THE BRETTON CLOUGH LANDSLIDES, DERBYSHIRE

by

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Summary

Three landslide areas have been identified in the South Pennine valley of Bretton Clough, occurring on Namurian sandstones and shales. Morphological and geomorphological maps of the landslides are presented, the geological context is discussed and a description of the features is given.

The slides are divided into four morphological units. These comprise: (i) the scar, (ii) the area between the scar and slide blocks, (iii) the slide blocks and (iv) the toe/river cliff. Major failure is likely to have taken place in the post glacial period at times of high groundwater levels. The geological structure and rock types has been an inherent factor promoting failure. The landslides are no longer active on the large scale, but minor regolith failures and rockfalls still continue.

Introduction

Evidence of late Quaternary mass movement is found on many Derbyshire slopes and ranges in scale from minor talus cones to large landslides. The latter are particularly common on outcrops of Namurian bedrock in 'White Peak' and the 'Dark Peak' areas of the Southern Pennines. Here the high hill moors and plateaus of gently dipping massive sandstone formations are dissected by deeply incised valleys eroded through sandstones overlying mudstones and shales of lesser resistance. This has been an inherent condition which has encouraged landslipping and other forms of mass movement (Waters, 1969). Most of these landslips have not been active for a considerable period of time, examples include those on Kinderscout, in the Edale Valley, the Alport Castle landslips in the Alport Valley (Johnson and Vaughan, 1983), Derwent Valley, Longdendale Valley (Johnson and Walthall, 1979; Johnson, 1980; Tallis and Johnson, 1980; Johnson, 1981), the Charlesworth, Chinley and Combs Rock landslips near Glossop (Johnson, 1965), the Buckstones landslips between Rochdale and Huddersfield (Muller, 1979) and those at Hucklow and along Bretton Clough. These represent fossilised landslides, major slope movements being a legacy of past conditions. However, many such slopes have retained their inherent instability on a superficial level. Indeed, road repairs have been necessary to arrest damage on the A57 road in the Ashop Valley. Of a more serious nature has been the damage and virtual destruction of the main A625 road on Mam Tor near Castleton, Derbyshire. Movement of small slump units within the fossil landslides resulted in large scale deformation and displacement of parts of the road, and led to the final closure of the A625 after years of road repairs. (For locality of major landslip areas, refer to Fig. 1).

A spectacular but as yet undescribed area of landsliding occurs within the valley of Bretton Clough, 20 km south west of Sheffield and 10 km north of Bakewell (see Fig. 1). In relation to the other major landslip areas, these are the most southerly in the Namurian outcrop before reaching the Dinantian limestone plateau to the south.

This paper represents a geomorphological description of the Bretton Clough landslides and considers the factors which may have influenced landslip development both locally and in the Southern Pennines as a whole.

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Relief and Geology

Bretton Clough lies at the northern margin of the area in the Southern Pennines known as the 'White Peak'. Bretton Clough is a small but deeply incised, steeply sided valley of some 3–4 km length, joining the nearby Abney Clough Valley to form a tributary of the Derwent Valley, 2–3 km to the north east. The Clough is mainly used for pasture, some arable farming on the gentler upper slopes and for recreational purposes. There is evidence of landsliding along a 2 km section of the valley on the steep, convex, north facing slopes. Within this section, there are three distinct landslip areas which occur at different heights. Large scale mass movement has occurred between a backscar elevation of 350 m OD and a valley floor elevation of 280 m OD; 325 m OD and 245 m OD; 335 m OD and 230 m OD on the westerly, central and easterly landslips respectively. Slope angles range from level ground to more than 40 degrees (shown in Fig. 4 and discussed later).

The Bretton Clough Valley is floored by Namurian bedrock, the main lithologies being sandstones and shales of the Kinderscout Group (see Table 1 and Fig. 2). The varying horizons have a simple distribution as indicated on the geological map (see Fig. 2). The landslip scar edges at 325–350 mOD are capped by well bedded Shale Grit (SG). This overlies shales and siltstones of the undivided Millstone Grit (MG) and a thinner 5 m band of Shale Grit (SG) within the shales further down the scar slope, a succession likely to have favoured mass failure because of the more competent well bedded sandstones overlying weaker mudrocks. This succession is best observed on the most westerly landslip scar. The upper Shale Grit (SG) horizon can be observed on the central and easterly landslip scars but the existence of a lower horizon of Shale Grit (SG) can only be speculatively deduced from broken outcrop lower down the scar slopes. Within the better preserved landslide blocks, parts of this succession has been retained, and crops out especially on the most westerly area. On the other landslide blocks, only broken outcrop of sandstone remain. Superficial deposits exist adjacent to, and within the landslip areas.

Solifluction or 'Head' deposits occur to the west of the most westerly landslip and also separate two landslips at SK 1990 7680. The component material consists of clayey or sandy loam with blocks of sandstone of all sizes and fragments of shale. These deposits are considered to have formed as slow debris flows moving downslope under saturated conditions in a periglacial environment. Mass transfer of pre-existing waste exposed bedrock surfaces and jointed rocks were therefore subjected to frost weathering which supplied further rock debris to be incorporated in the flows. Such deposits when frozen in a periglacial environment would have been impermeable, a condition likely to have promoted mass failure because of a build up of high water pressures within the slope. No dateable organic material is known to exist within the solifluction sequences at Bretton Clough. However, in the valley of Burbage Brook, North Derbyshire, an Allerod soil horizon separated two solifluction deposits and was dated at 11,590 +/− 360 years BP (Waters, 1969). In general the solifluction deposits of North Derbyshire can only be approximately dated relative to an established sequence of Pleistocene events for the Southern Pennines as a whole (Wilson, 1981).

Peaty deposits overlie some of the landslipped masses. These are associated with boggy ground, and are mainly found between the slippage scars and the slide blocks, in areas of impeded drainage. They are almost certainly of Holocene age. Recent alluvial deposits occur in small patches along Bretton Brook but there is little or no development of a floodplain.

