thornton Force, where the grassy slopes on till break the line of rock scars formed by the lowest beds of the limestone (Fig. 6). This buried valley has been traced back beneath the moraine by resistivity (Bruckshaw, 1948) and seismic (Wilson, 1980) surveys.

The Kingsdale lake

The Raven Ray moraine was left as a barrier across the mouth of Kingsdale during the final retreat of the Devensian ice. Decay of the ice, and retreat of its front from the terminal moraine, left its outlet meltwater temporarily ponded as a lake behind the moraine. The lake overflowed at the lowest point along the moraine crest, east of the valley's centre line, and the new channel was entrenched through till and into buried bedrock limestone. Where it rejoined the pre-glacial valley, Thornton Force developed over the strong limestone lip above a plunge pool that was undercut into the weaker low-grade slates of the Ingleton Group basement. The waterfall has subsequently retreated to its current position, with retreat of about 50 m if measured at the toe of the slope or 30 m if measured at the level of the waterfall lip. While the valley downstream was deepened by Devensian meltwater and by postglacial drainage, much of it dates from earlier stages as it is partly filled by the Devensian lateral moraine where it steps southeast along the North Craven Fault.

The proglacial lake behind the Raven Ray terminal moraine was drained when its outlet channel was entrenched into the till, but the period of the lake's life is unknown. Its maximum level was probably close to 265 m. Initially, the lake was only small, when the ice wall was still close to the moraine. Patches of

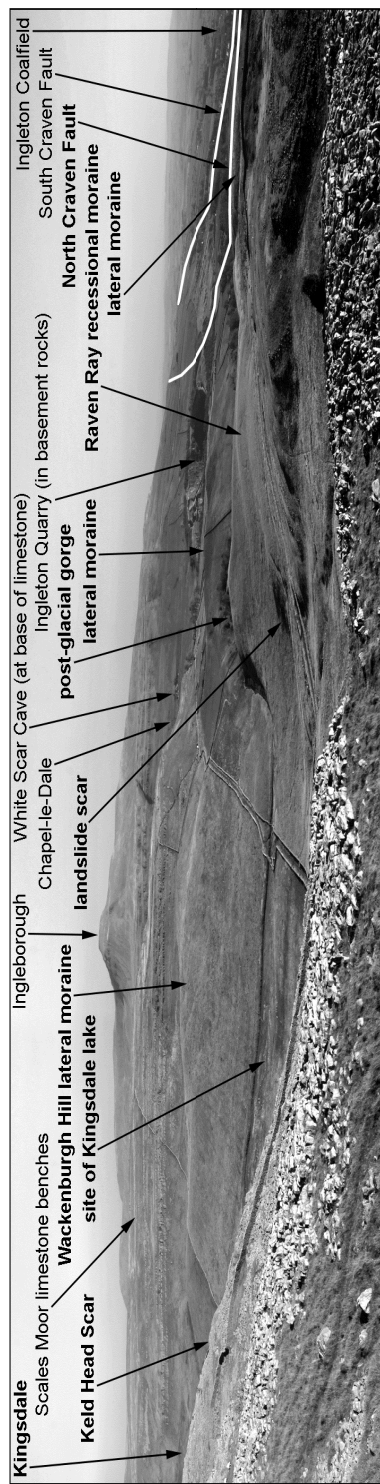


Fig. 5. Kingsdale and its moraines, seen from the limestone scars of its western flank



Fig. 6. Thornton Force, with the adjacent buried valley picked out by the margin of its till fill (solid line), and the post-glacial channel (broken line); the apparent overhang in the buried valley's right profile is only an artefact of the oblique view.

beach sand at elevations of just under 260 m on the slopes of the terminal moraine appear to be relicts of the lake at close to its highest level. Retreat of the glacier front saw the lake expand upstream, while its level declined and it was also being filled by the front of the gravel outwash from upstream. The lake clays that overlie the alluvial gravel reach more than 6 m thick under Sandymire, but extend only as far up valley as Keld Head, where they thin to nothing at close to the 253 m level. A broad scoop in the moraine face, with a matching terrace of debris below, appears to be an old landslip originating from unstable conditions when the lake level was high; this awaits confirmation, as the terrace material is till and shear surfaces have not been found in shallow excavations within it.

