ANOMALOUS LIMESTONE GORGES IN DERBYSHIRE

by

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Summary

The Matlock gorge of the River Derwent, Bradwell and Bradford Dales are anomalous in that they are incised into plunging limestone anticlines, when the mechanism of uniclinal shift should have resulted in the formation of a marginal shale valley. The main factor in the incision is shown, in all these cases, to be the obstruction of uniclinal shift by mounds of reef limestone projecting upwards above the slope of the former shale cover. The augument can be extended to explain the meanders of Dovedale and part of the Manifold valley. Factors explaining the presence or absence of rivers in the gorges include the occurrence or lack of impervious igneous rocks below the valley floors, the possible presence of early solution caves, and the size of the catchment area.

Introduction

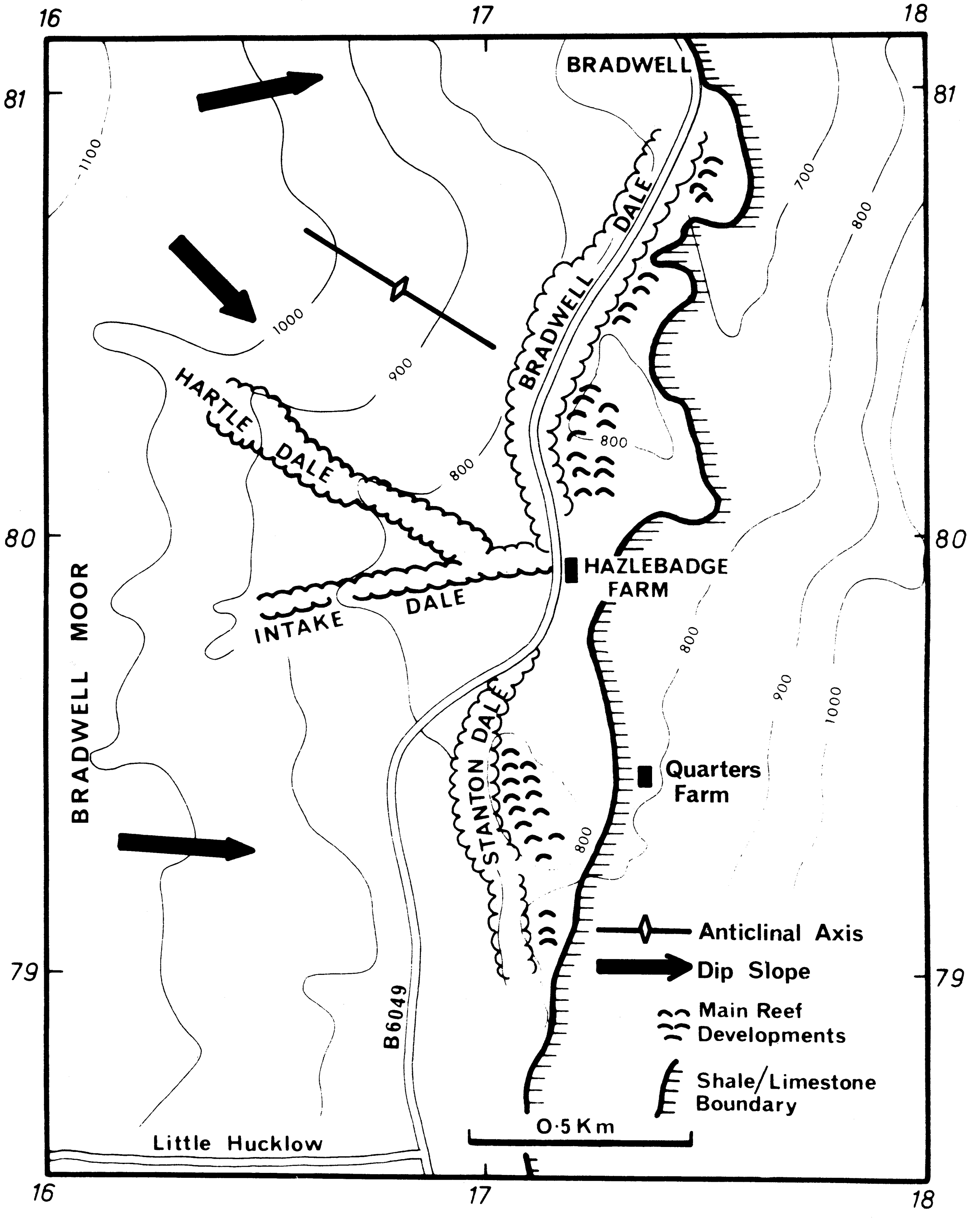
The gorge of the River Derwent, south of Matlock, has often been considered anomalous in that the river, instead of following the limestone-shale boundary has cut westwards and southwards through limestones, where the gorge transgresses the plunging anticlines of Masson Hill and Bonsall. As long ago as 1811, Farey commented on the situation of the Matlock gorge suggesting that the river had been superimposed from a former extent of the succeeding shales, which originally covered the limestone. The idea of superimposition has been used extensively by many other authors considering the cover to be different parts of the geological column. Thus a Triassic cover was required by Fearnsides (1932). Mesozoic or Tertiary cover by Green (1887) and Linton (1951), and Mio-Pliocene by Walsh *et al.* (1972). Vertical downcutting is assumed to be the main mechanism and the principal cause for the anomalous position of the gorge (Johnson, 1957); Waters & Johnson, 1958). Doornkamp (1971) noted that the vertical incision probably did not occur until after the early 1000 foot planation (which may or may not have been in the Early Pleistocene) and predominated over the general rule of eastward down-dip migration (lateral migration or uniclinal shift) of the Millstone Grit scarps.