In terms of regional geological structure, the Bretton Clough area lies at the margin of the Derbyshire Dome where Namurian rocks overlap the Dinantian limestone (Stevenson and Gaunt, 1971). The dips at this junction are low, trending north north west at approximately 7 degrees (see Fig. 2). No tectonic folding is evident locally and faulting has not been found in the area of the landslips. Jointing is a prominent feature in the sandstone horizons, occurring as many vertical and subvertical smooth fractures. A general cross jointing pattern is apparent from readings taken in the field (see Fig. 3). Localities A, H and I are away from the landslip areas whereas localities B, C, D, E, F and G are readings taken from landslip scar rock outcrop. Although a common cross jointing pattern is apparent, there is a wider dispersal of poles on the landslip scars (see especially localities D, F and G), suggesting that the landslip disturbances may have re-oriented joints. Despite this disguising of original joint patterns, it is likely that the combination of a steep hillslope, a regular cross jointing pattern and fairly upright joints will have promoted mass failure.

The Geomorphology and characteristics of the landslides

For a morphological and geomorphological analysis of the landslides, field mapping was carried out on a 1:2500 scale and was supplemented by air photo analysis. The morphological map (Fig. 4) uses symbols as proposed by Savigear (1965) and shading was in accordance with Cooke and Doornkamp (1974). The system adopted for geomorphological mapping and the symbols used were based on schemes described by Cooke and Doornkamp (1974), Brunsden and Jones (1972) and Brown and Crofts (1973). (See Fig. 5).

SHALE GRIT Turbiditic sandstones with shale partings (Stevenson and Gaunt, 1971). In Bretton Clough only the lower 11 metres of the formation are exposed, broken into two horizons along the landslip scars. These are well bedded, medium to coarse sandstones, 1–3 metres thick with shale partings. Away from Bretton Clough, the upper beds thicken upwards into massive sandstones. The sandstone weathers to a pale orange/grey colour from its oxidised brown/orange appearance. Figure 3 shows the jointing patterns on the scar outcrops, the sub-vertical joints encouraging present day rockfall as well as being a contributory factor in the mass failure along Bretton Clough.
SHALES IN UNDIVIDED MILLSTONE GRIT In Bretton Clough, these outcrop between the two bands of sandstone (Shale Grit) and beneath them, outcropping along Bretton Brook. Are grey shales of moderate fissility and weather easily to fragile tabular blocks.
SILTSTONES IN UNDIVIDED MILLSTONE GRIT These occur as thin beds of 0.5 metre thickness within the shales. The rock weathers to a grey/blue colour.
SANDY SHALES IN UNDIVIDED MILLSTONE GRIT These occur as thin beds of 0.2–0.5 metre thickness within the shales. Are much coarser than the shales, however they are still fissile and weather easily.

Table 1. Main lithologies in Bretton Clough.

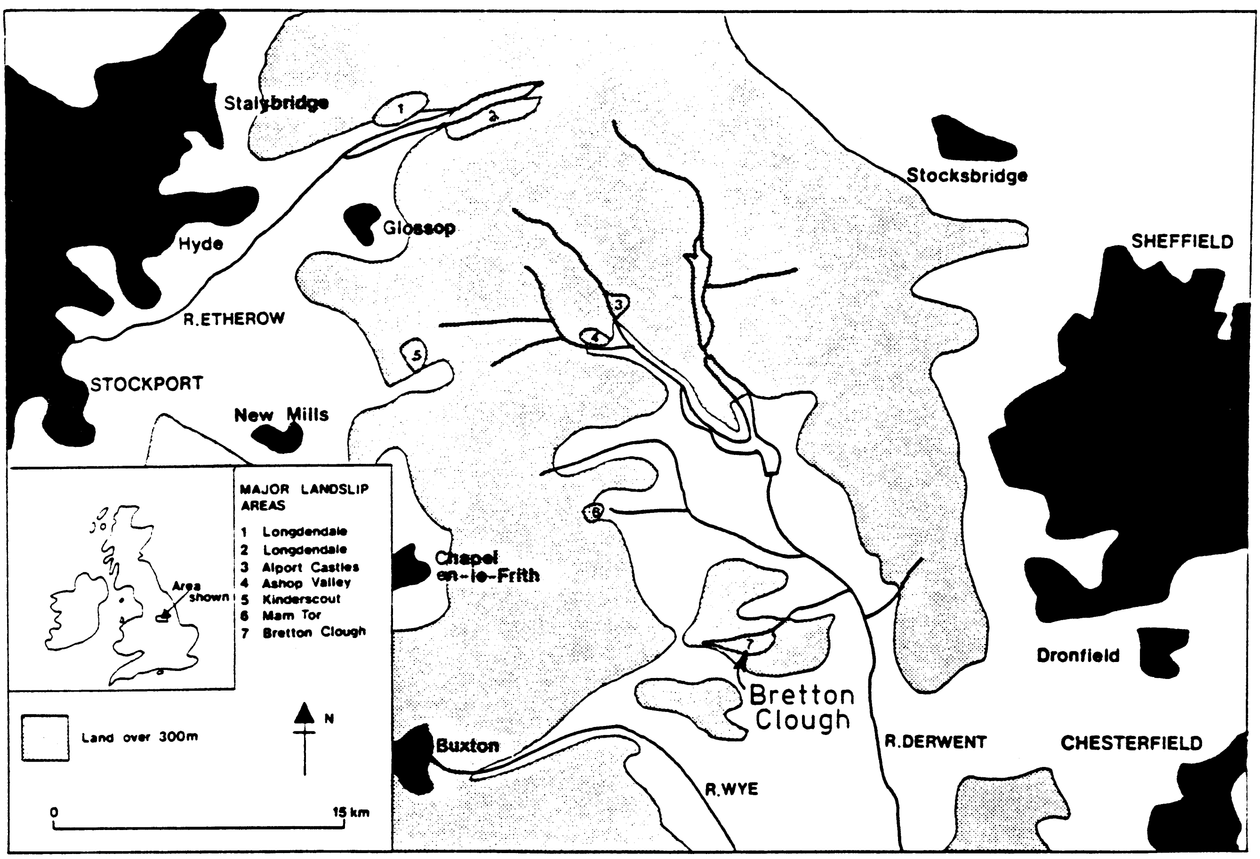

Fig. 1. Regional setting of Bretton Clough.

