THE ORIGIN AND SIGNIFICANCE OF DRY VALLEYS IN SOUTH EAST DERBYSHIRE

by

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Summary

Dry valleys occurring within the Triassic lowlands of south-eastern Derbyshire are described and their significance discussed. The valleys dissect patches of Wolstonian glacial drift present on the higher ground, and are frequently infilled with 'head' deposits of presumed Devensian age. Particular attention is focussed on a system of dry scarp-face valleys near Dale Abbey, and an attempt is made to trace the physiographic evolution of this restricted area. It is concluded that the valleys were formed largely by meltwater activity in a late Pleistocene periglacial environment. The suggestion is made that niveo-fluviatile processes played an important role in the evolution of south Derbyshire's landscape.

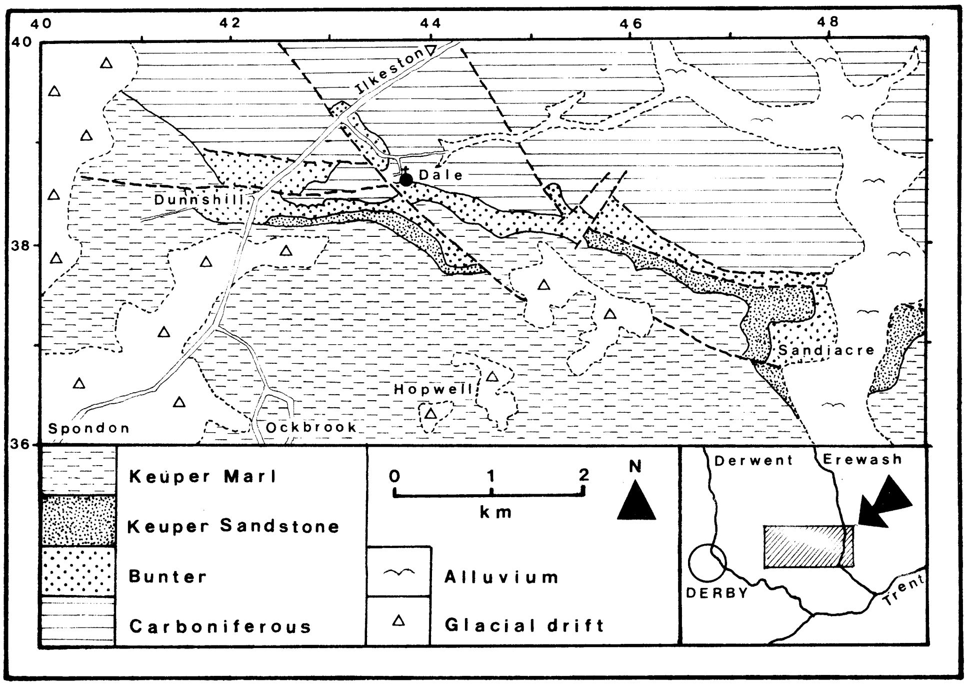
Introduction

A characteristic feature of the south Derbyshire landscape is its intensely dissected nature. Between the four major valleys occupied by the Rivers Dove, Derwent, Erewash and Trent occur extensive drainage networks which affect almost every part of the region. Many of the tributary valleys are either dry or contain misfit streams. Clearly these are indicative of changing hydrological conditions. Elucidation of the reasons for such changes is important to our understanding of the area's physiographic evolution.

In attempting to explain the extensive dry valley systems to be found on the Carboniferous Limestone outcrop of central Derbyshire, Warwick (1964) concluded that the valleys were initiated on overlying impermeable rocks and were subsequently superimposed. He further suggested that intermittent rejuvenation of the main valleys led to progressive elimination of the tributaries, many of which were left hanging. It was thought that much of this adjustment took place before the Pleistocene Period, and that only minor modification was caused by the succeeding glacial or periglacial episodes.

The results of a recent field survey (Jones 1976) of the district south of the Carboniferous outcrop appear to conflict with these views. Here, the scattered distribution of till deposits on the interfluves, as well as the frequency of minor valley incisions, suggests that the area has been subject to considerable subaerial erosion since it was last deglaciated (i.e. during post-Wolstonian time; cf. Shotton 1973). In an attempt to assess the extent and significance of post-Wolstonian dissection in south Derbyshire a sample study has been made of a relatively small area. That selected for specific analysis lies immediately to the east and north-east of Derby and forms the southern part of the Derwent-Erewash interfluve (text-fig.1). It is an area of Triassic bedrock bounded in the north by the Carboniferous outcrop and in the south by the valley of the River Trent. Within this area attention has been focussed particularly on the system of dry valleys occurring along the Dunnshill (SK 419385) - Dale Abbey (SK 443385) escarpment (see text-figs. 2 and 3) as it is believed that these are typical of similar features developed elsewhere. The origin and significance of the dry valleys is discussed below.

Mercian Geol. Vol. 7, No. 1, 1979
pp 1 - 18, 9 Text-figs., Plates 1 and 2.



Text-fig. 1 General geology of the Dale Abbey area.

