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A coastal landslide at West Down Beacon, Budleigh Salterton, Devon

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Introduction

It is intended that this preliminary, mainly descriptive, note will be followed by other papers on the historical development of the landsliding and on the geotechnical investigations being carried out in an area that is the subject of continuing research.

Examination of aerial photographs shows that there have been major changes in the morphology of the cliffs in the last few decades. The detailed morphology during 1980 (Fig. l) is largely the result of movement of the main landslide following a major fall of conglomerate from the upper cliff in September 1979. The positions of geological features referred to in the text are shown in the accompanying drawing (Fig. 2). The line of the cross-section (Fig. 3) drawn through the main landslide is also indicated in Fig. 2. Topographic surveying is by terrestrial photogrammetry with a Wild P32 camera mounted on a TI theodolite but only approximate analytical methods have so far been used.

Geology

West Down Beacon, at 130m above Ordnance Datum, is the highest point on the coast between Exmouth and Budleigh Salterton, Devon. This prominent feature is at the southern end of the escarpment formed by the western margin of the Budleigh Salterton Pebble Beds. This formation reaches a maximum thickness of about 26m in the coastal section, dips gently at about 3° ESE and is underlain by up to 275m of calcareous mudstone, referred to as the Littleham Mudstone Formation (Henson 1971). The cliff face just to the east of West Down Beacon consists of about 20m of weakly cemented conglomerate (the Budleigh Salterton Pebble Beds) overlying 100m of moderately weak, fissured mudstone (the Littleham Mudstone Formation). The conglomerate is truncated by erosion immediately west of here and the cliffs along to Sandy Bay are entirely in mudstone. To the east, towards Budleigh Salterton, the regional dip reduces the thickness of mudstone exposed and also the height of the cliffs. Several normal faults intersect the coast and, because they interrupt the flow of groundwater they often correspond to indentation of the cliff top. However, no faults are apparent in the immediate area of landsliding at West Down Beacon so they do not directly affect the mass movement.

In more detail the conglomerate consists of well-rounded, predominantly quartzite pebbles, cobbles and boulders in a silty sandy fine gravel matrix, very weakly cemented by authigenic kaolinite, feldspar and some quartz. Many of the cobbles are fractured and disintegrate when removed from their matrix. An overall red-brown coloration of the matrix is provided by haematite grain coatings.

Beds of cross-stratified silty sand with occasional thin mudstone laminae occur within the conglomerate which itself shows cross-stratification, channelling and some graded bedding. High-angle joints are present but are poorly defined because of the coarse texture. At the top of the exposure, a weathered profile grading up into a sandy, gravelly topsoil provides a more cohesive capping. The cohesion probably results from illuviated fines and a root network in the topsoil. At the base of the conglomerate is a layer of orange-brown, soft to firm clay which may represent the subaerially weathered top of the mudstone. However, as the mudstone provides an impermeable base to the conglomerate, this layer is more likely to be the result of continual softening and hydration of the top of the mudstone by groundwater flow in the conglomerate.

The underlying Littleham Mudstone Formation consists of a moderately weak, slightly calcareous silty mudstone, with occasional beds up to 0.6m thick of moderately strong, calcareous silty sandstone and sandy siltstone. The calcite is in the form of an authigenic granular cement, forming up to 10% of the mudstone and 20% of the siltstones and sandstones (Henson 1971). The mudstone is a dark red-brown colour, with frequent, small, pale grey reduction spots, whereas the coarser layers are usually pale grey from lack of haematite. The mudstone has widely-spaced high-angle joints and sub-horizontal bedding plane discontinuities, with a