From the maps, the landslips can be divided into distinct geomorphological units, (i) the scar, (ii) the area between the scar and slide blocks, (iii) the slide blocks and (iv) the toe/river cliff (see Fig. 6 and Plate 1).

(i) *The Scar*

There are three distinct landslip scar areas along Bretton Clough. These are at: SK 191781–199785 (see Plate 2), SK 200785–204784 and SK 206784–209787. The scars comprise four units.

Firstly, the crest zone lies behind and upslope of the main line of fracture. Slopes are characteristically convex and in some places steep (slope angles range from 12 degrees to 29 degrees). Evidence of small scale soil creep is present in the form of terracettes.

Secondly, the scar face occurs on the sandstone/shales mentioned in Table 1. It is characterized by two horizons of sandstone (Shale Grit) interbedded with shales/siltstones and thin siltstones of the undivided Millstone Grit (see Fig. 2 and Table 1 for a fuller description). The slope form is generally planar and very steep (29 degrees to 40 degrees) of 30–40 m high. Along all three scar faces, the continuity of the slope is often broken by a gently sloping terrace area. Present day instability includes minor regolith instability (curved tree trunks are especially indicative of unstable regolith—see Plate 4), small scale scree and areas of rockfall derived from the sandstone horizons.

Thirdly, a mid slope terrace or bench occurs along most of the three scar faces. On the westerly landslip, this is only present on the western half, and dips at 7 degrees to 12 degrees into the valley away from the scar face. The other half of the scar face has no terrace present. The central landslip scar has a complete terrace, but the easterly landslip only has a major terrace on its eastern half. These both vary in dip from 2 degrees to 12 degrees away from the scar face. Such terraces are accumulation zones for rockfall from the upper scar slopes and finer material from slope wash processes.

Fourthly, a debris slope occurs on the lower half of the scar faces, consisting of fallen material from the upper slopes. In parts, particularly the western landslip scar, merged talus cones are evident, composed of minor sandstone and shale fragments cemented by clays from slope wash processes (see Plate 3). The slope is thus characteristically concave in shape, but still very steep (29 degrees to 40 degrees).

(ii) *Area between the scar and slide blocks*

These are flattish hummocky marsh areas between the scar and the slide blocks, dissected by permanent and intermittent water courses. These are main areas of impeded drainage, and this has given rise to a building up of peat deposits since the main mass failures took place. The extent of this area depends on the nearness of slide blocks to the scar and thus varies over the three landslip areas. The westerly landslip has clearly defined extensive areas of marshland but such areas, in terms of a concise geomorphological unit are less well defined on the other landslips (refer to Figs. 4 and 5).

(iii) *Slide blocks*

These occur transverse to the scar, separated from the scar in most cases by flat marshy ground. Slopes both face towards and away from the scar and range in steepness from 4 degrees to 40 degrees, being generally planar in nature. However, these features are asymmetric in terms of slope length, the scar facing slopes being shorter. The size of these features also varies widely, from large slide blocks on the easterly landslip area to the better defined but lesser slide blocks on the westerly landslip. These make a distinct 'ridge and vale' terrain from 315 m OD–300 m OD to 290 m OD– 240 m OD. On the westerly landslip area, the slide blocks nearer to the scar have angular ridges capped by sandstone and steeper slopes (up to 40 degrees). These are of 10–20 m in height. The blocks near to the river cliff have rounded ridges, gentler slopes and are smaller in size. The vales separating these are broader, and often have areas of flat marshy ground (see Figs. 4 and 5). The central and easterly landslips have fewer but larger slide blocks of up to 40 m in height.

The slide blocks represent broken up segments of hillslope, and so still show a general stratigraphical succession of rock strata although mass movement has caused some disruption (see Plates 5 and 6). Those blocks with a well preserved succession would appear to have sandstone beds dipping into the valley corresponding to the regional dip and so very little rotation of beds, in these blocks, has occurred.

On the easterly landslip, at SK 788207, the largest slide block has secondary features of landsliding and so the slope facing away from the landslip scar shows the main geomorphological units mentioned so far on a smaller scale (see Figs. 5 and 6). This is also apparent elsewhere but of lesser morphological significance.

Evidence of present day minor failure on the slide blocks slopes is in the form of terracettes, mainly on the slopes facing away from the scar (see Fig. 5). There has also been minor rockfall from sandstone outcrops.

(iv) *Toe/river cliff area*

This leads from the slide blocks into Bretton Clough and is characterised by steep planar slopes above 40 degrees. There is only major break in the cliff, at SK 78601985, an area of solifluction material. A river cliff of similar characteristics also separates the two easterly landslips normal to Bretton Brook. As with the slide block slopes, present day minor failure is limited to soil creep and minor rockfall from outcropping horizons of sandstone.