Description of the study area

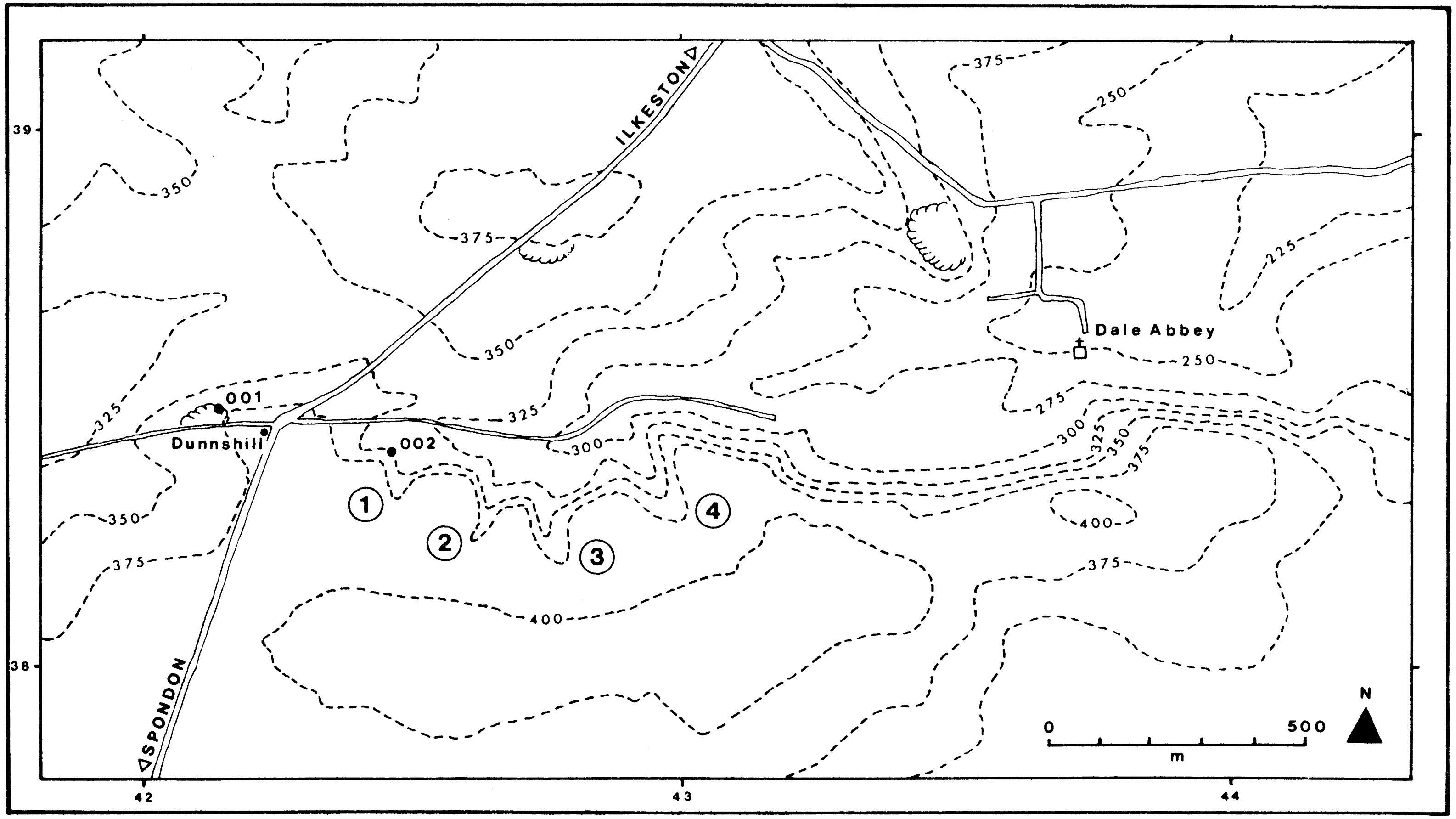
Geology

The bedrock over most of the area outlined above is Keuper Marl, but sandstones of Bunter and Keuper formations outcrop in a sinuous belt extending from Breadsall (SK 3639) in the west, to Sandiacre (SK 4736) in the east. Lithological descriptions of these rocks have been given by Gibson *et al.* (1908), Swinnerton (1948a) and Taylor (1966, 1968), and the local stratigraphical succession is illustrated in text-figure 3.

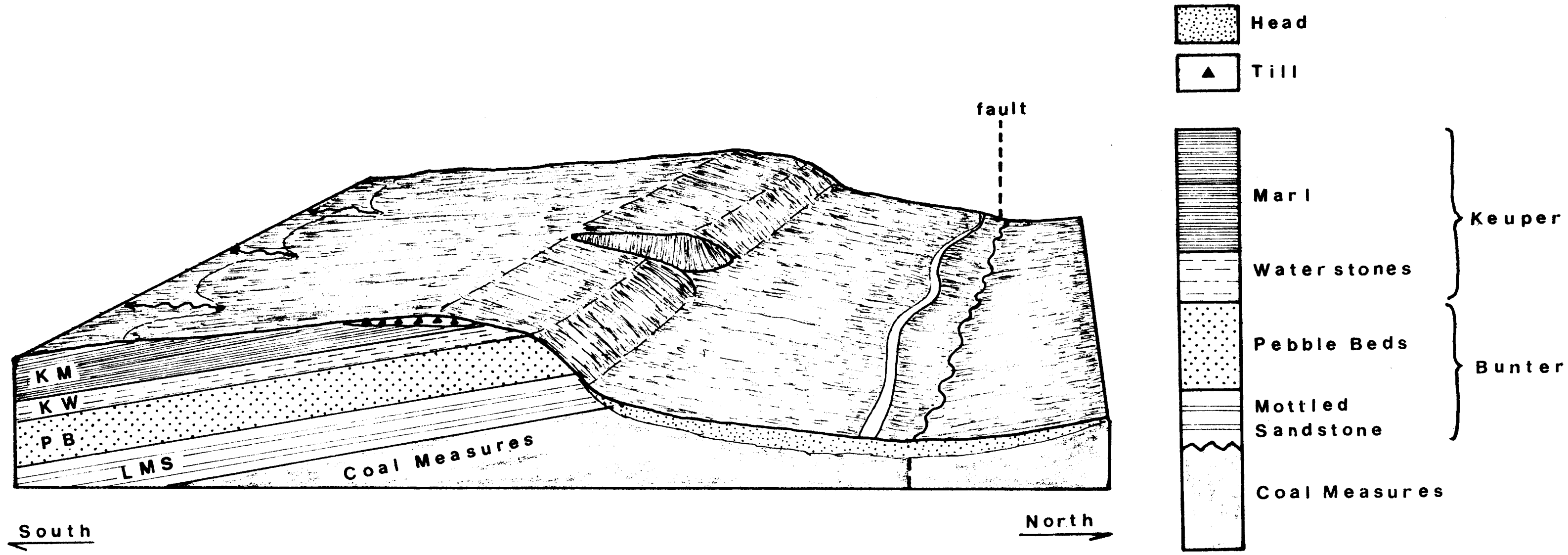
The superficial deposits include the scattered remnants of a formerly extensive till sheet of northern (Pennine) derivation (Jones 1976). Glacial deposits of eastern ('chalky') derivation which overlie Pennine tills in the Trent Valley further south (Deeley 1886, Posnansky 1960) are absent, with the exception of an isolated patch at Risley (Swinnerton 1948b). The Pennine and Chalky Tills appear to be penecontemporaneous (see, for example, Douglas 1974) and both are probably of Wolstonian age (cf. Shotton 1973). Thus the virtual absence of chalky drift on the interfluves, and its presence beneath alluvial deposits in the main river valleys (Jones 1976), must be indicative of a considerable degree of post-Wolstonian erosion on the higher ground. The occurrence of surficial flints in solifluction deposits on the interfluves may also be cited as evidence for the late-Pleistocene degradation of a former cover of chalky drift.