Whether or not superimposition took place from a pre-existing surface is immaterial to the present hypothesis. The problem to be considered is why uniclinal shift did not operate to divert the River Derwent's course to the east of High Tor and along the shale outcrop. Comparable limestone gorges are the middle section of Bradwell Dale, immediately south of Bradwell village, Bradford Dale, leading into Lower Lathkill Dale; and Stoney Middleton Dale, (Plate 4). Not all Derbyshire gorges are explained by the action of vertical incision from a superimposed cover or by the present hypothesis. For example, the Winnats Pass and Monsal Dale amongst others, can be explained by other mechanisms and are not discussed herein.

The relation of some anomalous gorges to reef limestones

By climbing to a viewpoint on the eastern rim of Bradwell Dale, (text-fig. 1), the highest point is at the top of one of a series of mound-like knolls of reef limestone. The reef-knolls project above bedded limestones, both within the Eyam Group, which strike generally along the dale side. These limestones are the topmost division the the Carboniferous Limestone as defined by Stevenson and Gaunt (1971). Looking westwards across the dale, the dip slope can

Mercian Geologist, Vol. 6, No. 1, 1976. pp. 59-66, 3 text-figs. Plate 4.



Text-fig. 1. Map of part of Bradwell Dale to show the relationship of the gorges to the distribution of reef limestones.

be seen rising towards Bradwell Moor, a mile or so further west. The slope is slightly less steep than the dip of the beds, so that older limestones are exposed on the Moor. Bradwell Dale cuts across an anticline plunging eastwards from the Moor so that the northern and southern ends of the gorge section extend on to the shale. If the dip slope is projected across the dale eastwards towards the viewpoint it intersects the cliffs perhaps 100 feet below the crest. This observation is the critical evidence. Uniclinal shift operated initiating the slope until the original river was trapped by the reef-knolls (text-fig. 2a). The knolls prevented further lateral migration and vertical incision predominated. The same features can be seen to the south in the next section of Bradwell Dale (Stanton Dale), west of Quarters Farm, where once again, a mound-like reef projects upwards to the east of Stanton Dale gorge.