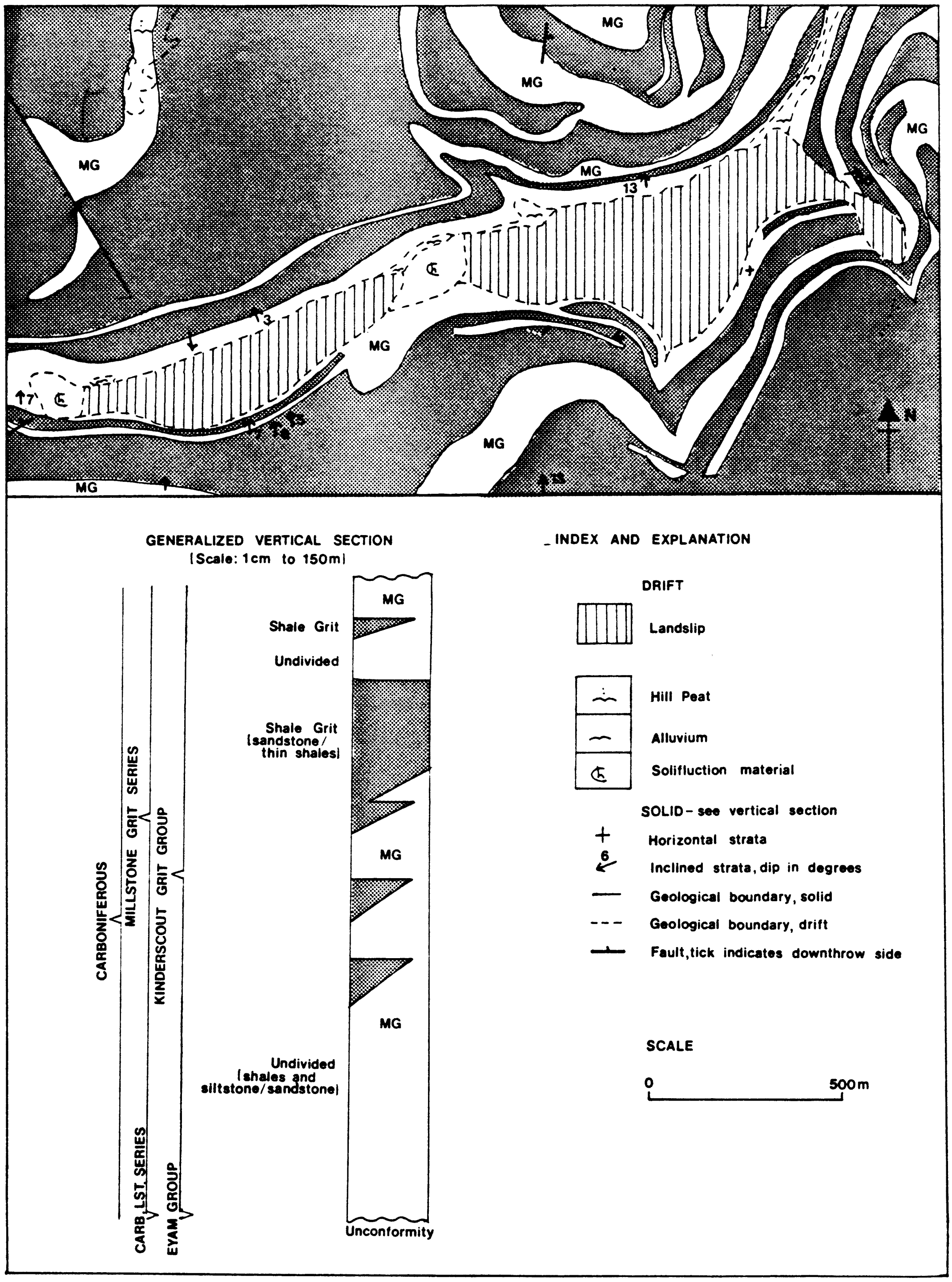

Fig. 2. Bretton Clough geology and stratigraphic succession.

Slope failure and factors likely to have caused failure

The landslide areas of Bretton Clough and their constituent units are easily identifiable as outlined, but their origin is likely to be less simply explained. An inherent factor was the geology of the region; an area of interbedded sandstones and shales gently dipping to the north (see Fig. 2 and Table 1). With a deep valley initiated in the early Pleistocene, later Devensian events started a chain of processes, acting on the bedrock and structure, which eventually gave rise to mass movement (the chronology of events is discussed elsewhere and in Table 2). The main factors for mass failure have been divided into groundwater, weathering and rock structure.

Firstly, groundwater will flow or accumulate in the rock bedding planes, joints, minor cracks and in pores in the rock material itself. The amount of groundwater will depend on the stratigraphic, structural and textural qualities of the rock and the prevailing environmental conditions. The local geological conditions in Bretton Clough favour groundwater accumulation because water bearing sandstones are interbedded with less permeable shales, thus strong hydraulic pressure differences will exist between the two different rock types. Also jointing in the sandstone varies in both width and continuity, so there will be variable distributions of water pressure with shearing forces varying from one joint to the next. The dip of the sandstone beds would have determined groundwater flow, high pressures building up along bedding planes if the outlet of water was limited. These structural features would have promoted failure and could be accentuated by environmental conditions. Thus in a wet climate, groundwater levels will be very high promoting instability because of high pore water pressures. In drier times, water levels are lower and so water will flow more freely, as at present. In a cold periglacial environment such as that of the Devensian, a combination of impermeable solifluction deposits on the slopes and ice, snowmelt or permfrost would also lead to an increase in water levels within the slope, the blocked drainage causing high water pressures. With periglacial processes being highly active on the steep slopes, the thick overburden on the underlying shales at the base of the slope and the gradual weakening by freeze—thaw processes would have enhanced the chances of valley floor bulging and thus the cambering of the sandstones upslope. Tensional stresses in the sandstone would therefore have been enhanced.

Secondly, chemical and mechanical weathering processes such as solution, hydration, oxidation, carbonation and freeze-thaw will reduce rock strengths to very low levels, especially shales. Mechanical weathering was enhanced in the colder climates and led to rockfall and talus slopes and an anastomosing network of open fractures facilitating subsequent chemical weathering during the warmer, humid inter-glacial periods. The net result was to reduce threshold failure in both sandstones and shales.

Thirdly, rock strength will be largely controlled by the size, continuity, and stability of joints, bedding planes and other discontinuities which because of their low resistance to shearing stress become preferred surfaces of shearing. Also the dip and jointing will determine rates at which water and weathering processes can penetrate. Joints are numerous in the sandstone and so there are many planes for water and weathering processes to act, promoting rockfall and general weakening of rock strength. Bedding planes dipping into the valley as at Bretton Clough will also promote rock creep where there is differences in rock strengths, the stronger rock either creeping over the weaker rock or the lesser resistant rock being squeezed outwardly under the pressure from the more resistant rock (Selby, 1982). The combination of failures and factors leading to failure are likely to be complex and major events are not likely to be concurrent. A proposed chronology of events are outlined elsewhere and summarised in Table 2.