Physiography

The general form of the central part of the Derwent-Erewash interfluve lying between Dunnshill (SK 4238) and Borrowash (SK 4134) is that of a cuesta (text-fig. 3; Plate 1, fig. 1). It has a steep north-facing scarp face aligned E-W and a more gentle southwards-inclined dip slope. Both the Bunter Sandstone outcropping on the scarp face, and the Keuper Marl forming the dip slope, are strongly dissected by minor valleys to the extent that the overlying glacial drift is restricted to isolated patches lying mainly on the higher ground. The overall morphology of the Keuper dip slope may be seen from Ockbrook Corner (SK 418372) on the main Spondon to Ilkeston road (see text-figs. 1 and 4). The road is located on the most elevated part of the dip slope and coincides with a local watershed which separates the minor drainage basins of Chaddesden Brook in the west from the Ock-Brook in the east, (text-fig. 4). Despite the



Text-fig. 2 Location of dry valleys (numbered 1-4) on the Dunnshill-Dale Abbey escarpment.



Text-fig. 3. Schematic block diagram to illustrate the physiography of the Dale Abbey area.

LMS = Lower Mottled Sandstone PB = Bunter Pebble Beds

KW = Keuper Waterstones KM = Keuper Marl extensive dissection of the ground, the general southward slope of the land surface towards Ockbrook (SK 4235) and Borrowash (SK 4134) is quite apparent. Further east, on the opposite (eastern) side of the Ock-Brook drainage system, the higher ground around Hopwell (SK 4336) makes a marked topographic feature. This may partly reflect the presence of a persistent and comparatively resistant skerry band in the Keuper Marl, but it is also clear that the area is a residual part of the 'initial' surface before this was extensively dissected by the Ock-Brook and more easterly Golden Brook drainage networks. Clayton (1955) depicted the elevated ground at Hopwell as representing a pre-glacial erosion surface remnant, but in view of the capping of till this suggestion must be regarded as rather unlikely.

Drainage

The impermeability of the Keuper Marl is suggested by the abundance of small streams draining the dip slope. During seasons of low rainfall, as for example the summers of 1975 and 1976, the streams become considerably diminished and often dry up completely in their upper reaches. Normally, surface water becomes noticeable between the 90 m and 105 m contour lines and, below this altitude, the streams are permanent under present climatic conditions. Above 90 m O. D., the streams are intermittent and occupy ill-defined depressions in the ground surface. Many of these natural depressions have been utilised by farmers for the excavation of land-drainage ditches. The overall pattern presented by the system of drainage ditches and natural channels is typically dendritic (text-fig. 4), the various tributaries ultimately uniting to form a single southward flowing 'consequent' stream (i.e. accordant with the bedrock dip) which, at Borrowash, occupies a deep incision in the Keuper Marl.

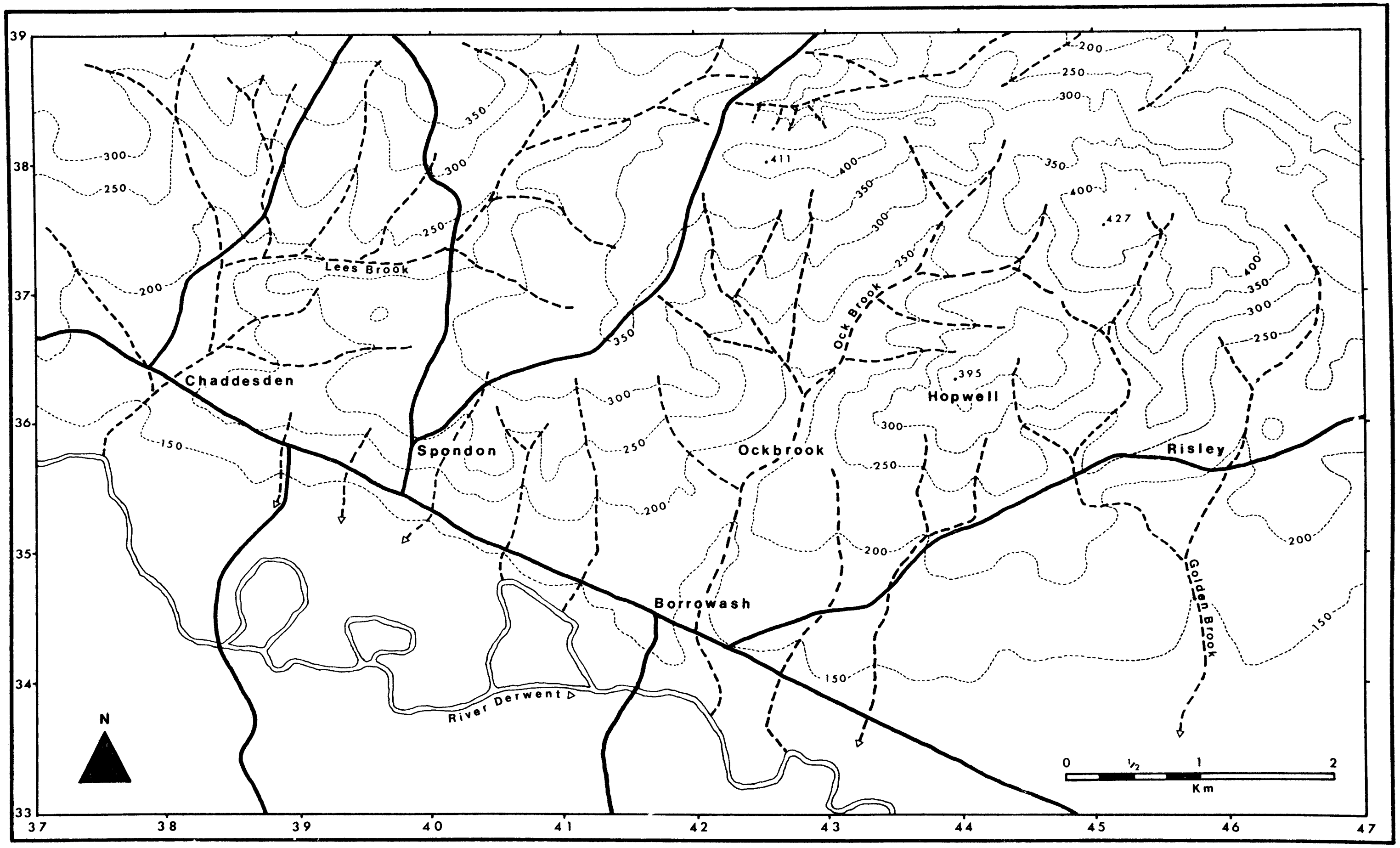
The Dunnshill-Dale Abbey escarpment and its associated dry valleys

Morphology

The road from Ockbrook Corner to Dunnshill is aligned almost parallel to the maximum slope of the ground and rises 15 m in approximately 1 km. At Dunnshill it crosses the faulted outcrop of the Bunter and passes on to the Coal Measures, (text-fig. 1). The Bunter outcrop at Dunnshill gives rise to a minor ridge, up to 7 m high, which dies out westwards in the direction of Locko Park (SK 4038). This disappearance may be due to a combination of causes including faulting, the westward thinning of the Bunter formation, and the unpenetrated blanket of till on Chaddesden Common (SK 3938). Eastwards from Dunnshill, the ridge increases progressively in amplitude, and at Dale Hills (SK 432383) becomes a prominent north-facing scarp face over 30 m high. This feature continues as far as Woodpecker Hill (SK 443384), but further east it is locally offset where the Bunter Sandstone is displaced by a series of NE-SW faults, and in some places the ridge is absent altogether.