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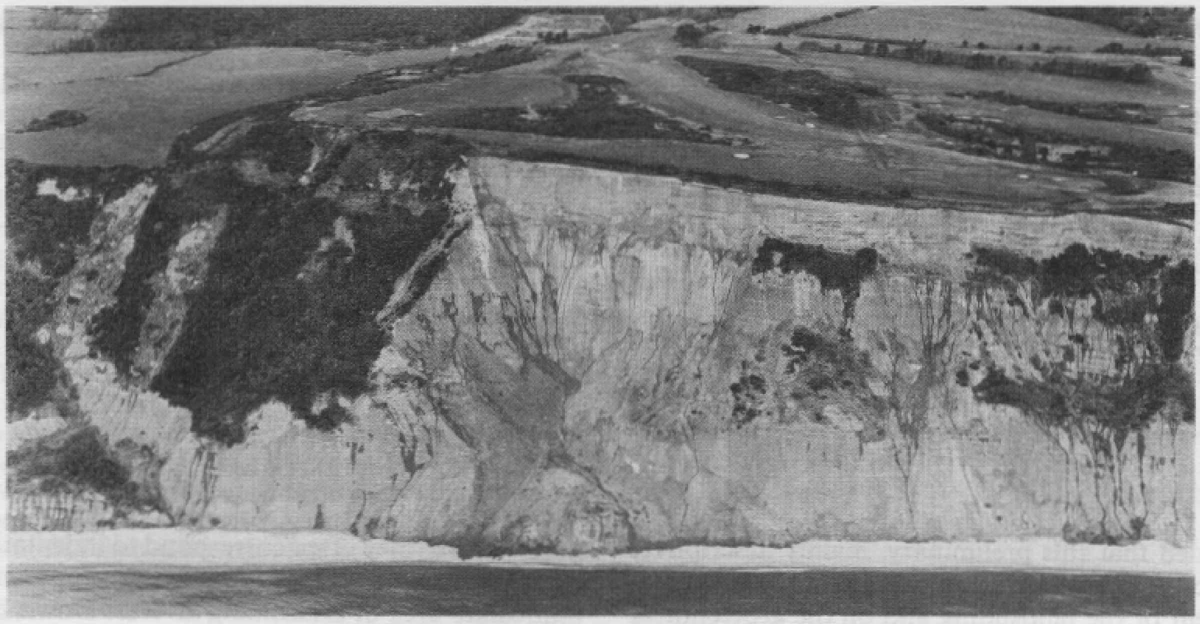

Figure 1. Oblique aerial view of West Down Beacon with the main landslide area in the middle of the picture. Photograph by J. Saunders on 22nd March 1980.

