DRY VALLEYS IN THE REPTON AREA OF SOUTH DERBYSHIRE

by

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Summary

Dry valleys within two adjacent catchments on the Triassic sandstone outcrop of south Derbyshire are described. Two main types of valley are distinguished on the basis of size and morphology. The origin of these valleys is discussed in the light of current views on Pleistocene events in the Middle Trent basin and the growing body of literature concerning dry valley systems in general. It is suggested that several processes have influenced the formation of the dry valleys and that the two main valley types have experienced different histories of formation and evolution.

Introduction

Dry valleys have attracted the attention of geomorphologists for many years. Much of the attention has been focused upon the dry valleys developed upon limestone bedrock, particularly the Chalk of England and France. More recently the wider distribution of such valleys has been recognised. Gregory (1971) and Jones (1979) have both examined dry and misfit valley systems on non-calcarcous rocks includings, for example, Triassic mudstones of relatively low permeability. In fact Jones (1971) drew attention to dry valleys developed upon the Triassic bedrock of the Derwent-Erewash interfluve to the east of Derby. However, a more extensive network of dry and misfit valleys on Triassic bedrock is to be found some 15 km to the south west in the vicinity of Repton (Fig. 1). It is these valleys, which are the subject of the present paper.

The 'Repton' dry valleys are features of the two adjacent drainage basins of Repton Brook and Foremark Brook which cover a total area of 32 km^2. These basins lie between the northern margin of the South Derbyshire Coalfield and the Trent valley draining to the Trent itself. The highest ground, of about 170 m O.D., is found in the Pistern Hills (346 208) at the south eastern margin of the Repton Brook watershed. The ground surface then declines progressively northwards to 70 m O.D. on bluffs overlooking the Trent flood plain. This 'surface' is heavily dissected by the drainage networks of the Repton and Foremark Brooks (Fig. 1), valley incision giving a relief amplitude of 25–30 m. In the upper parts of both basins, but significantly in the case of the more extensive Repton Brook, the Triassic cover has been breached to reveal the underlying Carboniferous strata (Fig. 2). This has been influenced by the southward rise in the base of the Triassic sequence and the wedging out of the Sherwood Sandstone formation in that direction. The effect is to produce a bowl like feature, in the upper Repton Brook basin, which is floored by Coal Measures but rimmed by Triassic sandstones and mudstones on all sides except the north. Here the edge of the main Triassic outcrop forms a low but distinct escarpment which has a height of approximately 30 m between Moxon's Hill (307 219) and Gravel Pit Hill (323 223). The trunk stream of the Repton Brook has cut a gap through this escarpment to the north of Nether Hill (312 217).

Within the main Triassic outcrop the valley floors and lower valley sides of the trunk streams are developed mainly on the Sherwood Sandstone with overlying mudstones and sandstones of the Mercia Mudstone group capping the interfluve areas. Patchy glacial deposits of presumed Wolstonian age (Shotton 1973) also occur on some of the interfluves, notably the more elevated sections to the south. It is with the Sherwood Sandstones that dry valleys are especially associated and the misfit nature of the existing stream network particularly evident. Within the main Triassic outcrops of the two catchments, 61% of the valley length of the Repton Brook network and 54% of the valley length of the Foremark Brook network is permanently dry or takes occasional surface flow in very wet periods.

In the study of these dry valleys field survey of selected valleys was carried out following initial map and aerial photograph analysis. However, much of the fieldwork was concentrated in the Repton Brook basin

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because completion of the Foremark Reservoir by Severn-Trent Water Authority in 1978 has modified a significant section of the Foremark basin.