Between Dunnshill and Dale Abbey (SK 4338) the continuity of the escarpment is broken only by the presence of four scarp-face dry valleys (text-fig. 2; Plate 1, figs. 1 and 2) and a number of less conspicuous surface depressions. The valleys are short, show incipient meanders, and look relatively youthful. They have steep sides but comparatively flat floors, particularly in their lower reaches (Plate 1, fig. 2). The longitudinal profiles show a rapid increase in gradient upwards causing the overall valleys to terminate abruptly when traced towards the escarpment crest. Morphological details of the Dale Abbey valleys are summarised in table 1 and text-figure 5. Although smaller, these dry valleys show many similarities to dry valleys described by Sparks and Lewis (1957) from the Chalk escarpment near Pegsdon in Hertfordshire.

At the base of the Dunnshill - Dale Abbey escarpment the ground surface slopes gently northwards, at approximately 4°, to a dry scarp-foot valley incised along the line of a fault (text-figs. 1 and 3). This valley increases in size eastwards, and at Dale Abbey contains the small 'misfit' stream of Sow Brook which is a tributary of the River Erewash. It seems clear that the westward extension of Sow Brook to Dunnshill and the associated scarp face tributaries formed part of a previously more extensive drainage system which, for the reasons discussed below, has considerably diminished in importance.



Text-fig. 4 Drainage pattern on the south-eastern part of the Derwent-Erewash interfluve.

Development of the escarpment

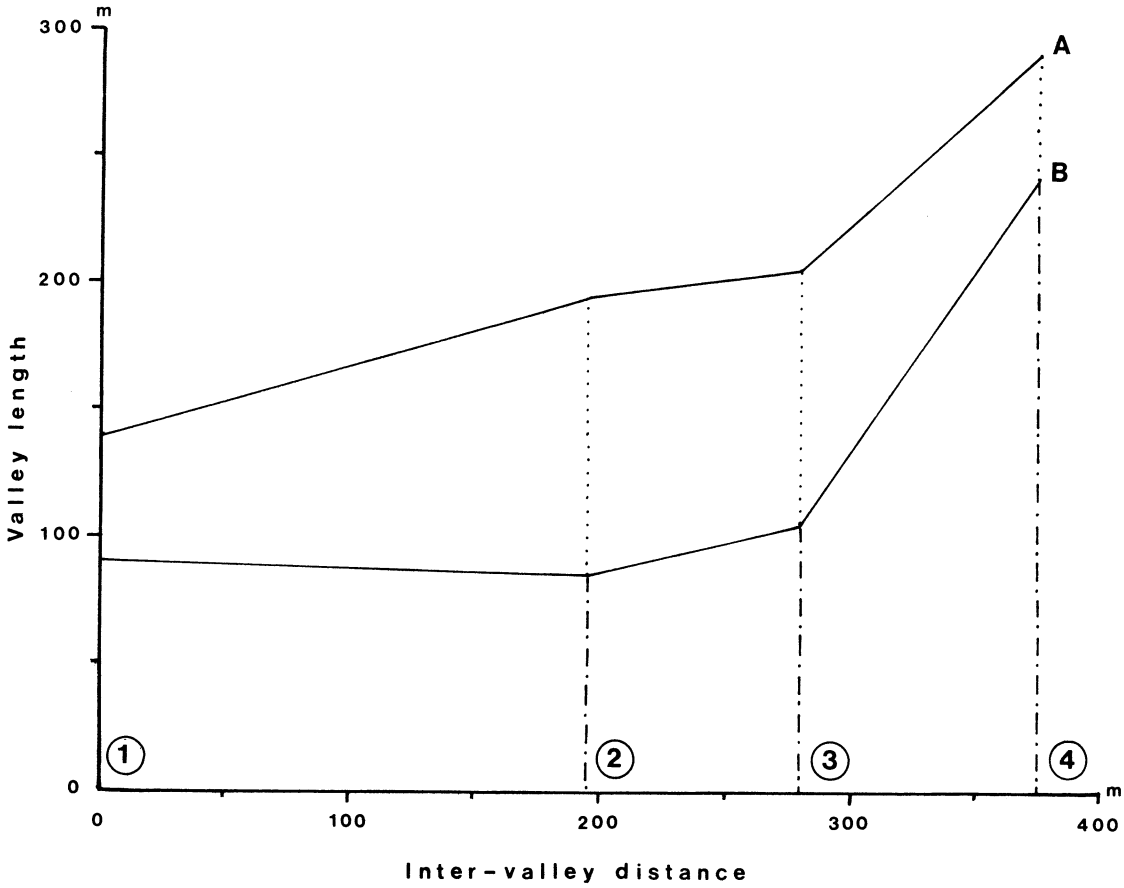
If it is conceded, as has been implied already, that the scarp-face valleys were cut by running water, it might appear that the only real problem is to explain why the streams have disappeared. However, in attempting to account for the presence of dry valleys in the Dale Abbey area it is apparent that certain other factors need to be considered. In particular, the origin of the valleys, as well as that of the escarpment itself must be established. As these features clearly result from processes no longer operative they provide an important clue to an understanding of Pleistocene landscape evolution.