Small scale processes are still very much active on the slopes of Bretton Clough, and these involve both minor rock and soil failure. Firstly, rockfall is evident along the landslide scars, fallen blocks having been derived from the sandstone horizons. Minor fragments of rock have led to talus cones accumulating on the lower slopes of the scar (see Plate 3). These are especially evident on the most westerly landslip scar. The sub-vertical joint pattern on the outcropping sandstone allows this to be a surface on which weathering processes can continually act.

Secondly, soil creep is a widespread process, occurring on the landslip scars and slide block slopes. The most prominent features are the terracettes, an interlacing network of low but long tracks which form continuous or intermittent staircases up some of the slopes (Selby, 1982). Another feature on the scar slopes are curved tree trunks (see Plate 4). It is believed trees on unstable ground will tilt downslope and tend to return to a vertical position during the period of rest (Zaruba and Mencl, 1969).

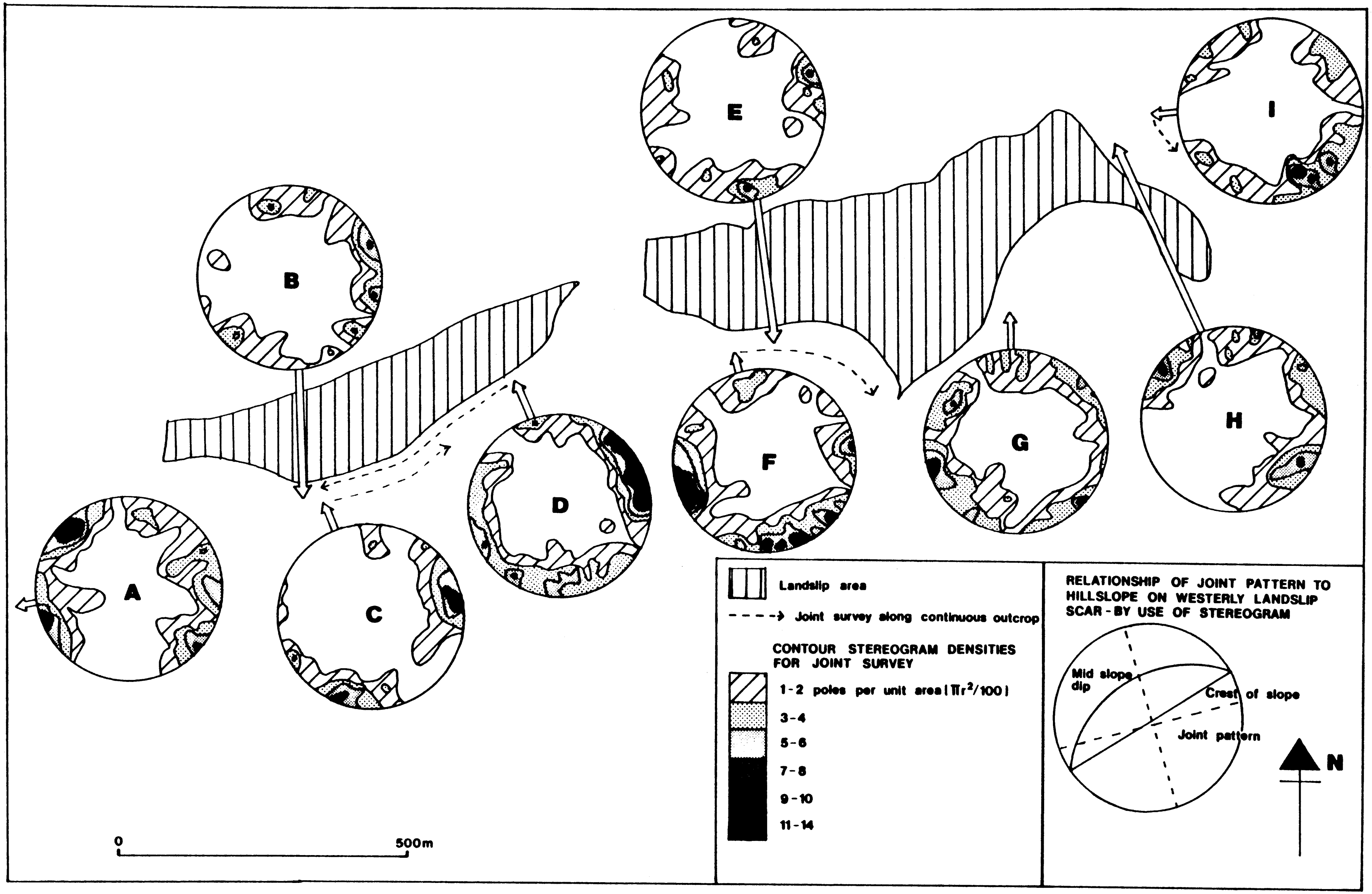

Fig. 3. Joint patterns in the sandstone horizons of Bretton Clough (methods based on Hoek and Bray, 1981).