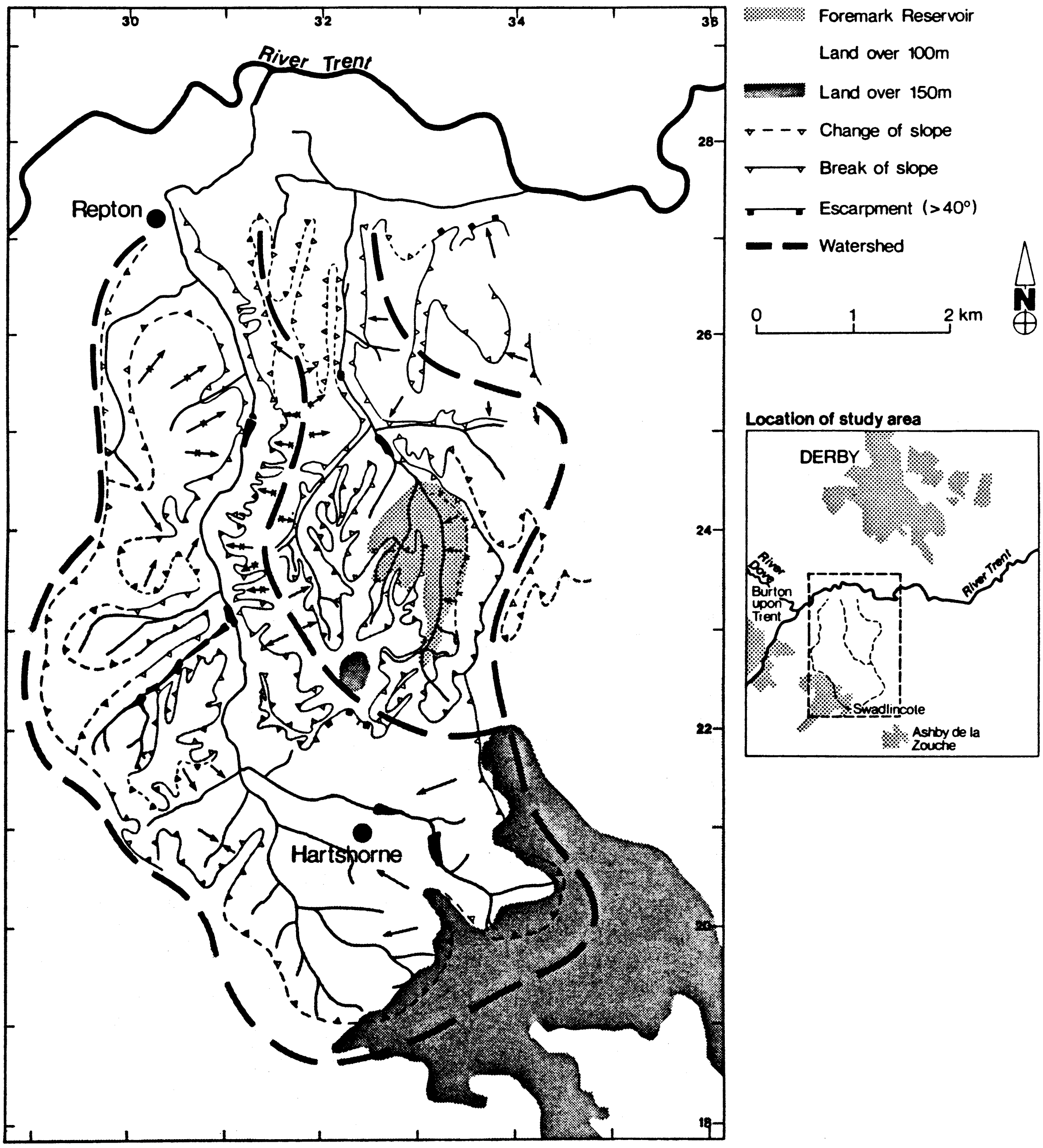

Fig.1. Generalised morphological map of Repton Brook and Foremark Brook catchments.

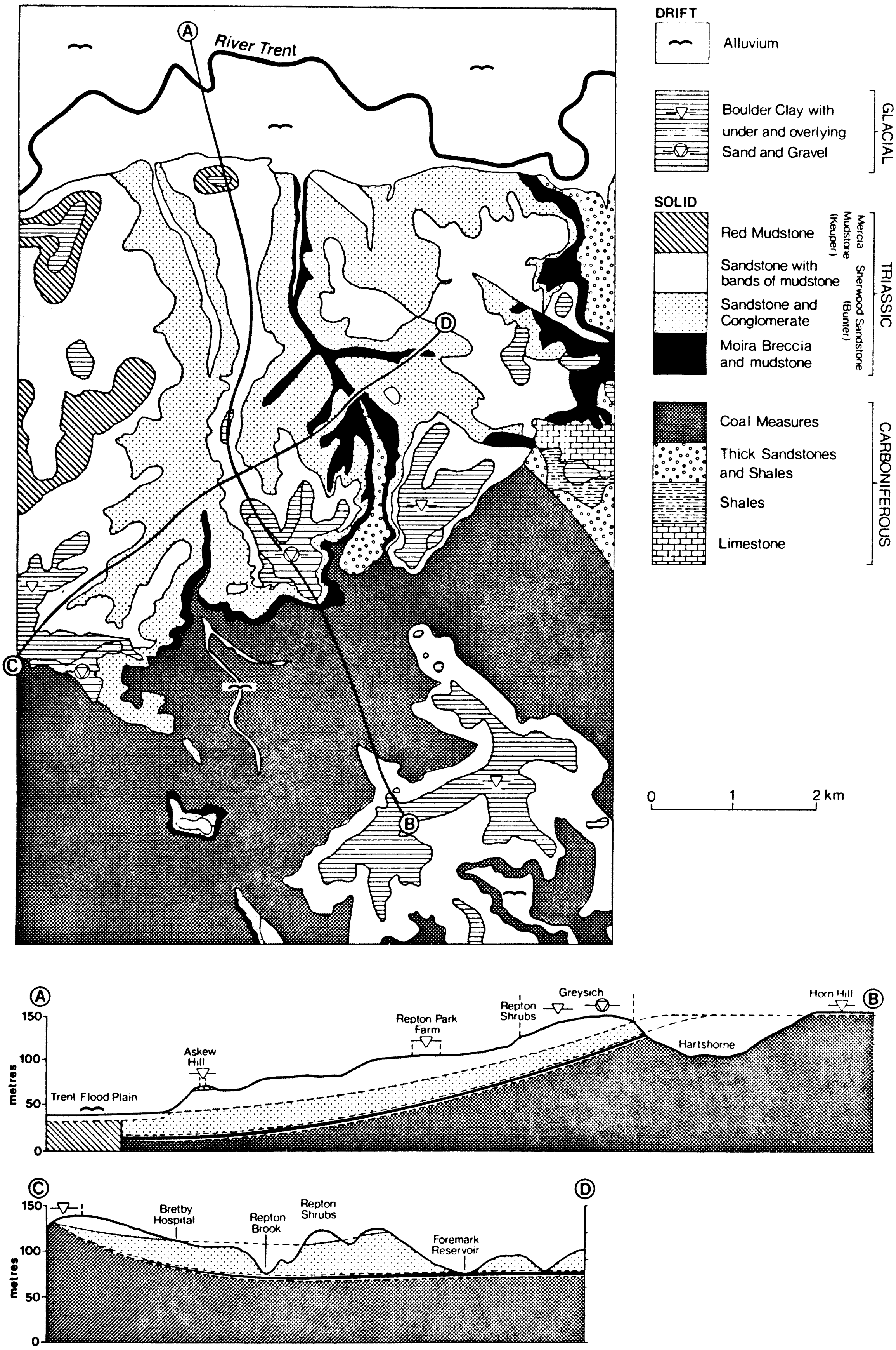

Fig.2. Geology of Repton-Hartshorne area. (Source: Geological Survey Sheet 141 Loughborough).

Dry valley distribution and form

The distribution of dry valleys in the Repton Brook and Foremark Brook drainage basins is shown in Figure 3. It is notable that the dry valleys are confined to the Triassic rocks of the two basins and in particular are associated with the Sherwood Sandstone outcrop. Summary figures for drainage and dry valley densities for the two basins are contained in Table 1 and these illustrate the extensive nature of the dry valleys on the Triassic outcrop. Dry valley densities for the whole of each basin are 1.07 km/km^2 and 1.46 km/km^2 for the Repton Brook and Foremark Brook respectively but when the Triassic outcrop alone is considered these densities rise to 1.99 km/km^2 and 1.52 km/km^2. Such values compare closely with dry valley densities from studies in other parts of Britain both on Triassic sandstones and rocks of different lithologies and age. For example Jones (1965) reports dry valley densities of 1.23 km/km^2 for the Lapworth valley in Warwickshire. Gregory (1971) gives values of 1.12 km/km^2 for the Kenn, Bray, Yeo and Creedy basins in south Devon. All these catchments are to a greater or lesser extent underlain by similar Triassic rocks to those found in the Repton and Foremark basins. Gregory (1976) sampled basins in six areas of Britain with outcrops of other permeable rocks including Chalk, Jurassic limestone and Carboniferous limestone. He found a consistent density of dry valleys with an average of 1.86 km/km^2 and a range of 1.14 to 2.32 km/km^2. Although short term fluctuations in drainage density have been shown to occur, for example by Hanwell and Newson (1970), and Gregory and Walling (1968), it is apparent that a considerable amount of contraction in the drainage net of the two basins has taken place since the formation of the valleys.