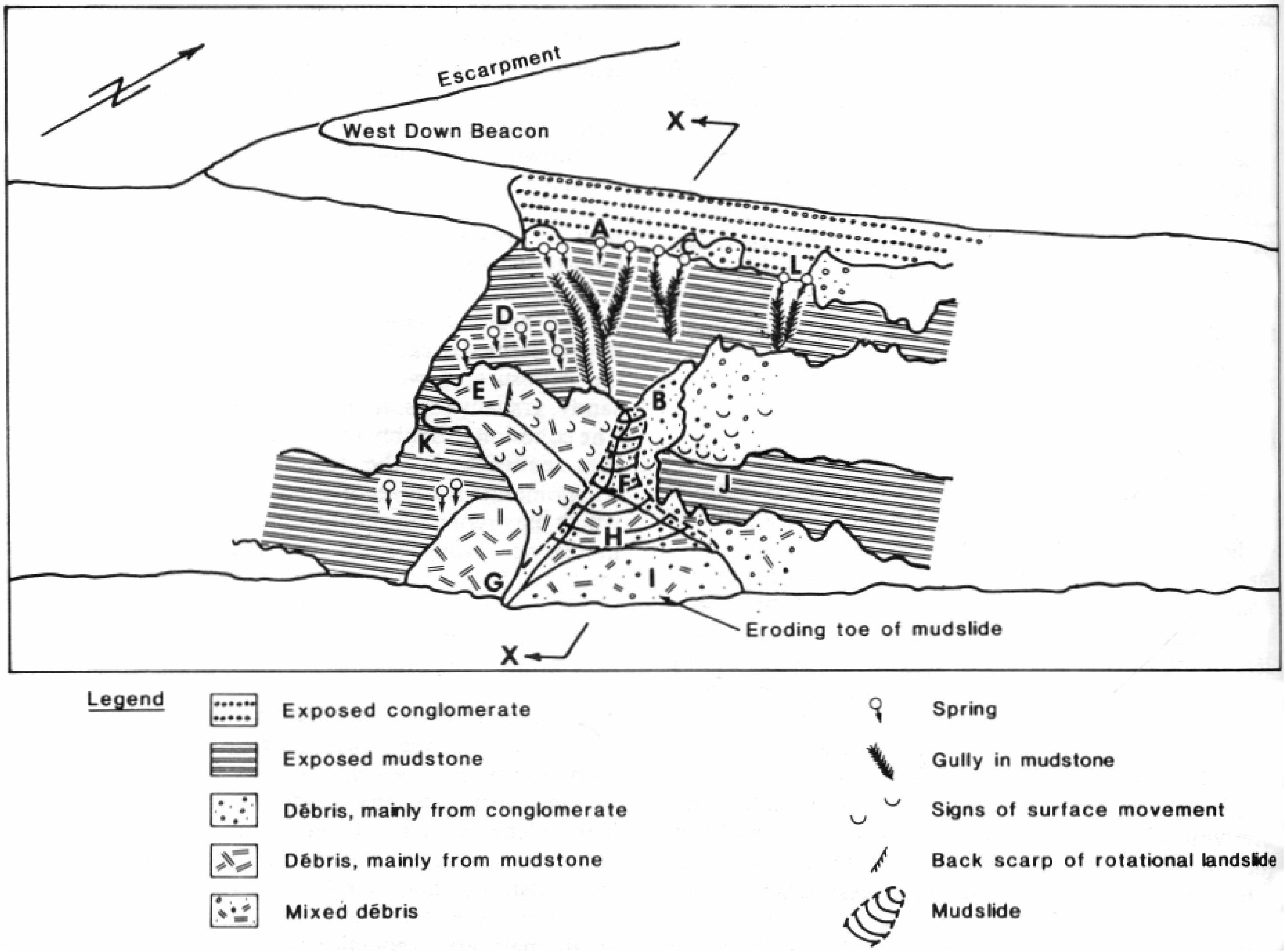

Figure 2. Interpretation of the landslide area of Figure 1. X-X indicates the line of the cross-section, Figure 3. The other letters mark areas referred to in the text.

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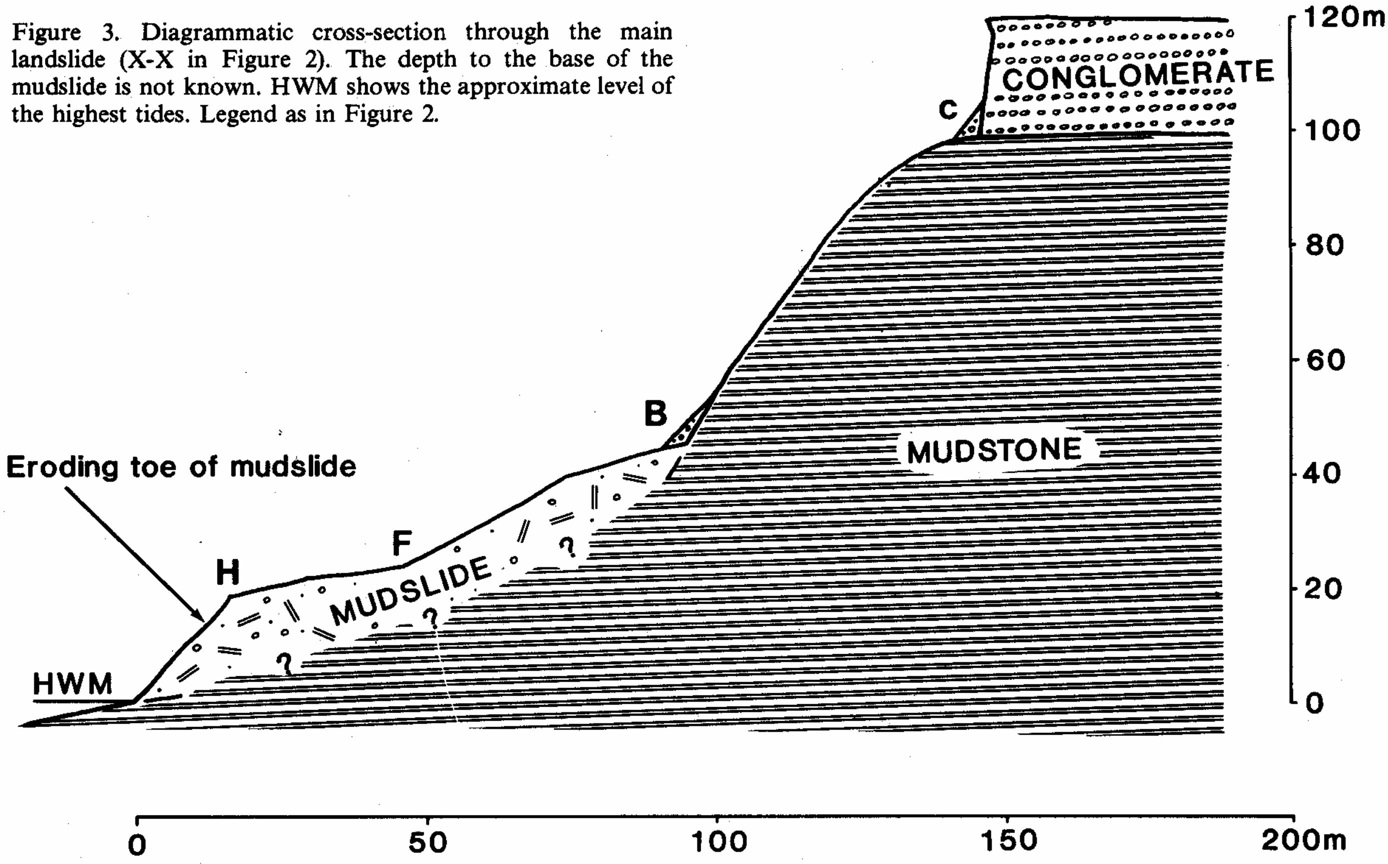