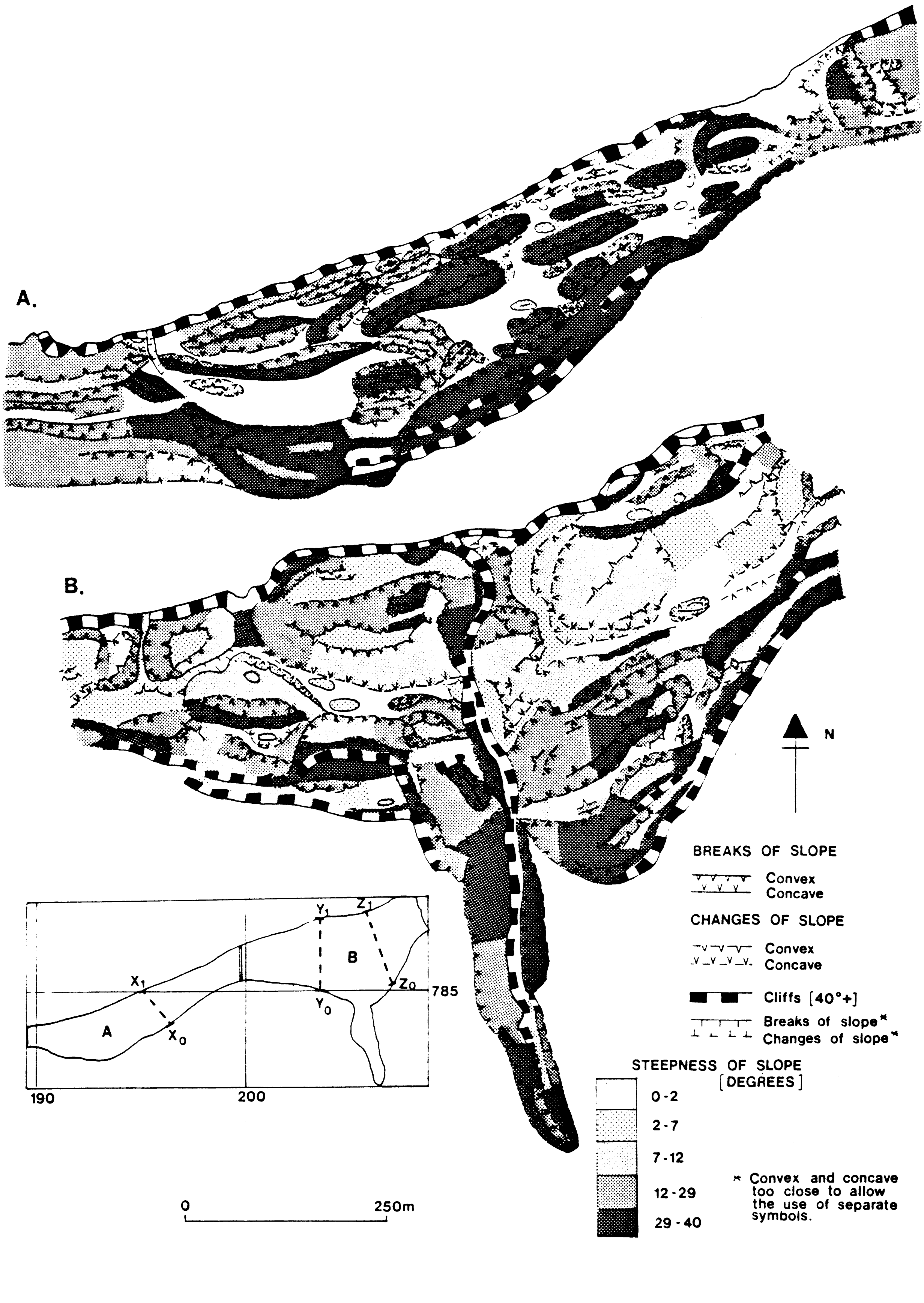

Fig. 4. Morphological map for Bretton Clough (symbols adopted from Savigear, 1965). Lines of sections X0 X1; Y0 Y1; ZO Z1 used in Text Fig. 6. Grid references are based on Ordnance Survey maps SK 17 NE, 27 NW.

