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Partially infilled gully systems on Dartmoor

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The broad outlines of the geomorphological history of Dartmoor, from the Tertiary Period to the present time, have been well established. But much of the fine detail still requires examination. Most slopes are mantled by a variable thickness of solifluction material (head) resting either on decomposed granite or fractured bedrock. The nature of the material demonstrates that considerable changes have occurred on most slopes. Some of the exposures show gullies infilled with the fine silty loam which caps much of the head. This type of gully is not integrated with any drainage system or related to any particular landform. However, gullies of a more integrated nature are common on many Dartmoor slopes and seem to represent an important phase in the evolution of the landscape. They occur in most of the large river basins and usually on long, east-facing slopes. They are especially common in the upper parts of the basins of the Rivers Walkham and Cowsic, where they are up to 10m wide and several metres deep. One of their distinctive features is the presence of layered infill, consisting of alternating layers of coarse sand and fine sand or silt. This suggests periodic episodes of erosion and deposition, the timing of which is difficult to establish. A possible mechanism for the initial incision is rapid snow melt from accumulated snow banks under a periglacial regime. The layered infill could have occurred at several times. One possibility is the immediately Post-Glacial period before a complete vegetation cover was established. A second possibility is that the infill represents soil erosion initiated by the vegetation changes created during the Bronze and Iron Ages. Whatever the timing of the phases, the gullies indicate an alternation of stable and unstable phases on many Dartmoor slopes.

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Introduction

There has been a growing realisation, over the last 20 to 30 years, that landform evolution involving gradual, continuous, sequential changes, as embodied in Davisian ideas, is inappropriate for a number of reasons. The increase in detailed information concerning past changes in climate, sea-level fluctuations, rates of uplift and continental movements indicate that conditions have varied enormously over the approximately 1.5 million years of the Quaternary Period, even more so if the 65 million years of the Tertiary Period are included.

More objective descriptions of landforms and the accumulation of data on rates of operation of geomorphological processes have shown that during stable periods, with relatively constant processes, characteristic forms will be produced. The logical extension of these ideas is that landscape evolution is episodic with long periods of stability being separated by shorter periods of instability. Thus, for any given set of environmental conditions, through the operation of a constant set of processes, there will be a tendency over time to produce a set of characteristic landforms (Brunsden and Thornes 1979). Thus, it is important to be able to establish the environmental conditions that have occurred in the past and to attempt to predict the dominant processes involved and the response in terms of landform development.

Geomorphological systems are subject continually to disturbances which arise because of changes in the external conditions of the system or from internal structural instabilities. Dartmoor has been subjected to a number of environmental changes, some major and some minor, and it is important to differentiate these changes as they will determine the scale of landscape response.

A number of studies have examined various aspects of the geomorphology of Dartmoor. These have included the construction of denudation chronologies (Brunsden 1963; Orme 1964), an examination of the weathering of granite and the evolution of tors (Linton 1955; Waters 1957; Palmer and Neilson 1962; Brunsden 1964; Gerrard 1974, 1978) and assessment of the impacts of past periglacial processes (Waters 1964; Gerrard 1983). Current processes are also being examined (Williams et al. 1984). Thus, the broad outlines of the geomorphological history of Dartmoor, from the Tertiary Period to the present time, have been established, but much of the fine detail still requires examination.

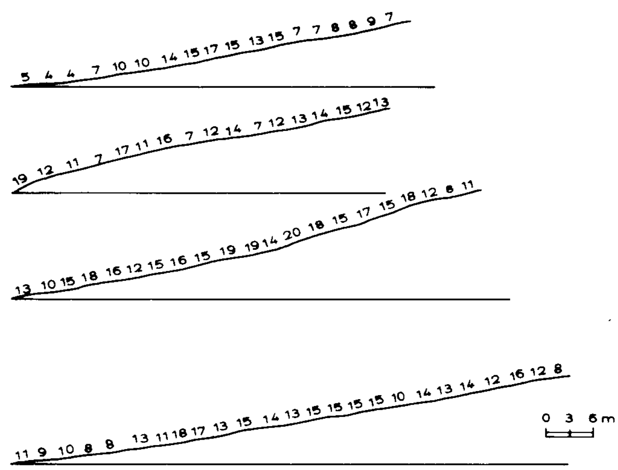

Figure 1. Long profiles of the floors of some `fossil' gullies in the basin of the River Cowsic (slope angles in degrees).