With regard to the escarpment, there would seem to be a number of factors contributing to its presence. There is a close relationship between the alignment of the scarp face and the adjacent fault: both have a general E-W trend and the scarp face departs markedly from this line only at the openings of the dry valleys (text-fig. 5). However, it is unlikely that normal differential weathering of the faulted strata is the primary cause of the escarpment since west of Dunnshill, where down-faulted Keuper Marl lies abruptly against the lithologically distinct Bunter Sandstone, there is little consequent topographic expression. The progressive increase in amplitude of the escarpment east of Dunnshill is suggestive of vertical erosion by an active tributary of the River Erewash lengthening its course by headward erosion. The fault provided a line of weakness which the stream utilised, and it is notable that the present day course of Sow Brook coincides with the line of the fault for part of its length. While vertical erosion by the scarp-foot stream may have accentuated the height of the feature, the subsequent preservation of the escarpment appears to have resulted from a change in hydrological conditions coupled, perhaps, with the effects of a protective capping of impermeable Keuper Marl and Waterstones and the present day vegetation cover.

This interpretation of the initiation of the Dunnshill-Dale Abbey escarpment implies that the present scarp-foot stream, Sow Brook, was formerly more active. The ability of a vigorous subsequent stream to perform vertical, and hence headward, erosion is well known (Small, 1970 p. 236; Sparks 1972 p. 140). In the case of Sow Brook, rapid erosion of this type would have been largely dependent upon a falling base-level. Its immediate base-level is, of course, the River Erewash. This river may be regarded, on a local basis, as a consequent stream for it is aligned parallel with the regional dip of the Triassic rocks, and has a discordant relationship with the underlying Coal Measures on to which it was probably superimposed. The Erewash, in turn, is dependent upon the River Trent, along which evidence of late-Pleistocene rejuvenation is to be found in the form of river terraces and buried channels (cf. Posnansky, 1960). It is known that negative movements of sea-level during the Pleistocene period were substantial and relatively rapid (cf. Mitchell 1977). Consequently, even the more distant tributaries of the Trent may have been quite quickly affected. The incision of Sow Brook and the resultant accentuation of the Dunnshill-Dale Abbey escarpment probably took place in response to such a period of rejuvenation.

Initiation of the scarp-face valleys

At some stage during its development, the Sow Brook subsequent stream appears to have acquired its own tributaries from the higher ground of the escarpment. These scarp-face valleys conform to the definition of 'obsequent' for they are inclined in a direction opposite to both that of the consequent stream (cf. Davis, 1909) and the geological dip of the beds (cf. Sparks, 1972 p. 10). Originally, they may have developed as seepages in a similar manner to that described by Dury (1959, p. 21). Water percolating through the permeable Bunter Sandstone would have seeped out at the junction with the impermeable mudstone bands in the underlying Lower Mottled Sandstone (text-fig. 6). The seepages developed into springs which, by gradually washing away detritus, worked back into the scarp face to become minor streams. Once channels had been developed these would have acted as preferential routes for rivulets during periods of abundant surface run-off and hence the scarp face valleys may have become established.



Text-fig. 5. Explanation opposite, p. 9, top.

MORPHOLOGICAL DETAILS	VALLEY NUMBER (see text-fig. 2)			
	1	2	3	4
Length to scarp face (m)	85	84	103	242
Length to scarp-foot stream (m)	137	191	203	290
Distance : scarp to stream (m)	52	107	100	48
Distance between valleys (m)		194	84	101
General alignment	168°	200°	187°	142°
Average inclination of valley floors	8°	8°	7°	7°
Average slope of valley sides at mouth of valley	22°	23°	26°	25°
Average slope of valley sides at mid-point of valley	24°	25°	28°	25°

Table 1. Morphological details of four scarp-face dry valleys occurring along the western part of the Dunnshill-Dale Abbey escarpment.

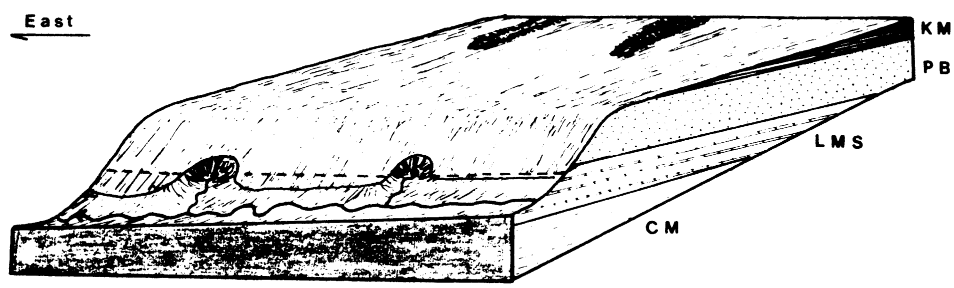
Text-fig. 5 (opposite p. 8, top.)

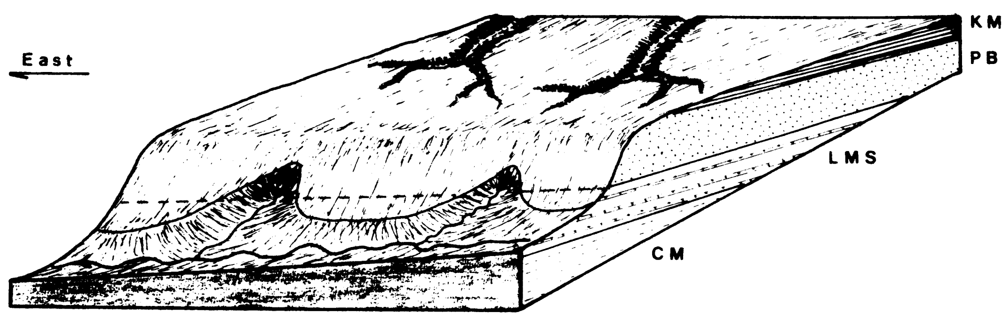
Graph relating the horizontal spacing of the four dry scarpface valleys to their individual lengths (valley meanders are not indicated).

A - Fault-line stream (Sow Brook continuation) which probably represents the original position of the scarp face.

B - Present scarp-face position.

1, 2, 3, 4. Lengths of dry valleys to stream (A) and present scarp face (B) shown in sequence from west to east.





Text-fig. 6

Possible origin of the scarp-face valleys as groundwater seepages. (for explanation see text)

CM = Coal Measures, LMS = Lower Mottled Sandstone,

PB = Bunter Pebble Beds, KM = Keuper Marl and Waterstones.