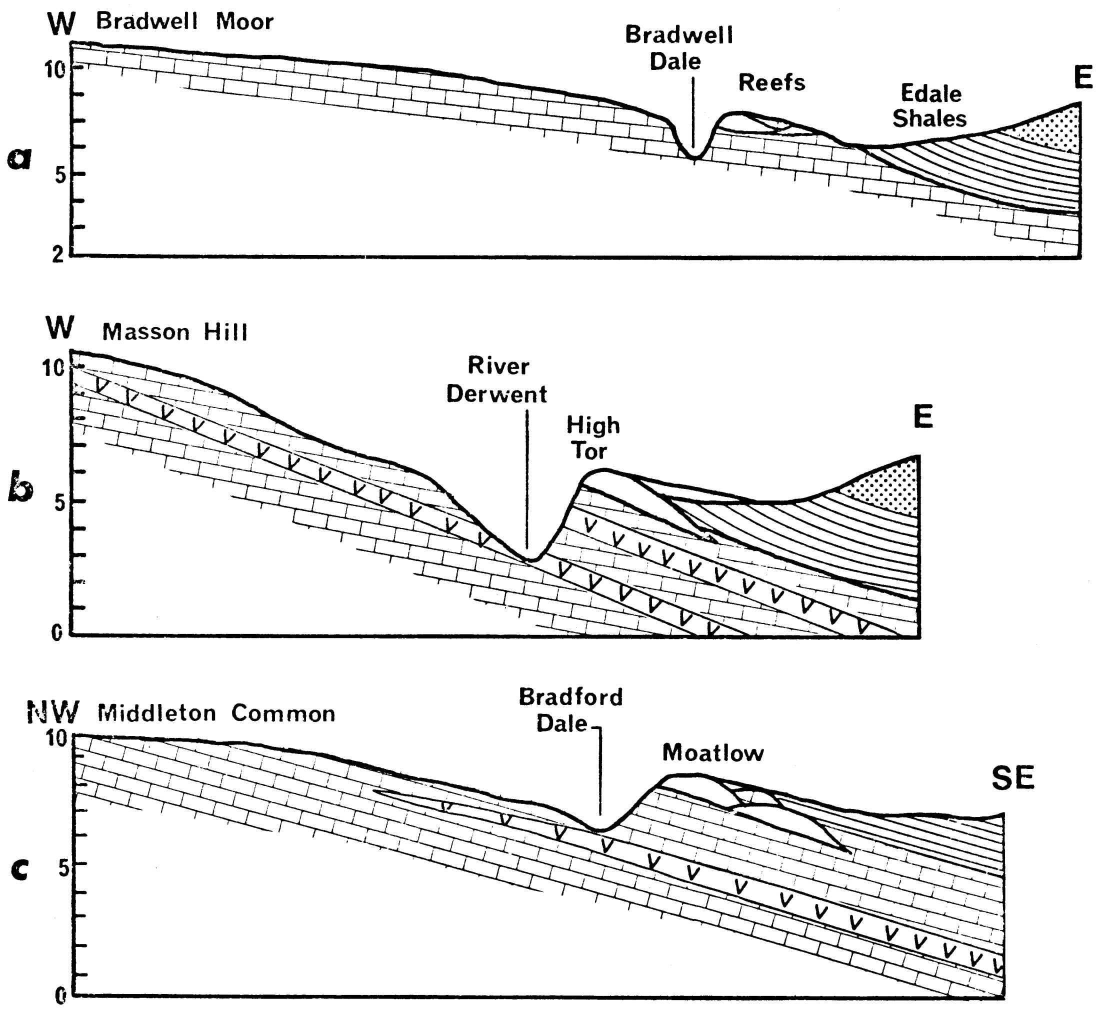
In both these examples, the basic cause of the gorge is simple; uniclinal shift was obstructed by the reef-knolls and vertical incision dominated.

If the Matlock gorge is examined with the same concept in mind, it is easy to see that reefs in the Cawdor Limestones (equivalent stratigraphically to the Eyam Group) lie along the strike and have much the same effect. High Tor projected upwards through the shales by about 100 feet, and there are similar but smaller reefs along the strike in Pic Tor, and Cat Tor (text-fig. 2b). If the ancestral Derwent was superimposed from the shale-cover so as to bare the limestone surface well to the west of the present gorges, high on Masson Hill, then uniclinal shift could have caused migration down dip until the river was trapped by the line of reef-knolls, including High Tor. Some undermining of these has undoubtedly taken place, resulting in the high joint-controlled face of High Tor, but the major factor in the origin of the "anomalous" Matlock gorge must once again be uniclinal shift obstructed by reef-knolls.