The availability of evidence with which to elucidate the fine detail will depend on the intensity of landscape changes and the sensitivity of the landscape. The sensitivity of a landscape to change can be expressed as the likelihood that a given change in the controlling factors of the system will produce a recognisable and persistent change. As rivers are highly sensitive to changes in the controlling factors, areas near river channels will be more sensitive to change than interfluves. But it also means that evidence for past activity in these highly sensitive areas is likely to be obliterated by more recent activity. Valley-side slopes, linking river channels with interfluves, are of intermediate sensitivity and should possess evidence of past changes if they are examined in sufficient detail.

Infilled gully systems

Many of the Dartmoor slopes possess large, quite deeply incised, gully systems which are very different to the more usual seepage hollows and gullies dissecting the blanket peat on the interfluves and plateau areas. They are also different to the gullies created by tinners. The location of the gullies is indicated by a lack of surface clitter. In general granite boulders are scattered quite liberally over the slopes but there are prominent gaps where the infilled gully systems occur suggesting that their creation occurred after the main phase of solifluction activity.

The gullies seem to represent a hitherto unrecognised phase in the evolution of Dartmoor slopes. They occur in many of the large river basins, usually on long, east-facing slopes, and are especially common in the upper parts of the basins of the Rivers Walkham and Cowsic in western Dartmoor. They are generally single channels commencing as shallow depressions on the upper slopes but soon becoming incised as much as 5m on the main parts of the slopes. However, some of the gullies on the slopes of the River Cowsic are more integrated and have achieved second order status.

Their long profiles are interesting in that they are highly irregular with some convex upward portions in distinct contrast to the 'normal 'concave upward long profiles of rivers (Fig. 1). This type of profile has been shown, in many parts of the world, to be associated with discontinuous gully systems created by water flow of an irregular nature and highly variable flow characteristics. Some of the gullies possess the more normal lessening of gradient as the main river is approached but many increase in angle and appear to plunge to the main river. This also seems characteristic of highly irregular but high energy water flow.

The other distinctive feature of these gullies is the presence of layered infill, which consists of an alternation of bands of coarse sand and fine sand or silt. This suggests periodic episodes of erosion and deposition with the infill possibly related to a later phase than the creation of the main gullies. Exposures in the gullies in the Cowsic river basin are limited but fortunately a gully in the River Walkham has a suite of 13 exposures spread throughout its length. The floor of the gully is generally flat but the exposures show this to be essentially formed of infill material. Exposure 1, at the lower end of the gully, shows an upper 10cm of bleached sand associated with the current development of a stagnopodzol, followed by 68cm of coarse to medium sand interspersed with a few granite boulders up to 15cm in length. A few ill-defined coarser layers can be discerned in this material. The base of the exposure is composed of coarse gravel and cobbles very similar to normal solifluction material (head) but with the finer material removed.

It is in exposure 2 that the first clearly discernible layering occurs. At least seven coarse layers, separated by finer sand or sand-silt, can be identified within a 42cm section of sandy material (Table 1). The basal deposit is again a lag-type material of coarse boulders, cobbles and gravel. This type of exposure is typical although the depth of sandy material and the number of coarse/fine layers varies (Table 2). There appears to be little

Table 1. Detail of material layering in exposure number 2 in a gully in the basin of the River Walkham, Dartmoor.

Layers from the surface	Thickness (cm)
Soil	10
Coarse Sand	12
Fine Sand/Silt	1
Coarse Sand	1
Fine Sand/Silt	3
Coarse Sand	1
Fine Sand/Silt	2
Coarse Sand	1
Fine Sand	3
Coarse Sand	2
Fine Sand/Silt	1
Coarse Sand	1
Fine Sand	2
Coarse Sand	9
Fine Sand	2
Coarse Sand	2
Coarse Rubble	unknown

Table 2. Depth and nature of material infill in a gully in the River Walkham, Dartmoor.

Exposure	Up Gully Distance (m)	Slope Angle (°)	Number of coarse layers	Infill Thickness (cm)
1	17	11	ill-defined	68
2	28	9	7	42
3	35	10	7	63
4	46	12	5	52
5	65	8	4	48
6	107	12	5	73
7	109	9	7	77
8	150	8	3	54
9	184	11	ill-defined	53
10	203	11	7	75
11	214	7	4	38
12	244	9	4	57
13	287	8	ill-defined	48

relationship between depth of infill and number of coarse layers and either inclination of the gully or position in the gully. This reinforces the impresssion that the gullies have acted in a discontinuous nature with varying erosional and depositional rates along their lengths.