EXPLANATION FOR PLATE 1

figure 1 — General view of the Dunnshill-Dale Abbey escarpment. The marked indentation in the scarp face is caused by emergence of dry valley No. 3 (see text-fig. 2). Terracettes and solifluction hummocks are visible on the lower slopes of the main scarp face.

figure 2 — Dry valley in the Dunnshill-Dale Abbey escarpment. This is the most westerly of the four scarp-valleys shown in text-fig. 2. The valley floor is infilled by solifluction material.

fig. 1

fig. 2

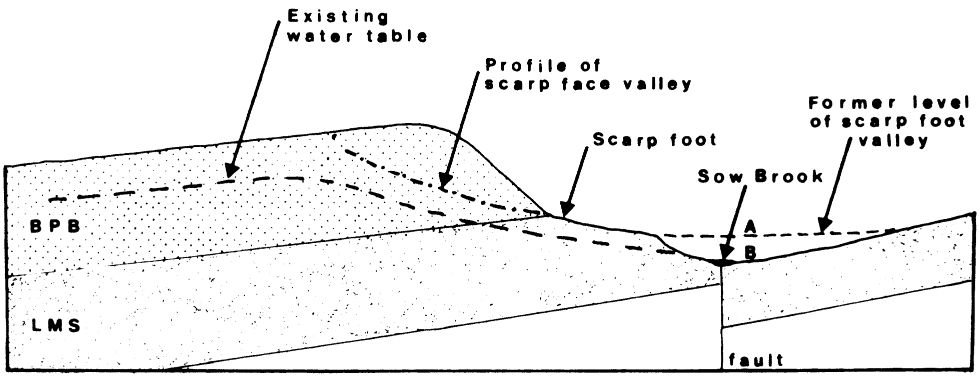
JONES, P. F. - Dry valleys in S. E. Derbyshire

The weakly cemented Bunter Sandstone would have been particularly susceptible to spring 'sapping' and stream erosion of this type. In the absence of a protective cover of vegetation the overall process would have been even more effective. This is apparent at the present day in places where the vegetation cover has been removed as a result of human activity. The loose surficial layers are quite rapidly eroded leaving a bare-rock surface which is subject to direct subaerial activity. Continued rainwash causes erosion channels and gullies to be cut into the sandstone, and during heavy rainfall, sand-flows occur which result in the deposition of detritus as fan-shaped masses at the base of the affected slopes. Examples of recent activity of this nature have been seen in the old quarry at Dunnshill (text-fig. 2, Loc. 001) and adjacent to the most westerly scarp face valley (text-fig. 2, Loc. 002) where the present rate of erosion seems to be remarkably rapid. As soil is washed away, the vegetation of immediately adjacent areas is undermined and eventually removed, thus progressively increasing the size of the affected parts.

Reasons for the valleys becoming dry

The theory outlined above accounts for the presence of the scarp-face valleys and explains why they increase in size towards the east: as Sow Brook lengthened its course by headward recession towards Dunnshill, the most easterly valley would be formed first followed, in sequence from east to west, by the other three. The more easterly streams were thus in existence for a greater period of time and consequently their valleys are longer and deeper. There remains, however, the problem of the present state of dryness.

Of the several hypotheses that have been advanced to explain why valleys run dry during the normal course of erosion (see, for example, discussion by Sparks 1972, pp. 206-14), that developed from the ideas of Chandler (1909) and Fagg (1923, 1939) is the most appropriate for the Dale Abbey situation. The essence of this hypothesis is that as valleys bordering an escarpment are deepened following rejuvenation, the ground water table is progressively lowered so that springs on the scarp face run dry and the emergent streams cease to flow (text-fig. 7) This hypothesis appears to demand that the escarpment remained stationary throughout



Text-fig. 7 Possible application of Fagg's hypothesis to the dry valleys occuring along the Dunnshill-Dale Abbey escarpment. Before rejuvenation the scarp face valley was graded to the scarp-foot stream occuring at level A. After rejuvenation the scarp-foot stream lowered its floor to position B. Consequent lowering of the water table has resulted in the scarp-foot valley being left dry. (cf. Sparks, 1972 p. 207).
LMS = Lower Mottled Sandstone, BPB = Bunter Pebble Beds

the process and that down-cutting by the scarp-foot stream was relatively rapid (cf. Sparks 1972, p. 207). It also implies that the valleys became progressively dry from their heads downwards.

Various factors suggest that the Chandler-Fagg hypothesis is not applicable to the valleys described in this paper. These are located near the source of a former scarp-foot stream where any down-cutting resulting from rejuvenation would have been negligible. Although very little recession of the Dale Abbey escarpment seems to have taken place (text-fig. 5), there is no evidence in the longitudinal profiles of the valleys to show that a succession of springheads migrated down-valley. It is notable that the River Erewash is itself a misfit stream and does not appear to have been responsible for the desiccation of its tributaries. Moreover, the fact that misfit streams are common throughout the entire area suggests that there must have been a much greater volume of surface run-off during the recent past and a subsequent change in hydrological conditions. An alternative explanation for the Dale Abbey dry valleys is thus required.

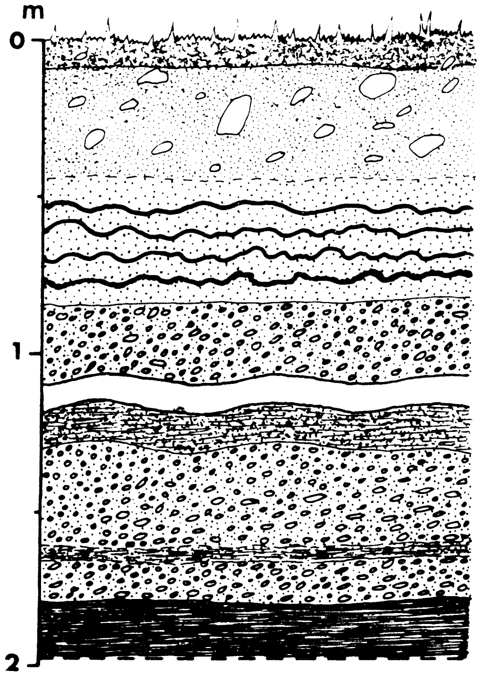
Reid (1887) suggested that certain dry valleys in the permeable Chalk of southern England could be attributed to meltwater flow during the Pleistocene Period. It was envisaged that the valleys formed under permafrost conditions when the bedrock was rendered impermeable through being frozen and seasonal run-off was restricted to the surface. Like southern England, South Derbyshire was not directly glaciated during the last (Devensian) cold stage and the area was subject to a prolonged period of periglacial activity. It seems likely that surface run-off resulting from seasonal melting of the upper ground layers would have been extremely effective in eroding the weakly cemented Bunter Sandstone. Such a mechanism would certainly account for the steep longitudinal profiles of the valleys which the theory of receding spring fails to do. It is possible, of course, that the valleys were initiated by spring sapping, but were subsequently modified by meltwater in the way described.