Other less obvious examples of anomalous gorges include Bradford Dale, between Alport-by-Youlgreave and the mouth of Gratton Dale, a mile or so north of Elton. Here, the dry valley system of Long Dale and Gratton Dale discharges at Dale End on to the shales where it gathers a few small streams, but instead of forming a shale valley along the limestone margin, the stream re-enters the limestone outcrop to form the gorge of Bradford Dale. Once again, a study of the dip slope profile to the west and northwest shows that, if projected eastwards across the Dale, it will intersect reef limestone crags on the east side (text-fig. 2c). Uniclinal shift has again been held up by the occurrence of reef knolls. These continue, though less well-developed, into lower Lathkill Dale, where the stream might have been expected to leave the limestone at the Winster road turning, but a series of reefs below Bowers Hall again trapped the migrating stream and vertical incision took place.

A final example, in which uniclinal shift may have been prevented, is Stony Middleton Dale, where streams might have been expected to migrate northwards down dip to run along the shales at the foot of Eyam Edge. There are small reef-knolls along the northern rim of Stony Middleton Dale, but they are weakly developed compared with the other examples given above, and once they were undercut, uniclinal shift might have been resumed if it were not for the loss of drainage to underground systems (Beck 1975).

In the above argument, the trapping of streams migrating by uniclinal shift down the shale-limestone contact by projecting reef-knolls has been shown to be a critical factor, but reef limestones occur elsewhere in Derbyshire and it is worth looking at the general relationship of reef-knolls to gorges. Both Dovedale and the Manifold Valley are incised into the limestone, but in situations where uniclinal shift seemingly could not operate down an inclined shale-limestone surface. Superimposition has taken place with more or less vertical down-cutting. However, the two dales' courses show a pattern of meanders, and it might be asked whether these reflect meanders superimposed from the former cover or whether they were caused by the presence of lithological features in the limestone. If the pattern of reef-knolls is plotted in Middle Dovedale (text-fig. 3), it can be seen that the dale tends to meander between them, being deflected at several points by massive reef-knolls. Some of them have, in fact, been trimmed rather than intersected by the streams, as a Ravenstor south of Mill Dale, and at Dove Holes Crag. The lower reaches of Dovedale are cut entirely through a complex of reef-knolls, from Tissington Spires southwards to Thorpe Cloud, but if the dips of the limestones with the knolls high on the dale sides are examined, it can be seen that the initial



Text-fig. 2. Sections to show the relationship of gorges to reef limestones in Derbyshire. (a) Bradwell Dale; (b) the Derwent Gorge at Matlock; (c) Bradford Dale.