The most comprehensive exposure is number 6 (Fig. 2). This not only reveals the material in the floor of the gully but also material on the side-slope. The centre of the exposure is composed of 73cm of sandy material with five coarser layers and the occasional fine sand and silt lens. This rests on the basal rubble as described in the other exposures. On the south, or left side, of the exposure the gully is cut into what appears to be undisturbed weathered granite. Above this is a layer of coarse angular head with the occasional large granite boulder. This head layer continues down the side slope and into the basal layers of the gully floor.

Alternations of coarse and fine material are usually created by variation in the capacity of the transporting medium. It is assumed that the coarse layers, some of which contain particles of weathered granite up to 1.5cm long, are deposited by comparatively high velocity water flow and that the finer material settles out when the velocity decreases. The alternations might also indicate differential activity on the neighbouring slopes or a contrast in processes. It is possible that some of the finer material is a wind blown input into the gullies. Examination of the soil on adjacent slopes also reveals coarse and fine layers in the lower parts of the profiles. This layering also occurs in soils on slopes without gullies and thus appears to be more than a localised occurrence.

These relationships suggest the following sequence. An initial phase of gully creation occurred which would appear to have been quite rapid and to have cut through whatever slope deposits existed and also through any weathered granite present on the slopes. This was followed by a period of slope activity in which the solifluction material moved into the gully from the sides and also down the axis of the gully. This may have been followed, or accompanied, by a period of water activity which flushed out some of the fines to create the coarse deposit now exposed in the floor of the gully. Once created, the gully acted as a repository for material moving off the higher slopes and represented by the alternations of coarse and fine sand. The slopes then became stabilised and a continuous soil and vegetation cover established. The gullies are still zones of preferred water movement with both throughflow and overland flow occurring. It appears that the present phase of erosion to create the exposures has been initiated by sheep. The exposures, once created, retreat by a combination of sheep action and undercutting by seepage.

Some of the gullies, as might be expected, possess rudimentary fans at their lower ends, but many do not and end abruptly on the level surface of the main valley infill with no indication that the two systems were ever linked. This implies that much of the main valley infill took place after the cutting of the gullies. Those tinners

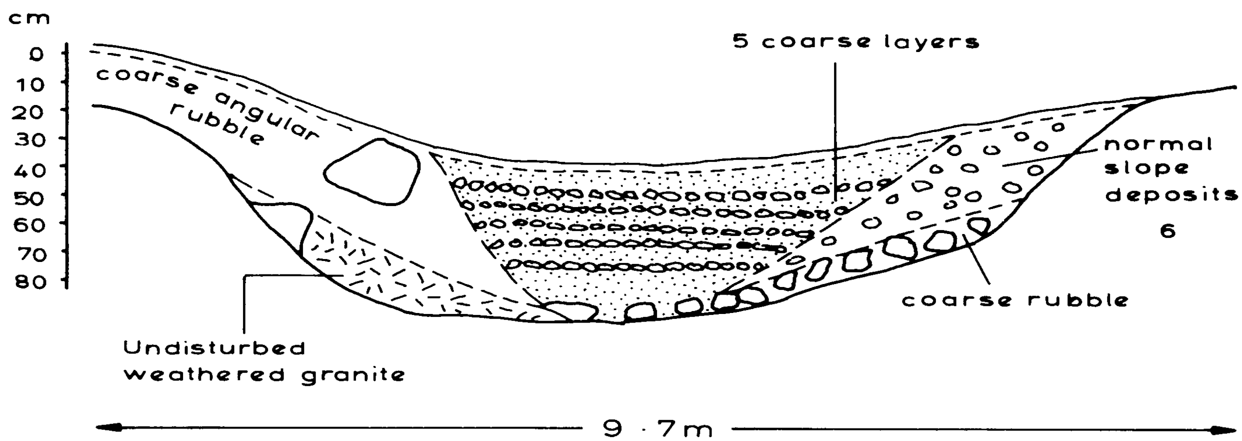

Figure *2.* Nature of the infill material in a gully in the basin of the River Walkham (exposure number 6).

possessing fans have clearly been active at a later stage which means that the gullies have been active at different times.