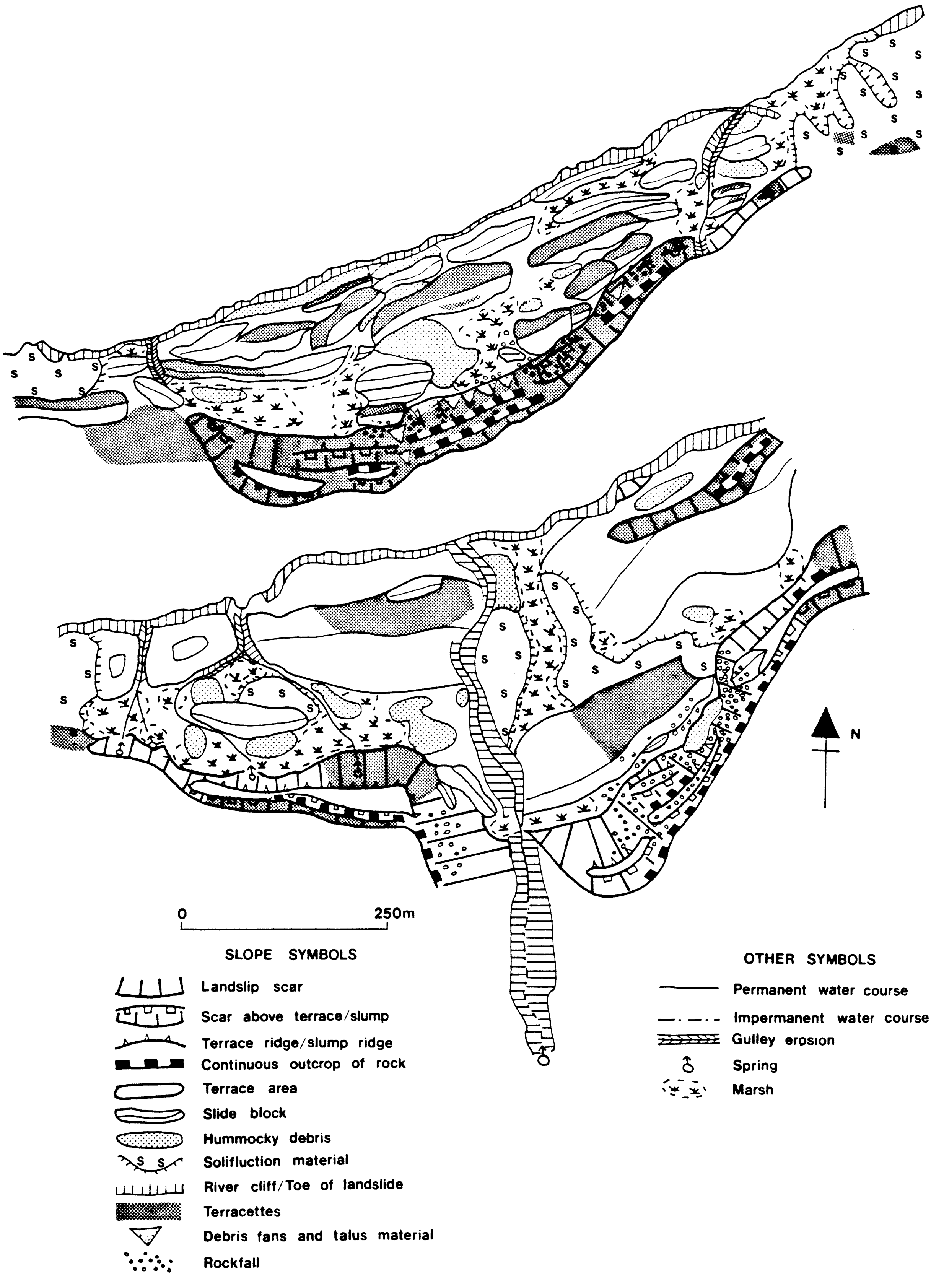

Fig. 5. Geomorphological map for Bretton Clough.

A chronology for the Bretton Clough landslides

A common method of dating landslides is by reference to pollen diagrams based on analysis of peat sediments found in slump depressions. These sediments are considered to have formed after slide movements ceased. In the absence of pollen evidence, dating can only be done relatively using geomorphological criteria (see Table 2).

Although peats in Bretton Clough have not been analysed, reference can be made to other work in the Southern Pennines. Tallis and Johnson (1980) dated the Longdendale landslides using basal peat deposits in the slump depressions, these being found to predate 7,000 years BP, a time when expansion of forest was occurring. Muller (1979) dated the Buckstone landslips between Rochdale and Huddersfield at around 7,500 years BP, a time of increased precipitation and thus higher groundwater levels. Recent examination of the Alport Castle landslips suggests that the associated peat formed between 8,300–7,600 years BP (Johnson and Vaughan, 1983), shortly after the last periglacial episode. Johnson and Vaughan (1983) state that it is likely that the main landslide took place after mantling of the slopes by periglacial 'Head' deposits, and suggested this landslip is one of the earliest to occur in the South Pennines. Johnson (1965) has also set a date for the Charlesworth landslips near Glossop at around 7,200 years B.P. However, other deposits in Longdendale post date 4,000 years BP (Tallis and Johnson, 1980). This indicates that events in the South Pennines were not concurrent but possibly initiated in a peak period of slip activity, to be followed by further landsliding events.

In the case of Bretton Clough, geomorphic evidence can be used to date features relatively and can be used on established events (refer to Table 2). The valley of Bretton Clough is likely to have been incised in the early Pleistocene (see McArthur, 1977). During the last glacial episode (Devensian) 20,000–17,000 years BP, the Southern Pennines are believed to have escaped the effects of the Devensian ice sheet. However, the area would have experienced periglacial conditions, and so the steep slopes would have been mantled with solifluction deposits, derived from the freezing and thawing of regolith coupled with mechanical weathering of the sandstone and shale outcrops. These deposits would have formed an impermeable layer thus blocking drainage and increasing water pressures within the slope. Freeze-thaw processes are also likely to have led to valley floor bulging as the weakened shales were squeezed by the heavy overburden and thus cambering of the overlying sandstones. This led to an increase in stresses building up within the slope. As the area recovered from the periglacial episode, water levels will have increased, further weakening rock strengths and increasing water pressures and shear stresses. It is likely that deep seated failure occurred at this period although probably in a series of stages.

The slide blocks on the easterly landslip areas are largely abraded and well vegetated and so are likely to be older than the westerly landslip slide blocks. The features on this landslip are well preserved and better defined. Secondary sliding will have occurred in the already weakened slide blocks (see Fig. 5). The age for this period of major landsliding can, as discussed, be deduced, only from the work on other South Pennine landslips. The landslide areas since the time of mass failure have been gradually abraded and dissected by present day fluvial processes. Mass movement is now restricted to rockfall and minor soil slope processes such as soil creep. For any further large scale failure to occur, groundwater levels would need to rise dramatically, because at present the springs adequately cope with water within the slope. Continued erosion at the toe of the landslide by Bretton Brook may induce small scale slope failure, but a larger volume of water would be needed to be of any significance.

Conclusion

Landslides are common on many North Derbyshire slopes, occurring on Namurian sandstones and shales. Bretton Clough, a South Pennine valley, has three landslide areas. For an effective description of such areas, morphological and geomorphological field mapping, as well as collection of geological data, is a necessity. Patterns and features may be derived from such analyses and can be used to develop and support landslip development ideas. It has to be concluded that mass movement in Bretton Clough has been a complex affair. It is thought that the combination of continued high groundwater levels and high water pressure, high intensity of weathering, the structural and stratigraphic arrangement of the rocks, the nature of the sandstones and shales, and the prevailing environmental conditions over a long period of time, all led to mass failure. This is believed to have occurred after the last glacial period (Devensian), a view held for the majority of South Pennine landslips.