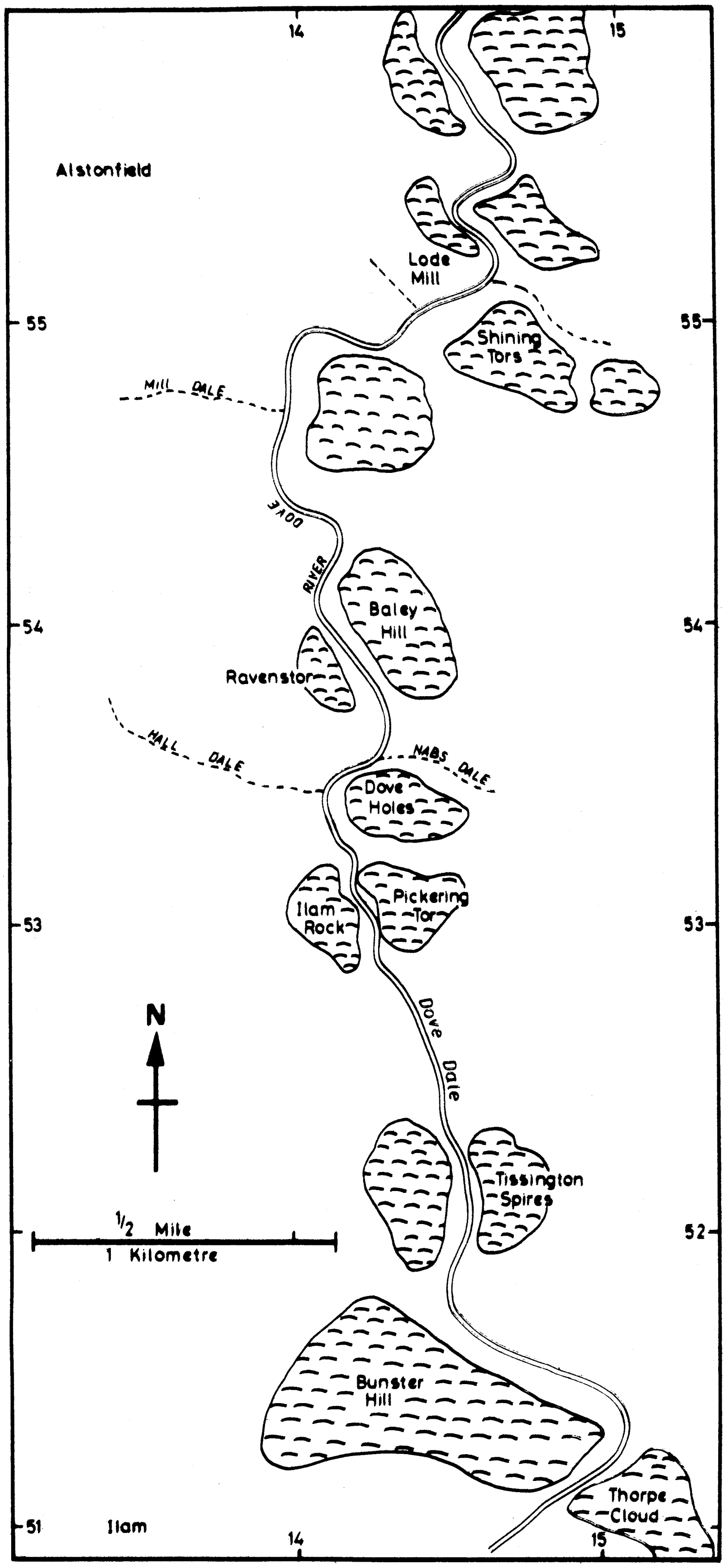
incision was controlled by these so that the river's course ran between the knolls. Only at a later stage was the course incised directly into lower reef-knolls. The mouth of the dale shows a sharp bend caused by incision being between the reef-knolls of Thorpe Cloud and Bunster Hill. In the Manifold Valley, similar deflections have been caused by reef-knolls such as Thors Cave Crag, Darfar Crag and Beeston Tor, but some meanders seem to have originated from other causes such as the strong folds affecting the limestone-shale sequence as at Ecton Hill. Even so, uniclinal shift has operated down the flanks of reef-knolls in both Dovedale and Manifold Valley in a fashion which can explain "anomalous" sections of those gorges. The reef-knolls have controlled the present course and the superimposition of meanders from a former cover need not be invoked as an explanation. The meanders have developed by lithological influences as vertical incision took place, concommitant with falling base levels to the south.