Table 1 Network characteristics for the Repton Brook & Foremark Brook basins

	Repton Brook	*Foremark Brook*
Whole Basin:		
Area (km^2)	21.60	10.40
Total valley length (km)	51.70	28.40
Total drainage density (km/km^2)	2.39	2.73
Drainage density of existing streams (km/km^2)	1.32	1.27
Dry valley density (km/km^2)	1.07	1.46
Triassic outcrop:		
Area (km^2)	12.10	9.50
Percentage of area on Triassic sandstone	40.00	45.00
Total valley length (km)	38.70	28.10
Total drainage density (km/km^2)	3.25	2.81
Drainage density of existing streams (km/km^2)	1.28	1.26
Dry valley density (km/km^2)	1.99	1.52

While the overall pattern of dry valleys is significant, the composition of the network also requires close attention. On the basis of scale and morphology, distinct variations can be identified in the valleys which make up the dry valley net, and two main types of dry valleys can be distinguished.

Type I valleys. These are the larger dry valleys of the area. They generally have lengths in excess of 300 m and depths greater than 15 m. They are characterised by steep sides with maximum angles in excess of 25° and mean angles greater that 10° (Table 2). However, in this category two valley sub-types can be recognised. On the one hand, some valleys such as Repton Park Farm Valley 1 (Plate 2A), (Fig. 4A) are relatively short, often a little deeper and in general possess a steepened head. In some case the valley heads open out and bifurcate in a manner reminiscent of the "fish tail" heads of scarp face coombes of the North Downs (Kerney *et al.*, 1964). The resemblance to scarp face coombes is well illustrated by the long and cross profiles (Fig. 4A) though the flat floor typical of many coombes is largely absent. However, other valleys are longer, less steep sided and do not possess the steepened head but often have tributary valleys. Hill Farm valley (Fig. 3) represents a good example of this type. The contrast in length and valley-side slope angle is indicated in Table 2 whilst a flatter valley bottom is suggested particularly in cross profile 2 (Fig. 4B). The frequency distributions of slope angles (Fig. 6) also bring out the differences between the valleys. The Hill Farm valley type more closely resembles in form the valleys presently supporting streams and may be compared with the valley of Watery Lane (309 234) and a second valley containing Bretby Fish Ponds (305 231). Both of these contain small underfit streams fed from the impervious Triassic mudstones on the interfluves. Similar valleys may be found in the Foremark Basin such as that followed in part by Robin's Cross Lane (258 326) and a more substantial valley system running past Loscoe Farm (316 246).

Table 2 Morphology of selected dry valleys

	Length (m)	Depth (m)	Maximum valley side Slope Angle (°)	Mean valley side Slope Angle (°)
I Repton Park Farm Valley 1 (A)*	340	22	30	16.16
I Hill Farm (B)*	550	19	26	12.34
II Six Hills Valley E (C)*	129	7	21	9.35
II Swale (D)*	57	4	13	6.93

*NB The locations of dry valleys are indicated by the letters A, B, C and D in Fig.3 inset.

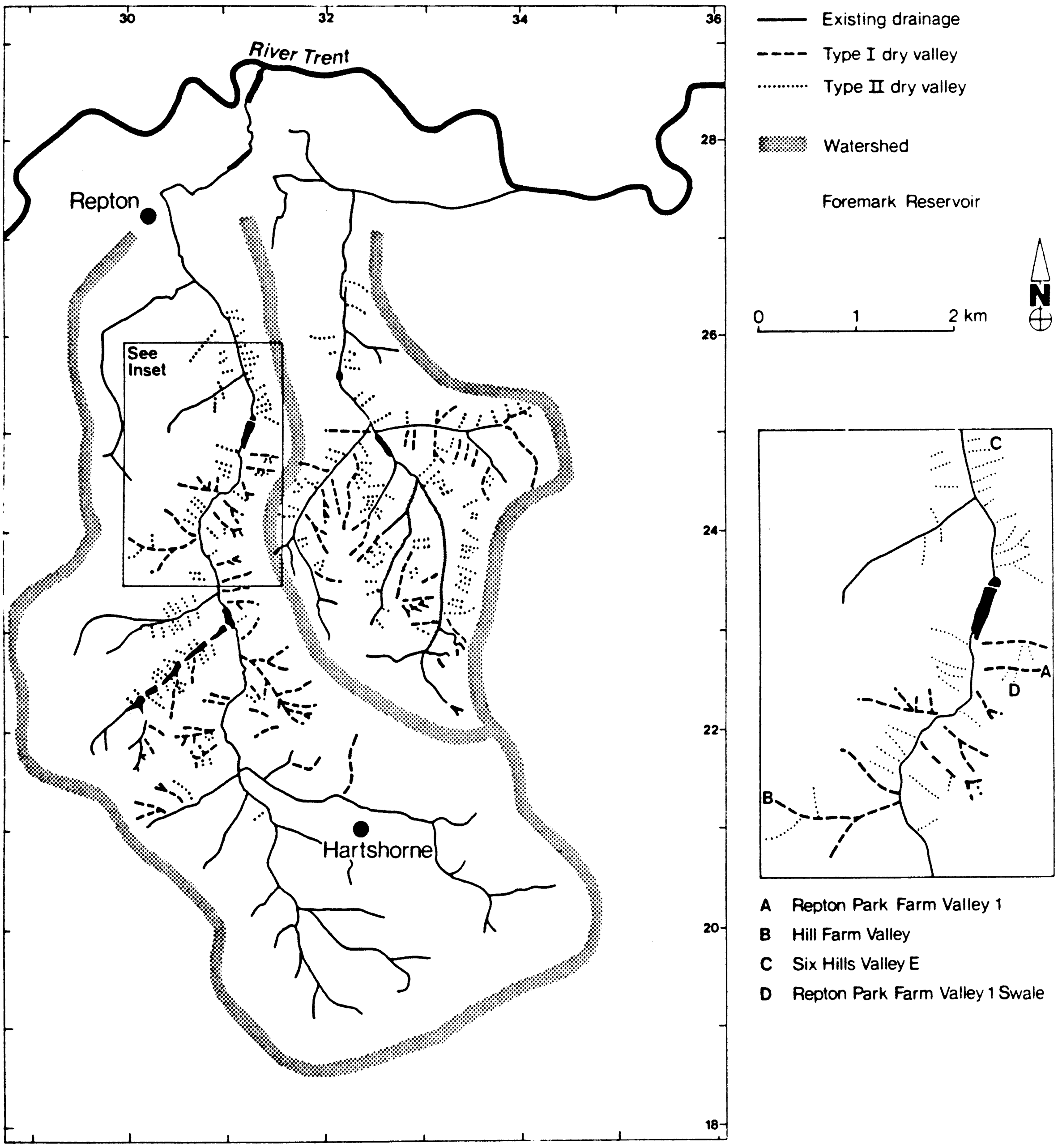

Fig.3. Dry valley distribution.