Discussion

The exact timing of these active phases is difficult to establish. A possible mechanism for the initial incision is rapid snow melt from accumulated snow banks under a periglacial regime. Similar gullies elsewhere have been attributed to this mechanism (Wright 1969). This possibly ties in with the fact that most of the gullies occur on east-facing slopes and have large, relatively flat plateau areas as their catchments. They do not seem to occur on slopes with narrow interfluves. The relationship with east-facing slopes may also be related to differential action during a periglacial regime. Marked valley-side asymmetry exists in western Dartmoor (Gerrard 1982). East-facing slopes have greater mean and maximum angles than west-facing slopes. The few exposures that exist indicate that the head layer is thickest on the west-facing slopes. Westerly winds would have resulted in the accumulation of snow in the lee of west-facing slopes which would have led to increased snow melt and possibly snow avalanche activity on east-facing slopes. This introduces the possibility that the gullies were initiated by snow avalanches.

The layered infill could have been developed at several times. One possibility is the immediate Post-Glacial period before a complete vegetation cover was established. A second possibility is that the layering represents soil erosion initiated by maninduced vegetation changes during the Bronze and Iron Ages. Any land use or climatic change may have been sufficient to trigger a phase of localised erosion and existing gullies would be natural `sinks' for eroded material.

Pollen analysis and archaeological remains allow a tentative chronology of environmental changes to be erected (Simmons 1964a and b, 1969; Staines 1979). The climate improved quite rapidly at the end of the last glacial period and trees such as hazel, oak and elm became established. Pollen zones V to VII (94505450 BP) contain some spores of bracken, grasses, compositae and light-demanding trees such as rowan. This correlates approximately with the Mesolithic Period and perhap the start of deforestation. During Neolithic times (5300-4450BP) the climate became wetter, the soils began to be leached and blanket peat developed. By the beginning of the Bronze Age (4450-3500BP) peat was accumulating on high ground and pollen evidence suggests that forest clearance, agriculture and pastoralism continued during the Bronze Age. The middle to late Bronze Age (3500-2450BP) continued the process with bracken and compositae increasingly in evidence. Cooler summers and wetter winters then ensued around 2450BP with Eriophora established and with the appearance of Sphagnum and Molinia.

The most extensive investigation of soil and land use changes from about 3000BP to medieval times has been conducted on Holne Moor by Maguire et al. (1983). Evidence from buried soils indicates that the modern stagnopodzols may have started to form about 2700BP. If the same relationships apply to western Dartmoor it would suggest that the soil, up to 20cm thick, now present on the surface of the gully infills started to develop at approximately the same time or perhaps slightly later as the soils are slightly less mature than those found elsewhere. This would mean that the erosion that led to the infill probably occurred during the late Bronze Age to early Iron Age.

Conclusions

It is possible to propose a tentative chronology for environmental changes and associated geomorphological activity (Table 3). It is suggested that the large gullies were created by increased runoff associated with snow melt activity at the end of the last glacial period. The landscape then gradually stabilised as a complete cover of soil and vegetation developed. Although there were many minor fluctuations in activity throughout the main part of the Holocene, the next major phase of landscape change seems to be associated with a combination of climatic and land use changes during the Bronze and early Iron Ages. Localised erosion was initiated and the pathway of soil development altered. The gullies acted as zones of preferred water and

Table 3. Suggested chronology of landscape change on Dartmoor during the Holocene Period.

Period (BP)	Geomorphological Activity
10250-9450	Some solifluction, gullying, soil erosion
9450-8450	Landscape stabilisation, soil and vegetation development
8450-7450	Extensive soil development (brown earths?)
7450-4450	*Soil* and vegetation changes start of peat development
4450-3500	Peat accumulation on high ground, forest clearance, some erosion
3500-2450	Quite extensive erosion, soil modification
2450-1000	Gradual landscape stabilisation, podzol development
1000-present	Localised effects due to tinning, enclosure and improvement, generally a stable phase

sediment movement and the layered infill was created. Following this episode the slopes became gradually inactive as the presently occurring soil and vegetation developed. Analysis of detailed relationships between soil and slopes in the basin of the River Cowsic suggests that soils have yet to achieve equilibrium with landforms (Gerrard 1988). It must be stressed that the chronology presented is highly tentative and requires much more information to establish its validity. But it appears that the infilled gully systems, described in this paper, reflect a hitherto unrecognised phase in the landscape evolution of Dartmoor.

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