Other Factors in Gorge Development

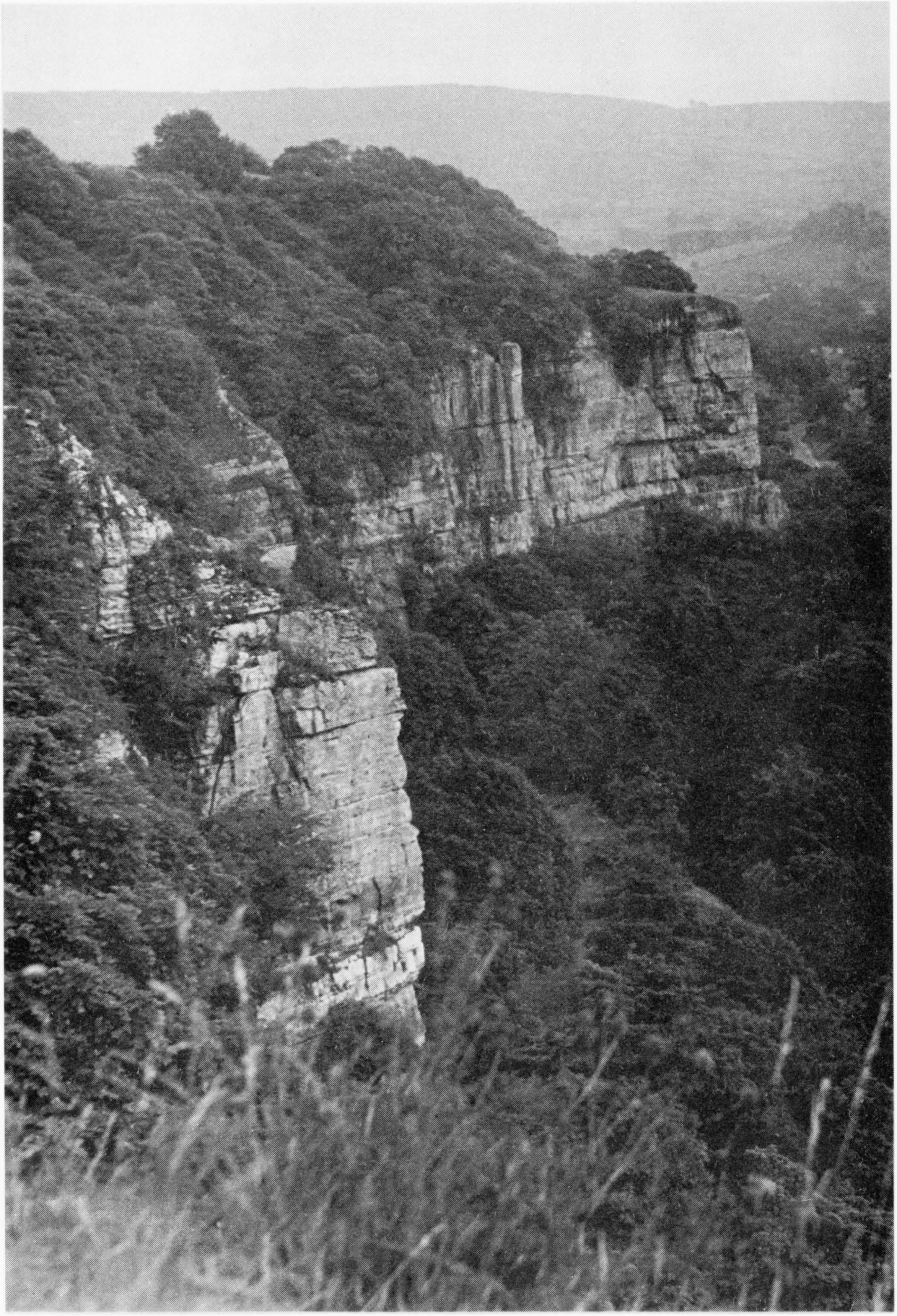
If the prevention of uniclinal shift by reef-knolls has been the prime factor in siting the gorges, are there other factors which have enhanced the gorges? And can the obvious differences between some gorges with rivers and some without be explained? Taking the second question first, in most of those cases where the rivers run through the gorges either or both of two factors operated. Either sheets of basaltic lavas and ashes (toadstones) occur at or just below the valley floor and, being impervious, prevent loss of water to the subsurface. Alternatively there has been interference with the natural situation by man. In the Matlock Gorge, there are several toadstones and they form natural barriers to subsurface drainage beneath the valley floor, but in Bradwell Dale, the highest toadstone is about 200 feet below the valley floor, and drainage is underground via the passages of Bagshaw Cavern (Ford *et al.* 1975). Bradford Dale and lower Lathkill Dale have toadstone close beneath the river bed, for at least part of their length, and much of the stream channel is articially aligned and sealed with clay to minimize seepage into lead mines. The stream in Stony Middleton Dale is mostly discharge from lead miners' drainage soughs. The River Manifold goes underground for most of the year, but the Dove stays on the surface, though this may be partly due to the small dams and clay-puddled pools put in to "improve" the fishing. These distinctions between gorges with streams, and those without are only matters of present day drainage and they have no bearing on the origin or formation of the gorges.

However, a factor which probably had some effect on the rate of incision of the gorges is the extent to which underground drainage became established. In spite of the presence of toadstone barriers in the Matlock Gorge today, at high levels early in the incision history, there were phreatic cave systems oriented more or less along the strike but these were subsequently choked by fluvioglacial outwash before many integrated vadose stream caves could develop. Relics of these choked caves can be seen in the numerous mines on the west slopes of the Gorge. Thus, an inherent weakness in the limestones, in the form of caves, now mostly sand-filled, may have been exploited by the River Derwent during early stages of incision. This is not to say that any part of the gorge is, or ever was, an unroofed cave system but downcutting would have been more rapid if pre-existing caves were encountered in the river bed. There are scattered caves with what appears to be fluvio-glacial sediment in Bradwell Dale but their relationship to the early incision of the gorge is far less obvious and they were probably not a significant factor in incision.