Table 3 Morphometric measures of east and west facing valleys in the Repton and Foremark basins

	Repton Brook		*Foremark Brook*		*Combined*	
	East Facing	West Facing	East Facing	West Facing	East Facing	West Facing
Drainage Density (Regression)	1.6 ($V = 1.60A^{0.57}$)	1.94 ($V = 1.94A^{0.65}$)	3.15 ($V = 3.15A^{0.94}$)	2.14 ($V = 2.14A^{0.75}$)	1.78 ($V = 1.78A^{0.63}$)	2.14 ($V = 2.14A^{0.71}$)
Drainage Density (A/V)	4.83	5.51	4.26	5.06	4.65	5.31
Relief Ratio (R/L)	73.65	91.98	64.08	68.08	70.70	81.15
Number of valley links (N)	24	23	17	11	41	34

A = basin area
V = total valley length
L = basin length
R = total relief within basin

Type II valleys. These are smaller dry valley features which occur frequently in both basins. Again there are significant variations in size and morphology ranging from very small swale like features to better developed valley forms. The latter typically occur on the sides of Type I valleys or notch the shoulders of the main stream valleys. They are usually straight without tributary development and are exemplified by the valleys known locally as the Six Hills immediately south of Repton village. The morphology of a single example is summarised in Table 2 and Figure 4C. Valley lengths are commonly between 130 and 180 metres and depths vary between 6 and 10 metres. Valley side slopes are smoothly convexo-concave with maximum slope angles ranging between 7° and 9.5°. The frequency distribution for valley E (Fig. 6) illustrates the contrast with the Type I valleys. While these valleys commonly exhibit a slightly convex long profile, a further point to note is the tendency for close grouping. For example in the Six Hills area, six dry valleys are found in a distance of 400 m giving a switchback appearance to fencelines running across the trend of the valleys (Plate 2B). Distances between the centre lines of the valleys range from 61 m to 72 m. Other examples of such groupings are to be found in both basins such as below Foremark Park Farm (336 233) in the Foremark basin.

The other Type II valleys, the very small swale features, occur on the sides of many valleys in the area. These shallow furrows may be as little as 70 m in length and 3 to 4 m deep. Slope angles are small, rarely exceeding 13° and mean angles are usually less than 7°. The long profiles of these swales are convex; differing only slightly from the form of the main valley side slope (Fig. 4D).

Valley asymmetry is a feature of many chalk dry valleys of southern England. Gardiner (1983) also describes valley asymmetry in dry valleys on the Triassic rocks of Cannock Chase. At the basin scale a gross asymmetry was identified by Gardiner between west and east facing dry valleys of the Sherbrook catchment. West facing valleys occurred at greater density, were steeper and less fully integrated in terms of fluvial organisation. At the scale of the individual dry valley Gardiner found that south facing slopes tended to be steeper than north facing.

Using the same techniques asymmetry in the Repton and Foremark basins was investigated but was found not to be so clearly developed. Valley densities are higher for west facing dry valleys but this is not consistently shown for both methods of density calculation (Fig. 6, Table 3). Basin slopes, as measured by relief ratio, are steeper and the number of valley links smaller for west facing dry valleys in both basins confirming a gross valley asymmetry. However when individual dry valleys are considered neither a pronounced nor consistent degree of asymmetry between north and south facing valley sides can nor be clearly identified (Table 4).

Finally, a feature characteristic of both the Type I valleys and the larger Type II valleys is that in some cases they "hang" above the present day main drainage lines. In the Six Hills valleys for example, the mouths of some valleys lie as much as 6.5 m above the level of the Repton Brook though the average figure for these "hanging valleys" is 4.92 m. "Hang" of a similar magnitude does occur in the case of some of the major dry valleys but is difficult to quantify accurately because of road construction in the main stream valleys.

Table 4 Valley side slope angles for selected dry valleys

	North Facing Mean valley-side slope angle (°)	*South Facing* Mean valley-side slope angle (°)
Repton Park Farm Valley 1	15.1	16.8
Repton Park Farm Valley 2	14.2	12.9
Combined	14.6	14.9
Hill Farm Valley	12.2	12.7
Six Hills Valley D	10.2	8.4
Six Hills Valley E	8.5	10.1
Combined	9.4	9.2
All valleys	12.8	12.7

Origin of the dry valleys

The wider debate concerning the origin of dry valleys, has resulted in a diversity of explanations for their formation. Gregory (1971) reviewed many of these explanations in the context of the dry valleys of the Triassic rocks of the Otter basin in south east Devon. It is worth noting that hypotheses of formation put forward need not be mutually exclusive. Individual dry valleys may have their origin in the operation of many different processes requiring contrasting environmental conditions. The need for any explanation to take account of both the cutting and drying phases of dry valley formation was emphasised by Jones (1979).

In the case of the dry valleys of the Repton area it is necessary to consider explanations for their origin against the background of the denudational history of the area and, in particular, Pleistocene landscape evolution. The two streams form a small element of the Middle Trent basin where notable contributions to the elucidation of Pleistocene sequence of events have been made by Clayton (1953), Posnansky (1960) and Rice (1968). Testimony to late Pleistocene changes in the level of the Trent is provided by a suite of terrace features and buried channels identified by Derbyshire & Jones (1980). In summarising the geomorphic activity of the late Pleistocene, Jones & Charsley (1985) argue that much of the basic form of the present day drainage pattern of south Derbyshire was created by widespread drainage modification in the Wolstonian glacial phase and that subsequent interglacial (Ipswichian) and glacial (Devensian) phases completed the detail through processes of fluvial erosion and periglacial degradation. It is possible that parts of the existing drainage pattern pre-date the Wolstonian glacial period, either being little disrupted by Wolstonian events, or being re-established along original lines following deglaciation. However, this seems unlikely particularly for relatively small streams such as the Repton and Foremark Brooks. Hence, it appears that following initiation, either directly on the Triassic rocks or onto a cover of glacial deposits, during the Wolstonian, the two streams have responded to a general lowering in the local base level represented by the Middle Trent. In so doing they have worked headwards and cut down through the Triassic sequence until, in the Repton Brook, basin headwaters have been established on the underlying Coal Measures through the fashioning of the Hartshorne Basin.