Against the meltwater hypothesis of dry valley formation must be set the conflicting views of Dury (1959 p.33, 1965) who suggested that many dry valleys in the Chalk were formed during periods of greater precipitation. Dury's evidence for this contention is derived from the existence of surface streams in some of the valleys following unusually heavy rainfall. It is notable that the most easterly dry valley at Dale Abbey also occasionally contains a trickle of water, and a small winding gully is present along its floor. Thus some consideration must be given to the possibility that the Dale Abbey dry valleys developed under a much wetter climatic regime and are not related to permafrost. There is, however, little independent evidence for a prolonged period of increased rainfall. By contrast, the effects of Pleistocene periglaciation are moderately well known (Worsley 1977). Furthermore, there are other positive reasons for believing that the Dale Abbey dry valleys are largely periglacial in origin and these are discussed below.

Evidence of periglacial action

Temporary exposures in the vicinity of Dale Abbey and elsewhere have revealed superficial deposits of periglacial type which are much more extensively developed than might be assumed from the limited amounts of 'head' portrayed on existing geological maps. Without such exposures, interpretation of these deposits would have been difficult. Because of their lithological resemblance to the subjacent bedrock, they have often been regarded as *in situ* regolith. However, the superficial deposits are normally crudely stratified and display other structural differences. At many localities in the region the deposits have been dissected by streams and they do not appear to be forming at the present time. There can be little doubt that these deposits are the product of mass-wasting under a climatic regime different from that operative today, and it is inferred that they are related to periglacial activity during the last (Devensian) cold stage of the Pleistocene period (Waters 1969, Jones 1976).

The subdued ridge of Bunter Sandstone at Dunnshill is capped by a thin layer of unconsolidated sand and gravel comprising a concentrate of rounded quartzite pebbles. Similar pebbles occur in the underlying bedrock but are sparsely distributed. The deposit may be examined in the old quarry alongside the bridle-road to Locko Park, 100 m west of Dunnshill (text-fig. 2, Loc. 001). A more extensive exposure was revealed during road and pipe trench excavations in July-August 1972. These excavations displayed a varied sequence of superficial materials dipping sympathetically with the slope of the ground surface. A measured section taken on the north side of the ridge is shown in text-fig. 8. Almost 2 m of unconsolidated pebbly sands with intercalated sandy clays completely obscured the scarp face and rested on a stiff red clay which possibly represented downfaulted Keuper Marl (cf. text-fig. 1). The volume of superficial material present seemed incompatible with the existing low relief of the Bunter Sandstone ridge at this point, and yet the absence of obvious 'erratic' pebbles did not indicate derivation from a former glacial cover. It is suggested that the Keuper Waterstones formation, which overlies the Bunter Sandstone to the south (text-fig. 1), formerly extended north-



Text-fig. 8 Section in solifluction deposits at the foot of the Bunter Sandstone ridge near Dunnshill.

wards to Dunnshill to make a more conspicuous morphological feature. Extensive solifluction on the scarp face would have resulted in the degradation of this feature, and the deposition of the resultant detritus on the lower slopes. Whereas this activity would have been particularly effective in a periglacial environment, subsequent subaerial modification probably continued for some time. It is likely that slopewash assisted in the formation of the existing subdued relief until the process was arrested by vegetation growth.

Although the solifluction deposits and subjacent bedrock on the scarp face and valley sides east of Dunnshill are poorly exposed, they are occasionally revealed where quarrying and recent farming operations have removed the protective vegetation cover. The most extensive exposure currently available occurs on either side of the most easterly dry valley where there is a 200 m section along the scarp face. Here, the bedrock immediately adjacent to the dry valley is affected by minor cambering (Locality 002, text-fig. 2). In the space of only 10.0 m the Bunter Sandstone is downwarped to the extent of at least 1.0 m, and at the same time is strongly affected by a series of downward tapering joints and fissures (Plate 2, fig. 1). Complete detachment and valley-ward tilting of sandstone blocks has taken place along some of the joints (text-fig. 9; Plate 2, fig. 2) so that the arrangement closely resembles a small-scale version of the dip-and-fault structures described by Hollingworth *et al.*, (1944).

The fissures are infilled with unconsolidated pebbly sand which constitutes disintegrated bedrock. No faunal remains have so far been discovered in the sand, but an apparently similar sand-filled fissure at Stapleford, 7 km to the east, was reported by Swinnerton (1945) to contain numerous bones. The bones represented small rodents, birds, frogs and toads, and included a species of lemming and four voles now extinct. A comparable fauna has been recovered from Langwith Cave, 16 km north of Stapleford, where it was associated with late Palaeolithic implements (Mullins, 1913).

The joints at Dunnshill have a general NNE-SSW alignment, parallel to the trend of the scarp face valley. They are clearly related to the cambering and presumably developed contemporaneously with it. Any suggestion that the valley alignment was predetermined by the joints seems unrealistic in view of their sparse development away from the valley. Moreover, the alignment of these structures does not conform to the pattern of tectonic joints identified in this area by Weaver (1974). Since it is clear that both cambering and fissuring

EXPLANATION FOR PLATE 2

figure 1 — Cambering and gulling of Triassic bedrock near Dale Abbey (cf. text-fig. 9). Bunter Pebble Beds resting on subhorizontal Lower Mottled Sandstone (centre right) are downwarped into a scarp-face valley (extreme left). Immediately adjacent to the valley the Pebble Beds are strongly fractured and some sandstone blocks have become completely detached.

figure 2 — Close-up view of detached blocks of Bunter Sandstone associated with cambering near Dale Abbey (see above). The blocks have a valley-ward tilt indicating their displacement downslope. The gull (centre right) has been infilled with weathered detritus from above (cf. text-fig. 9).