Within the lake, dark lacustrine silts and clays accumulated to survive as the small flat area of Sandymire, between Raven Ray and Keld Head (the name Sandymire derives from sand banks within the modern river channel). Underwater exposures in the deepest pool in Kingsdale Beck show that these are at least 6 m deep, but their base on a deltaic front of gravels is not seen. Fragments of *Chara* are abundant in these lacustrine clays, except that they are almost completely absent from a layer 3.6 – 4.1 m below the main surface, as revealed in a core taken from the bed of the beck. This barren middle layer may represent a cessation of plant growth during the colder conditions of the Loch Lomond stadial, but the sediments have not yet been dated. Within the clay profile, and one metre above the barren layer, a cluster of beaver-chewed willow branches was exposed in the beck channel, and subsequently lost to erosion (Batty, 2008). Whether this was a beaver dam, a lodge or just a channel log jam, its wood has been dated to 7.7 ka BP and implies a contemporary wetland environment at about 251 m, with all or most of the lake already gone.

Up-valley from the Sandymire flat, the main Kingsdale floor has a low gradient on a ramp of alluvial sediments that were deposited as glacial outwash from the waning glacier and later by post-glacial streams. Along the dale floor upstream of Sandymire a cable trench revealed about a metre of disturbed sediments and derived loessic soils overlying alluvial gravels, whose base was not exposed.

A Kingsdale lake that was formed after retreat of the valley glacier at about 15 ka, and was drained by 7.7 ka when beavers occupied a wetland, indicates incision of its outflow gorge within no more than about 8000 years. This might be a rather short time to entrench through more than 10 m of limestone in the rocky ravine on the east side of the terminal moraine; there has been only about a metre of channel lowering in a similar period since the beavers chewed and placed their wood. It is possible that some ancestral feature was breached through the Raven Ray gorge. This may have been a left-bank marginal overflow channel that was exhumed, or could have been an older cave passage that was unroofed. The upstream continuation of either feature lies in a buried valley revealed by the rockhead profile on the east bank just north of Raven Ray, and now plugged by till of the lateral moraine.

Stalagmites that are now about 300 mm below water level inside Keld Head and dated to both 2.49 and 4.5 ka, indicate that the Sandymire alluvial flat, onto which the cave drains, was then marginally lower than it is today. Holocene alluviation on the flat may have been aided by the dam-building efforts of beavers, and also by sporadic flood events. A huge flood in 1941, one of a number to have washed away all the field walls across the valley floor, dumped a mass of debris into what had been a deep pool in front of Keld Head, though this had no lasting impact on the water level through the caves. Cut timbers exposed by the river at Sandymire, 0.5 m above the beaver-chewed wood, date from the Bronze Age at about 3.5 ka and indicate man's increasing activity in Kingsdale (Batty, 2008). In the early 1800s, the river channel was straightened for much of the length of Kingsdale upstream of Keld Head; the section down the western edge of the alluvium has been maintained since by periodic re-excitation. The almost flat section across Sandymire was partially straightened but has since developed new braids and meanders.

The 2012 excursion

The Kingsdale excursion starts with a walk of less than 3 km, mostly on a good path (Fig. 7). The second part is a short walk to a cave where a torch is needed.

#1. From the bus drop-off on the Kingsdale road at NGR 689748, the route heads southeast through the gate beside the sheepfold. The Hunts Cross scar to the north marks the line of the North Craven Fault (the South Craven Fault had been crossed close to 688740 before the steeper climb onto the limestone).

#2. At the second gate, the Ingleton Glen can be seen below. The River Twiss follows the North Craven Fault away to the right. The Pecca slate quarry is below to the left. In the distance, Ingleborough descends to the Craven Faults on its right; on its lower slope, the buildings at White Scar Cave (a resurgence) identify the basal unconformity of the limestone, and the Ingleton greywacke quarry extracts roadstone from the basement rocks below. The viewpoint is on the edge of the Kingsdale west lateral moraine. The east lateral moraine forms the hump of Wackenburgh Hill to the left, and the grassy ridge across the Glen.

#3. At the northern end of the old limestone quarry, the view ahead is up the valley to the Raven Ray recessional moraine. Thornton Force is just out of sight. The profile of the buried valley is best seen straight ahead along the continuing walk, and is essentially V-shaped, indicating final incision by meltwater and not just by the glacier prior to retreat.

#4. From the seats and platforms beside the path, Thornton Force can be seen where it has retreated about 30-50 m back into the preglacial valley side. Showers of water can be seen coming from a bedding plane left of the main waterfall; they are fed by leakage in the riverbed above. Both sides of the buried valley are marked by the disappearance of the lowest limestone scars into the grass-covered slopes of till.