The fluctuation of climate and geomorphic activity associated with the sequence of events outlined above would undoubtedly provide the changing hydrological conditions suitable for both valley cutting and drying particularly on permeable rocks. However, different origins may be envisaged for the two main dry valley types identified in the Repton and Foremark basins. The Type 1 valleys, longer, deeper and in general more integrated with the mainstream valleys, are more likely to have had a complex evolution closely tied to the main Repton and Foremark drainage lines. If they were initiated in the cold glacial and periglacial periods of the Wolstonian the subsequent higher water tables in the porous sandstones associated with wetter periods may have sustained valley development during the Ipswichian. This would have been followed by renewed and vigorous erosion in the severe, Devensian periglacial environment which affected the area. Hence these valleys may have been operational in a variety of environments since the Wolstonian. On the other hand, the shorter and shallower Type II valleys which notch the sides of the larger valleys or the shoulders of the mainstream valleys, are likely to have been formed later. It seems therefore, that they are more recent features which probably developed during the late Devensian periglacial episodes.

This speculated origin matches that advanced by Williams (1980) in considering the dry valleys of the chalklands of southern England. He states that the majority of valleys appear to have been initiated before the onset of periglacial conditions with substantial interglacial excavation associated with higher water tables. Subsequent evolution was seen to be mainly the result of periglacial erosion during the late stages of the Quaternary, and from a consideration of valley asymmetry, it has been estimated that periglacial downcutting was responsible for at least 15% and sometimes 30% or more of the depth of the valleys.

There is abundant evidence to suggest that periglacial conditions in south Derbyshire were at least as severe and probably more severe than in southern England during the late Devensian. Jones (1979), identified solifluction deposits in the Dale Abbey area 15 km to the north-east of Repton. Jones & Charsley (1985) also referred to a 5 m thick composite fill of recent alluvium and older solifluction gravel in the valley of Brailsford Brook to the north west and similar fill in many of the dry valleys around Brailsford (255 415). Spink (1964) reported "considerable thicknesses of gravelly material ... thought to be material travelled from the hilltops by solifluction" on the flanks of the Sence valley north east of Heather (390109) some 12 km to the south of the area. In addition he described an example of frost wedging in the Middle Lount coal seam to the south east of Packington and reported these effects up to 4 m below the surface in the Sence valley. Such features have also been described from the gravels and floodplain deposits of the Trent and Dove by Posnansky (1960) and Jones & Derbyshire (1977).

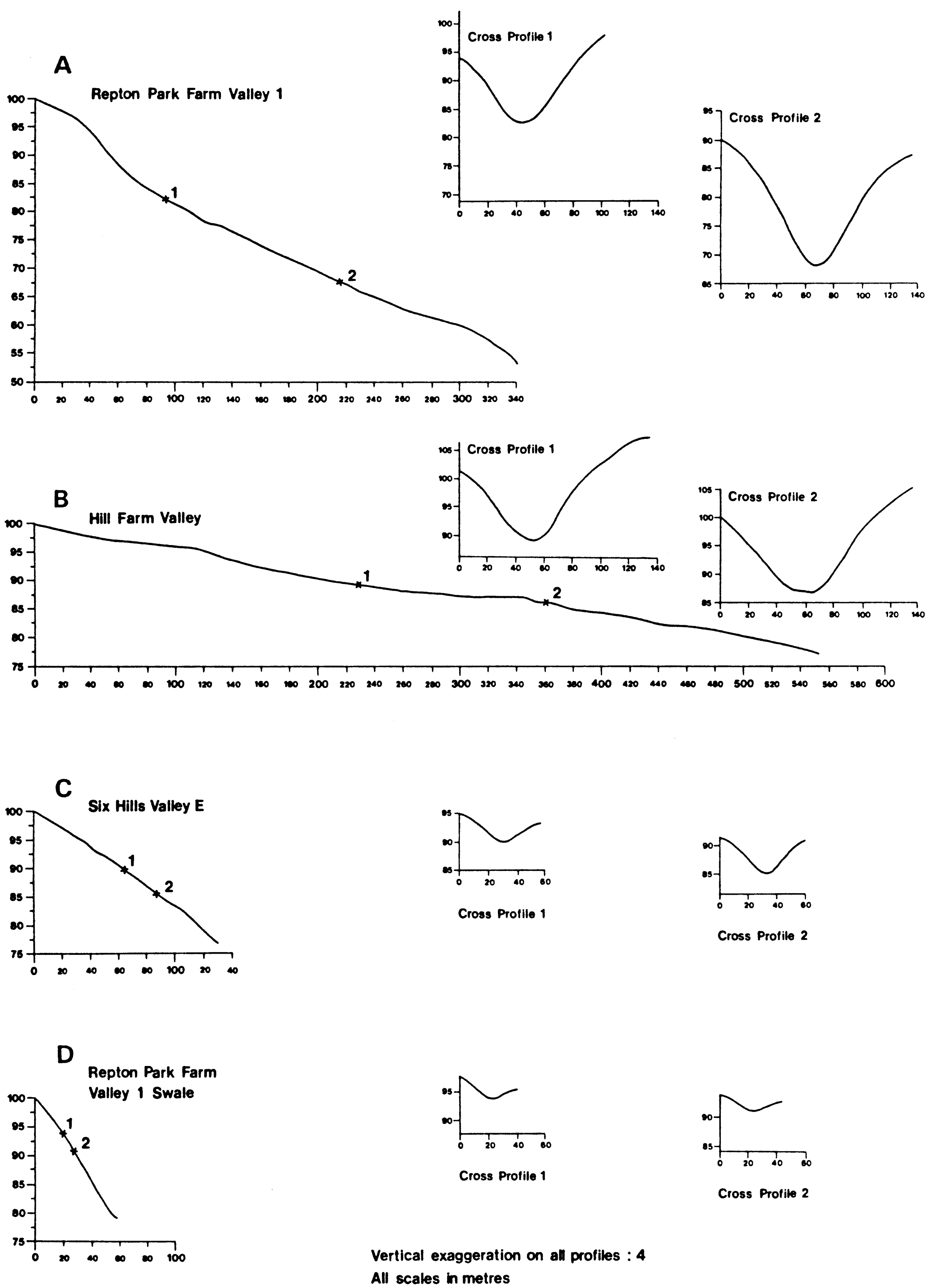

Fig.4. Long and cross profiles of selected dry valleys. All measurements taken with slope pantometer of fixed distance 1.5 m except Hill Farm Valley long profile which was summarized with a quick set level.