EVENT	AGE	EVIDENCE FOR AGE	FACTORS INDUCING EVENT
Rockfall and terracettes	Post landsliding and present day	Observed rockfall. Curvature of tree trunk. Regolith instability. Destruction of dry stone wall.	Weathering processes causing rockfall. Wet and dry cycles on steep slopes causing terracettes (Gerrard and Webster, 1979).
Dissection of landslip areas by minor streams. Small dry valleys at crest of scar.			Present fluvial processes
Secondary slumping in westerly area.	Post 7000 years BP		See factors below.
Large scale landsliding.		Features well preserved.	
Secondary sliding within slide blocks and another episode of block slide in easterly area.		Arrangement of slide blocks suggest different stages of slippage at SK 206787 and SK 207788. These overlap in plan, the former being nearer to landslip scar and so likely to more recent.	Further failure due to much reduced rock strength and lower thresholds for failure.
Major landsliding in easterly area.	? c 7000 years BP	Date based on older landslips within the S. Pennines. Blocks are largely abraded and well vegetated.	Area recovering from periglacial episode so large amounts of ground water present, thus high pressures and rates of shear stress. Weakened rock materials reduced further by weathering and deep seated failure ensues.
Solifluction deposits mantling slopes during periglacial episode. High water tables maintained because of blocked drainage thus high pore water pressures. Increased weakening of rock strength with valley floor bulging and upslope cambering.	Devensian (20,000–17,000 BP)	Based on established sequence of Pleistocene events for Southern Pennines (Wilson, 1981).	Mechanical weathering processes breaking up sandstone and shale outcrop due to cold climate. Freezing and thawing of regolith leading to deris flows downslope and blocked drainage. Increasing overburden on shales at valley floor level.
Present day dry valleys seen near crest of scars (at SK 20597817).	? Pre land-slippage.	Slide blocks are normal to all others in area at SK 20507852. Is not clear if valley predates larger landslides or dissects landslides.	Spring sapping processes. Present day lower spring levels have left upper part of valley "dry".
Incision of deep valleys with steep slopes.	Early Pleistocene.	Established events in late Tertiary for S. Pennines (McArthur, 1977).	Rejuvenated streams initiated by changes of relative levels of land and sea in Pleistocene (Waters, 1969).

Table 2. Chronology of events in Bretton Clough.

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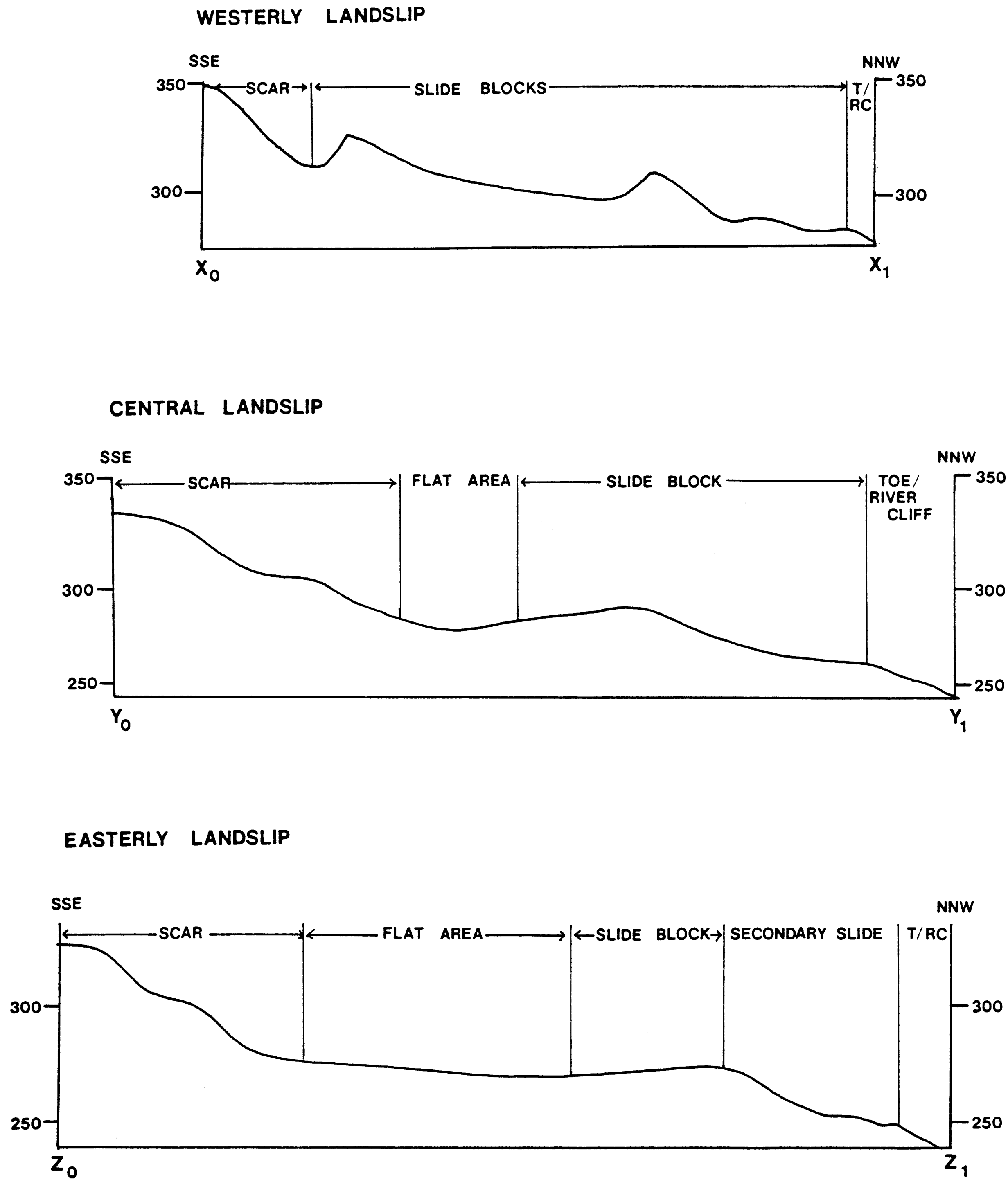

Fig. 6. Cross sections for the three landslip areas. Lines of sections shown in Text Fig. 4.

Plate 1. The most westerly landslide in Bretton Clough. Different geomorphological units are clearly visible, that of the scar, area between scar and slide blocks, and the slide blocks.

Plate 2. A section of the scar of the most westerly landslip. The midslope terrace feature is non-existent at this locality. The debris slope is visible along the lower half of the scar (from SK 19537828).

Plate 3. Two talus comes on the most westerly scar slope (at SK 19657838).

Plate 4. A tree with curved trunk on the most westerly landslide scar (at SK 19277820).

Plate 5. Stratigraphic succession of sandstone and shales is preserved in a slide block (at SK 19607834).

Plate 6. A large slide block near to the scar face of the most westerly landslip, its stratigraphic succession seen in Plate 5. On the scar itself, there is a smaller more recent rotational slump within the shales (at SK 19607834).