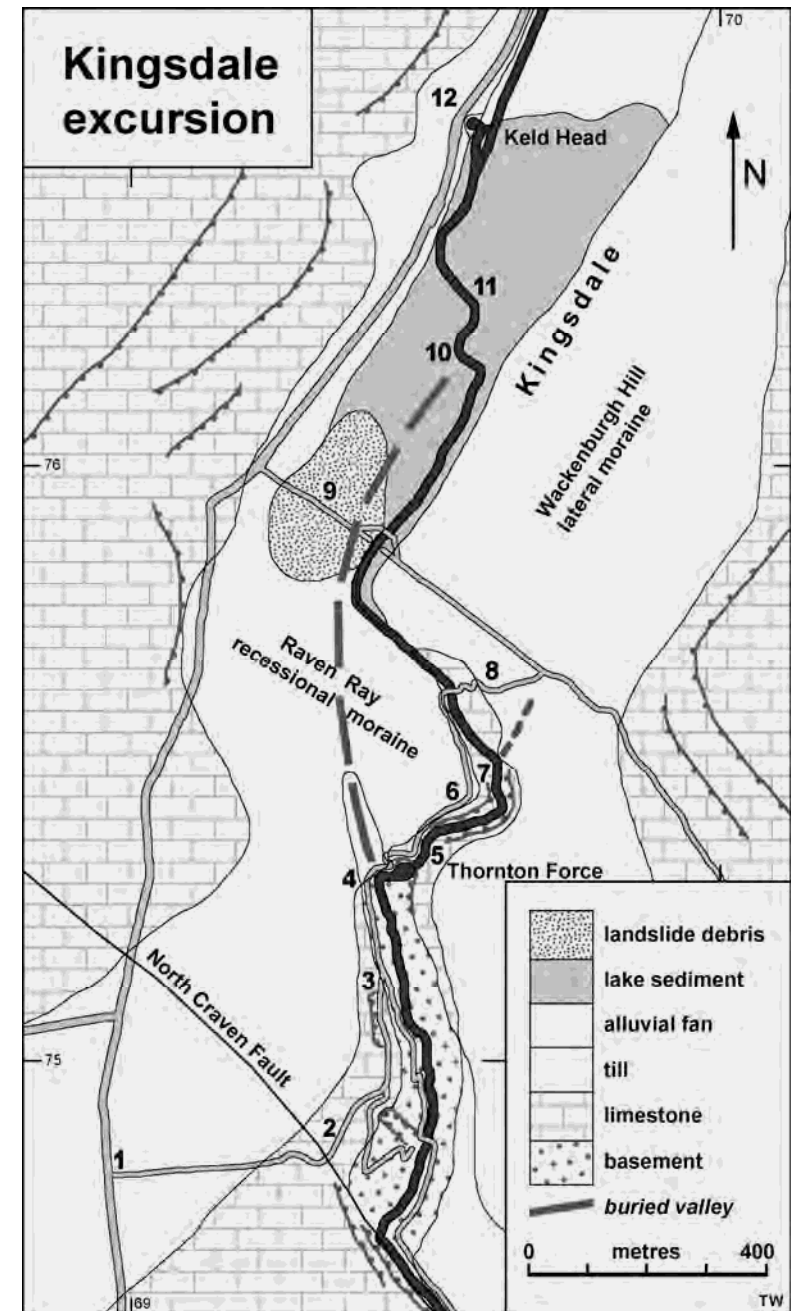


Fig. 7. The excursion route from Thornton Force to Keld Head, with the stops numbered.

#5. In the riverbed above Thornton Force, two fissures are normally obscured by water, but have been seen to be capable of swallowing the entire flow at times of extremely low water. They feed to the shower seen at stop #4.

#6. From the crest of the path over Raven Ray, the extent of the recessional moraine and the postglacial trench through it can be appreciated. To the southwest, the western lateral moraine can be seen as a distinctive feature that appears to be superimposed on the broader expanse of till that lies along the edge of the Craven Lowlands.

#7. Down by the river, the small tributary buried valley can be seen in profile in the far bank where till underlies a grassy slope between limestone scars. Its upstream source, as either a surface channel or from a cave, is unknown, as is its downstream destination, either through the limestone gorge or buried in the till slopes west of the river. Immediately downstream lies the post-glacial limestone gorge (that is the true Raven Ray). Its size may promote debate on some origin other than very rapid fluvial excavation through bedrock, whereby the river may have exhumed an older channel or breached a cave.