fig. 1

fig. 2

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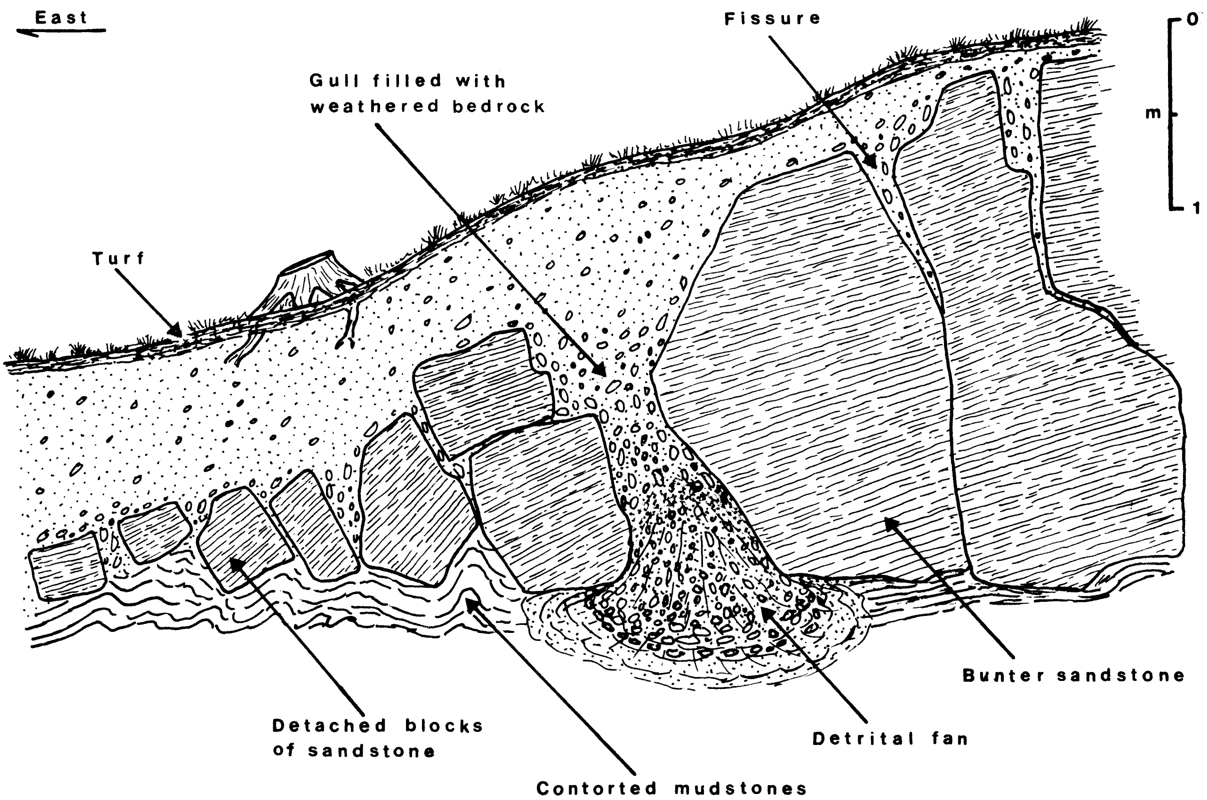

Text-fig. 9 Cambering and gulling of Bunter Sandstone near Dale Abbey (c.f. Plate 2, fig. 2).

occurred in response to instability created by the valley incision, the following sequence of events is postulated:

(1) Initiation of the valley;

(2) Cambering and associated fracturing of bedrock on the valley sides; eventual widening of joints and gravitational collapse;

(3) Weathering and disintegration of surface horizons;

(4) Solifluction or downwash of weathered detritus to infill joints and valley floor;

(5) Initiation of vegetation cover; progressive reduction in the effectiveness of weathering and mass-wasting.

These events are separated only for convenience and it must be emphasised that certain processes probably operated simultaneously.

Although the origin of cambering and associated non-diastrophic structures has been the subject of considerable debate, it is now generally accepted that the majority of documented examples formed in a periglacial environment. Such phenomena appear to be widespread in Derbyshire, and in some cases they occur on a large scale (Buist and Jones 1977). It is not possible to place absolute dates on the sequence of events identified at Dale Abbey. However it seems likely that the processes of valley incision, cambering and solifluction were all intimately associated during the last (Devensian) cold stage of the Pleistocene period.

Interpretation and regional significance

The Dale Abbey valleys may have been initiated as springs during a warmer (interstadial) phase of the Devensian stage, and were subsequently deepened and lengthened by seasonal meltwater flow under permafrost conditions. Eventual melting of the permafrost, and the resultant saturation of the bedrock, would have greatly facilitated cambering and assisted in the mass movement of loose material on the valley sides. As climatic fluctuations since the last (Ipswichian) interglacial are thought to have been considerable (Coope 1975) it is quite likely that suitable conditions for activity of this type occurred on more than one occasion. In north Derbyshire, Waters (1969) has distinguished several 'head' deposits on slopes below 'Gritstone' escarpments, and at Burbage Brook, an intercalated soil horizon (dated 11,590 ± 360 years BP) indicated that periglacial modification of the landscape continued well into Late Glacial times.

Elsewhere in South Derbyshire, dry valleys are found on all types of bedrock in almost every part of the region. Particularly notable are the dry valleys which occur on the Keuper Marl since this rock is sufficiently impermeable to support surface streams under present climatic conditions. Many of these latter valleys are small, shallow features which conform to the definition of 'dells' (Washburn 1973, p.215-6). Examples may be found on the western side of the Derwent Valley north of Derby (e.g. SK 349388) and between Breadsall (SK 3739) and Chaddesden (SK 3837) on the Derwent-Erewash interfluve. They are invariably floored by solifluction material, and many of the larger features are represented on the geological map (Sheet 125, 1972) as trails of 'head'. Some of the valleys are almost entirely infilled with solifluction detritus and are recognised in the field as shallow linear depressions towards which the ground surface slopes gently from either side over a wide area.

It has already been mentioned that the degree of post-Wolstonian erosion in South Derbyshire must have been considerable. Wolstonian glacial deposits on the interfluves have been deeply dissected and so severely degraded that only where they occupy former depressions are they preserved in any quantity. It is suggested here that much of this erosion took place during the Devensian cold stage and that the increased volume of surface run-off was provided by snowmelt and the seasonal thaw of permafrost. The valley incisions probably increased soliflual activity by creating steeper slopes. They would also have acted as gutters in transporting the eroded detritus to the main river valleys to augment the fluviatile sediments (see Jones *et al.* 1979). Solifluction and slopewash would have continued after the streams became inactive, thus creating the valley infills and the present slope morphology, until these processes were retarded by vegetation growth during Holocene times. Such activity probably played a much more significant role in the evolution of Derbyshire's landscape than has been recognised hitherto.

Conclusions

South Derbyshire has been subjected to considerable erosion in post-Wolstonian times. This is reflected in the scattered distribution of tills on the major interfluves and in the frequency of minor valley incisions. The abundance of dry valleys and misfit streams testifies to changing hydrological conditions. Whereas dry valleys on the Carboniferous Limestone outcrop of Central Derbyshire have been attributed to superimposition from an impermeable cover, those on the Permo-Triassic rocks further south are less easily explained in this way and appear to be indicative of a fluctuating climate. The available evidence suggests that the dry valleys of South Derbyshire are largely a legacy of the Devensian periglacial environment, and that niveo-fluviatile processes played an important part in the evolution of the landscape.

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