More striking is the complex dry valley network converging on Bradwell Dale, evidence of a high rate of run-off in periglacial conditions; similar networks can be seen to converge on most Derbyshire limestone dales, and the larger the potential catchment the deeper the dale. The River Derwent in the Matlock Gorge has the largest catchment, and the Gorge is the deepest and most impressive. The catchment also includes the Wye Valley which had an important ice tongue (Straw 1968) providing melt-water which doubtless enhanced the rate of incision. The proglacial lake suggested by Smith *et. al.* (1967) as accumulating in the Darley Dale area at this time could only have held up downcutting temporarily and is unlikely, in itself, to have been a prime factor in the incision of the gorge. A much more important



Text-fig. 3. Sketch map to show the River Dove meandering between the main reef limestone masses.



Stony Middleton Dale looking east from the west end of Shining Cliff to Castle Rock and the Derwent Valley. (Photographed by J. Travis)

factor was the more rapid downcutting of the Derwent downstream of the gorges as shown by the lower terraces described by Waters & Johnson (1958). This adjustment to lower base levels during the later Pleistocene has resulted in knick-points which have not yet had time to migrate far upstream of the gorge.

When incision takes a gorge below the level of the reef-knolls, which initiated the process, if a gently graded thalweg to a stable external base level is reached, then vertical incision may be replaced by lateral slope retreat and the reefs may be either undermined, with collapse ensuing, or they may just weather back. No examples of landslipped reef-knolls have been found, but a few have reached what may be described as geomorphological instability, and may slip one day.

Chronology of anomalous gorge development

Absolute dating of gorge development is impossible owing to the lack of firm dates for Pleistocene events in the area, but a partial relative chronology can be proposed. None of the anomalous gorges contain till, loess deposits or silty drift (a mixture of loess with insoluble residues), though these occur on the interfluves. The last widespread glacial advance is thought to have been in the Wolstonian (Waters & Johnson 1958) but loess was probably deposited in the Devensian, under periglacial conditions. Loess and silty drift are easily erodable and if deposited in the gorges, could very easily have been removed by run-off in later Devensian times. Thus, present gorge development can only be established as post-Wolstonian, though of course, there may have been earlier phases for which no evidence survives.

Although the Matlock Gorge still has a river and is presumably still being incised, Bradwell Dale is dry and Bradford Dale only has a very small intermittent stream (held up by artificial dams). In the latter two cases, incision could only have taken place under conditions of high run-off and only the periglacial melt-waters of late Wolstonian or Devensian times would have had the necessary power.

Some of the gorges have high-level caves choked to varying degrees with sediments probably originating as outwash from the Wolstonian ice or from reworked earlier outwash gravels. No loess or far-travelled erratics have been recognized in these caves though no sedimentological studies are known to have been carried out. As the caves themselves clearly pre-date incision, they are probably pre-Wolstonian, but their fill is late or post-Wolstonian, and incision has taken place since then.

Thus, all that can be deduced is that the incision of the gorges as they are seen today is either of late-Wolstonian or of Devensian date. Some modification is still going on, particularly in those gorges with active rivers, but in general, the development of anomalous gorges is a relatively young feature of the landscape.

Conclusions

To summarize, the Matlock and Bradwell Dale gorges can be demonstrated to have resulted from superimposition of rivers from a former cover of shales and younger rocks onto the limestone, followed by uniclinal shift down the dip slope until trapped by projecting knolls of reef limestone, particularly well-developed on the Masson Hill and Bradwell Dale anticlines.

A similar sequence of events is true for the development of some other Derbyshire Dales, notably Bradford Dale and Stony Middleton Dale. With modifications, the same factors seem to have operated in Dovedale and the Manifold Valley. Additional factors in the incision of the gorges include the possible presence of solutional caves, with or without fluvioglacial infills, the size of former catchments as indicated by dry valley networks, melt-water run-off from the Wye Valley glacier and the adjustment of the lower course of the Derwent to progressively falling base-levels.

Acknowledgements

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