#8. The top of the steps above the first footbridge provides a fine viewpoint. To the west lies the ridge of the Raven Ray recessional moraine, with the sloping rockhead of its buried valley indicated by the limestone/till boundaries of each side of the river in front of it. East of south, the ridge of the east lateral moraine is seen in profile, and Wackenburg Hill to the northeast may be debated as part of the same moraine. West of south the postglacial gorge is seen in profile, with the shoulders on each side defining the maximum level of the Kingsdale lake, correlating with the beach sands away to the west (nearer stop # 9). Mesolithic flints have been found close to this site, and a Bronze Age axe-head was found under the Cheese Press Stone, the large boulder of limestone high on the scars to the northwest.

#9. From the green track west of the second footbridge, the flat area of the lake sediments extend up the dale floor until they are replaced by the gently sloping ramp of outwash gravels beyond. To the southwest, the broad scoop in the face of the Raven Ray moraine may be debated as the scar of a landslide or not; the nature of the material in front of it has not been investigated. A strip of beach sand has been found across the face of the moraine and is interpreted as deposition when the postglacial lake was close to its top level.

#10. On the Sandymire lake flat, the beaver dam and Bronze Age timbers were both buried in re-worked fine-grained alluvium, and there is little to see unless the river level is extremely low. The timbers were of the same age as material in nearby hearths, but their origin or purpose remains unknown.

#11. The far bank of the river exposes a clean face in the top metre of the fine-grained sediments deposited in the short-lived Kingsdale lake. The remains of stone drains are below water level (out of sight in the near bank a little further

upstream) may indicate a past lower level of the river, but it is difficult to recognise how the dale floor profile has changed, perhaps only in historical times.

#12. Before re-boarding the buses, the pool of Keld Head can be seen below the road. The cave exit is out of sight underwater, almost directly beneath the road, and the pool's exit at the far side and its junction with the artificial channel has been changed by flood events at various times in the recent past.

The road up the dale parallels the artificial flood channel and provides views of old meander scars on the gently graded alluvium. Opposite Braida Garth farm road, the truncated pre-Anglian cave passage now known as Roof Tunnel lies in the hillside a few metres from the road, where an oil-drum and its wooden lid mark the Valley Entrance excavated through the till by cavers in 1967.

#13. From the bus drop-off at NGR 706791, and through the gate into the field above the road, the low rises of Brown Hills can be seen a little further up the dale. It is open to debate if these are an eroded recessional moraine, Rogen moraines, or drumlins.

#14. Yordas Cave (Fig. 8) was used as a show cave in Victorian times. There are no lights inside and each person must have a torch. The first few metres may have a muddy floor (it varies after each flood) and parts of the roof are just under head-height. This opens into the Main Chamber, a fragment of a very old passage with its downstream continuation choked by breakdown and mud, though the stream passes through, and eventually emerges at Keld Head. The chamber is larger upstream to the right, with a floor of cobbles washed by the stream, and fragments of calcite false floor and cemented cobbles high on its walls; these have not yet been dated. A narrow but passable fissure leads to the foot of a waterfall shaft (the Chapter House), where the stream descends from a higher passage that links to various sinks in the stream bed just below the shale boundary at the top of the limestone.

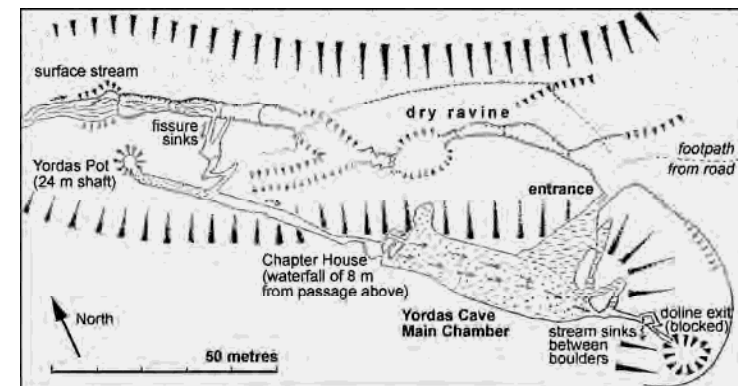


Fig. 8. Plan of Yordas Cave and its adjacent ravine.