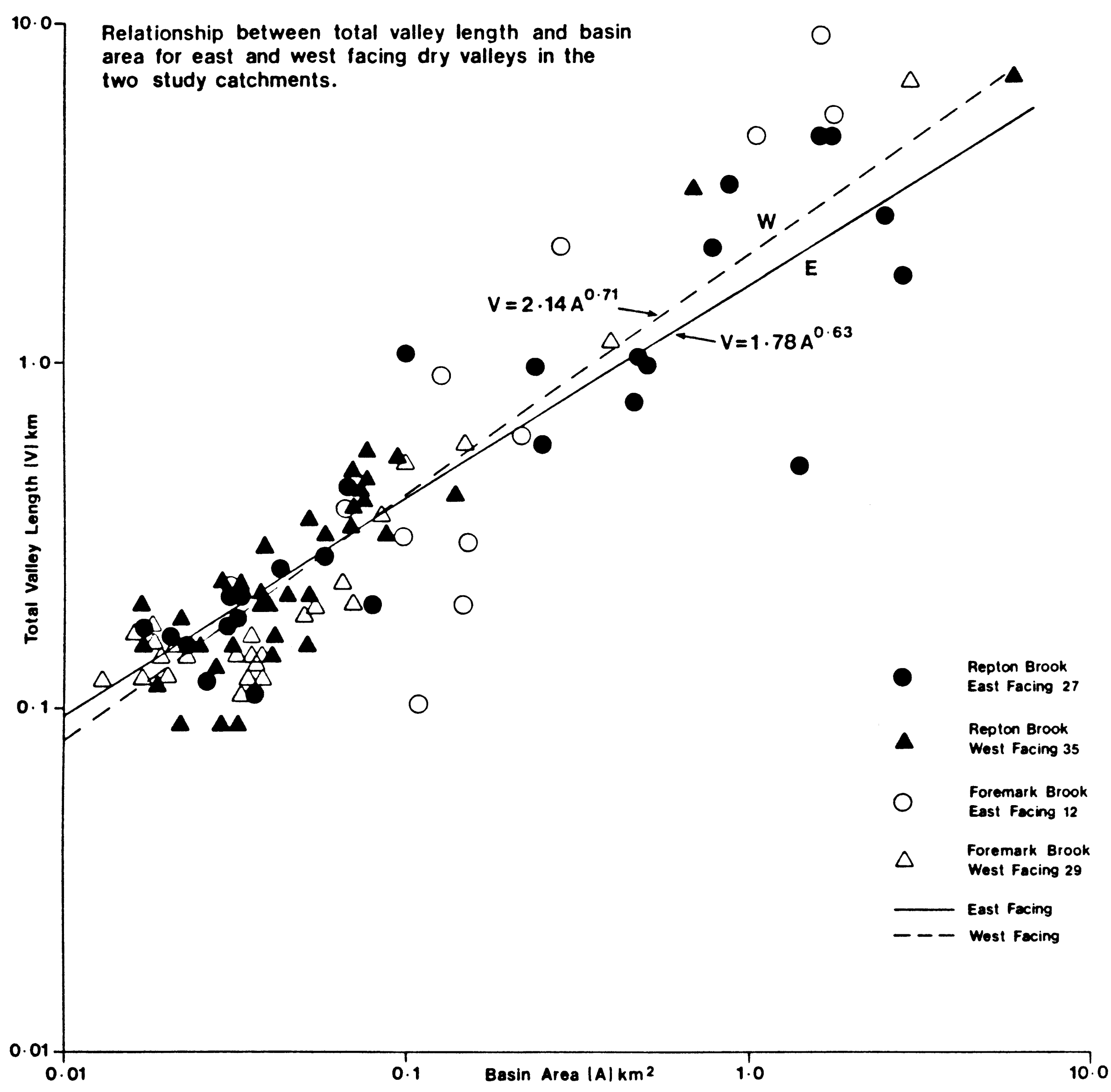

Fig.5. Relationship between total valley length and basin area for east and west facing dry valleys in the two study catchments.

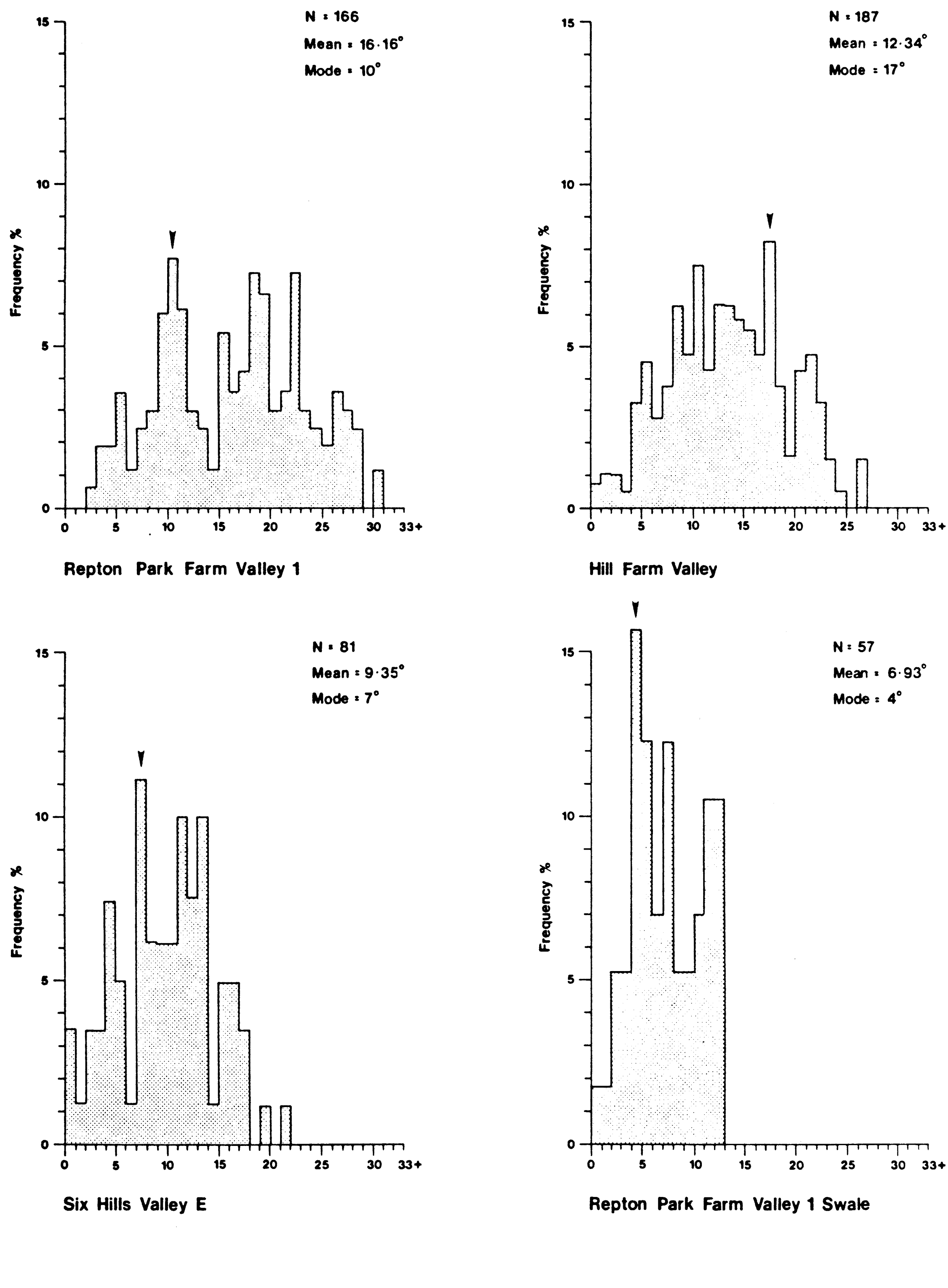

Fig.6. Frequency distributions of slope angles for valleys shown in Fig.4.

Exposures of superficial materials, especially valley bottom sediments are generally lacking in the Repton and Foremark basins but it would seem likely that solifluction materials are present. A limited number of hand augered boreholes did indicate the presence of more than one metre of unconsolidated, ochreous, pebbly sands with intercalated clays in some of the Six Hills and Repton Park Farm dry valleys. These deposits may represent the remnants of more substantial periglacial solifluctional sediments but the effects of post-Devensian slope wash and in situ weathering of the sandstone bedrock cannot be ruled out. Clearly much further work is required to ascertain the nature and extent of these deposits.

Gardiner (1983) interpreted the two levels of asymmetry present in the Cannock Chase dry valleys as evidence of differential solifluctional and fluvial activity controlled by aspect in the late Quaternary and Holocene. As noted little asymmetry was observed in terms of north- and south- facing aspects for side slopes of individual valleys but gross asymmetry for the east and west facing sides of the main Repton and Foremark valleys did seem to be present. Hence as Gardiner (1983) suggests the west facing valley slopes of the Repton Brook and Foremark Brook may have been subject to less fluvial activity because a shorter duration of permafrost led to a shorter period of runoff over frozen permeable bedrock. This resulted in elements of valley development from earlier solifluction dominated conditions being preserved with a relatively low level of overall fluvial organisation and apparently high valley densities. Such an interpretation is only one possible explanation and requires corroborative evidence such as may be provided by the investigation of superficial sediments.

It would seem therefore that periglacial and nivation processes such as freeze thaw, solifluction and runoff from seasonal melting of upper ground layers, have played a major part in the development of all the dry valleys in the Repton and Foremark basins. In the case of the Type I valleys these processes may not have been the cause of initial formation but may have produced substantial enlargement and modification. In the case of the Type II valleys it is a strong possibility that they originated and developed under periglacial conditions. Their size and location has already been noted but in addition their occurrence in regularly spaced groupings as in the Six Hills may also be indicative of the action of niveo-fluvial processes associated with snow patches capping the interfluves. Jones (1965) discounts such an origin for the dry gullies of the Arden Sandstone Series of the Lapworth Valley in Warwickshire because no evidence of outwash fans was found. However, once broken down, the relatively weakly cemented sandstones would provide detritus relatively easily removed by slope processes and runoff. Williams (1980) describes rhythmically spaced giant "flutes" which run down the face of chalk escarpments in southern England, proposing them to be former snow avalanche chutes. The description of the form of these flutes suggests such an explanation may be appropriate at least to the Six Hills valleys as well as to the small swales identified in the study area.

The role of the water table and spring sapping in the formation and development of the dry valleys is problematical. Small (1965) emphasised the importance of such processes in chalk dry valley formation but morphological evidence, such as pronounced headward steepening of valleys, is ambiguous. Jones (1979) suggested seepages at the junction of the Bunter Sandstone with the impermeable mudstone bands of the underlying Lower Mottled Sandstone may account for the initiation of the Dale Abbey dry valleys but downcutting has only reached this junction to any great extreme in the Foremark basin and hence could only be postulated for that basin. There is, however, no direct evidence of the action of springs or previous water table positions and consequently their significance must remain speculative.

Finally the role of Man cannot be ignored when discussing dry valley formation. Gregory and Walling (1968) drew attention to the way in which Man may cause channel network adjustments. Direct interference with channels in terms of damming and water abstraction may lead to loss of discharge. In addition, ground water abstraction from porous or permeable substrate may produce local water table lowering which leads to the disappearance of surface streams. Such a process has undoubtedly been a factor in the Peak District, with lead mining the stimulus for water abstraction, and is perhaps also implied by Lamplugh *et al* (1911) in ascribing dry valleys on the Sherwood Sandstone outcrop of Nottinghamshire to a recent lowering of water tables. In the Repton and Foremark basins abstraction of water from the sandstone aquifer has taken place but not on a large scale. However, there has been a clear modification of the valleys by Medieval and post-Medieval mill construction. At least five mills are known to have existed on the Repton Brook alone, but the effect of ponding is difficult to judge. The "hang" of some of the dry valleys may represent a main channel response to Man's interference or simply an adjustment in the main channel to late-Devensian and Holocene changes in climate and local base level. However, as Paterson (1977) points out, the hanging nature of some valleys may be caused by variations in thickness of superficial deposits. Hence, a careful exploration of the sub-surface morphology of the valleys is necessary.

In discussing the origin of the dry valleys it is interesting to speculate on the palaeodischarge conditions which may have been responsible for cutting the valley systems. Dury (1965) estimated that since Devensian times theres has been at least a 20 fold decrease in bankfull discharge for rivers in lowland Britain. However, Cheetham (1980) found that in the case of the Kennet drainage, density changes pointed to a 4 to 10 fold decrease. The following relationship was used in the Kennet study:

$$q = 0.063\,D^{1.59} \qquad (SE = 0.1094\,m^3s^{-1})$$

where q is the discharge of the mean annual flood per km^2 in m^3s^{-1} and D is drainage density in km^2.

The application of this relationship to the Repton and Foremark drainage systems is summarised in Table 5. The figures suggest that a decrease of discharge between 1.5 and 5 times could have occurred since the valleys were in operation in the late Quaternary. However, such calculations can only at best be an indication of possible changes since many assumptions are implicit in their application. In particular, an assumption is made that all the valleys functioned at the same time and indeed that all the valleys were actual drainage lines. It must also be noted that the relationship used by Cheetham (1980) is based on work by Carlston (1963) for fifteen basins in eastern USA and hence may not be valid either for an inferred late Quaternary permafrost environment of for basins of the size of the Repton and Foremark catchments. On the other hand, values of mean annual flood predicted from present day channel densities are confirmed by estimates of bankfull discharge. This may imply some validity for the discharge-drainage density relationships at least as a general indication of palaeodischarge changes.

Table 5 Palaeodischarge calculations for the valley network

	Drainage Area (km^2)	Channel Density ($km\ km^{-2}$)	*Calculated Present Day Discharge* $Q_{2.33}$ (m^3s^{-1}) Mean	95% Probability Range (± 2SE)	Valley Density ($km\ km^{-2}$)	*Calculated Palaeo-discharge* $Q_{2.33}$ (m^3s^{-1}) Mean	95% Probability Range (± 2SE)
Repton Brook	21.6	1.30	2.06	-2.66 6.79	2.39	5.44	0.71 10.16
Foremark Brook	10.4	1.27	0.96	-1.32 3.23	2.73	3.23	0.96 5.51

Conclusion

Attention has been drawn to a well developed system of dry valleys on the permeable Triassic rocks of the Repton/Foremark area of south Derbyshire. On the basis of size, morphology and distribution, two main valley types have been identified. The major valleys are thought to have had a longer, more complex evolution than the smaller valleys being associated with large scale environmental change in the Middle Trent basin since the Wolstonian glaciation. The smaller valleys probably reflect Devensian periglacial and niveo-fluvial processes which may also have played a significant role in developing the larger dry valleys. Whilst these interpretations remain speculative as a result of the lack of clear evidence, a two fold division of valley type is in keeping with findings from other studies in south west and southern England. A detailed investigation of the nature, distribution and origin of the superficial deposits of the Repton area is necessary to throw further light on the development of the dry valleys.

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Plate 2A. Repton Park Farm Valley 1 leading to its confluence with the Repton Brook Valley (centre of photograph). Note swales on left valley side and the 'level' nature of the interfluve area on the skyline.

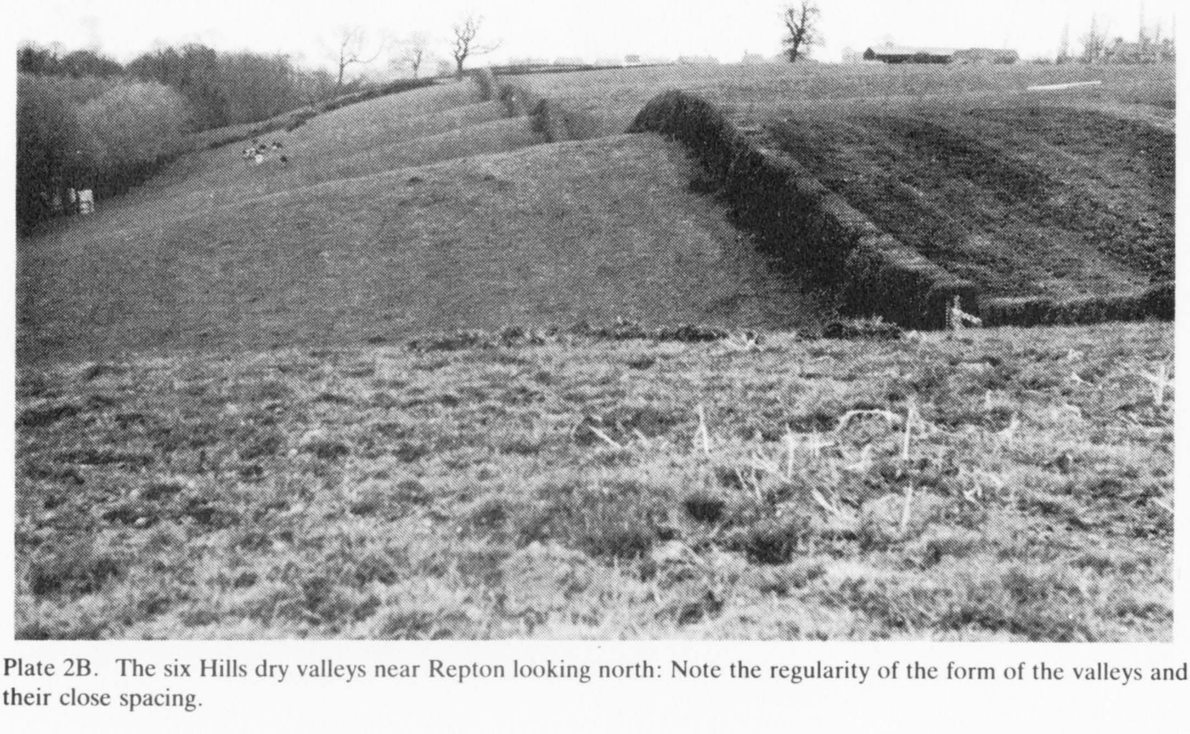

Plate 2B. The six Hills dry valleys near Repton looking north: Note the regularity of the form of the valleys and their close spacing.