Figure 3. Diagrammatic cross-section through the main landslide (X-X in Figure 2). The depth to the base of the mudslide is not known. HWM shows the approximate level of the highest tides. Legend as in Figure 2.

randomly oriented network of curved fissures between them. The harder grey layers tend to have the planar joints but not the fissures. The fissure spacing of the unweathered mudstone averages about 150mm. The exposed face of the mudstone quickly develops a freer fissure spacing as wetting and drying occurs.

Description of landslide area

This section describes the salient points of the area of landsliding, the descriptions in general following a sequence from the upper part of the cliff down to beach level.

The base of the conglomerate has a regional dip to the east-south-east but borehole evidence and a resistivity survey 3km inland (Sherrell 1970; Henson 197 l) indicate that locally this surface displays marked relief. At the coast the groundwater levels are drawn down by drainage out of the cliffs. The flow of groundwater towards the cliffs becomes concentrated by any relief of the underlying impermeable mudstone. The main areas of landsliding at West Down Beacon seem to occur where concentrated flows emerge from high up on the cliff face at the base of the conglomerate.

The groundwater emerging (e.g. at A in Fig. 2) causes seepage erosion at the base of the very weakly cemented conglomerate and assists in its oversteepening. This leads to sudden falls of the cliff above. The larger falls, occurring every few years, cause cliff-top recession of the order of 2 to 3 metres and involve near-vertical slices of conglomerate. The shape of the upper cliff suggests that poorly developed joints partly control the geometry of the slices. There is a range in scale from these infrequent large falls down to the falling of individual pebbles, which becomes a continuous process during the winter months. Typically the d6bris from the large falls rapidly reaches B (Figs. 2 and 3) but that from the small scale falls can form screes on the ledge on top of the mudstone and be banked up against the lower part of the conglomerate as at C.

The weathered top of the conglomerate and topsoil develops overhangs of up to lm making the cliff-top area extremely hazardous. Tension cracks and other signs of incipient movement are generally absent on the cliff top above the conglomerate so there is usually no warning that a fall is imminent. It is thought that the slight cementation of the conglomerate renders it brittle So that small strains are followed immediately by sudden collapse (to the west of the conglomerate escarpment tension cracks are found in the more plastic mudstone).

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The emergent groundwater runs over the mudstone in the cliff face, softening the surface and forming gullies. The thin resistant beds of grey siltstone and silty sandstone to some extent impede this gully development. As can be seen at D (Fig. 2) water also emerges from the mudstone at particular levels, some of which correspond to the grey layers. The gully erosion and surface softening lead locally to instability of the fissured and jointed mudstone and there are frequent falls of blocks up to 0.5m in size. These blocks disintegrate and soften rapidly on exposure.

On the western side at E where there is only a little conglomerate débris, the softened mudstone has been affected by rotational slips and the resulting backtilting has interrupted the surface drainage. The slips direct some material into the main slide area between B and F while other material is contributed to the flow of débris towards G (Fig. 2).

Since the fall from the conglomerate in September 1979, sand, gravel and cobbles have formed the greater part of the débris visible beneath the cliff at area B. Water running down the face of the cliff collects in this débris and a reservoir of perched groundwater is formed. Since the photograph (Fig. l) was taken an extensive crack has developed in the débris at B showing that the débris itself, when saturated, is only marginally stable.

In the main area of débris accumulation at the head of the landslide there is, if local gullying is ignored, a general surface slope towards the beach of 26° from B to F. Downslope from F there is usually only accumulation of the small amount of débris which comes in from the sides. The surface slope from F to H (at the top of the steep face at the toe) is about l0°.

It is known that, very soon after a major fall from the conglomerate, the main landslide extends across the beach. Direct erosion of its toe at each high tide results in slumping. En échelon tension cracks can then be found at H. The landslide débris appears to keep the storm beach to the seaward side and this prevents the sea from directly attacking the cliffs to either side of the main landslide area.

When the landslides are less active, blocky falls take place from large masses of mudstone (up to at least 4m x 8m in area) exposed at I in the face at the toe. That these masses have suffered some internal disruption is revealed by distortion of pale grey layers. The blocky falls show that the internal disruption has not everywhere caused remoulding severe enough to destroy the fissure and joint pattern. A block of relatively undistorted conglomerate and basal clay, the block having an exposed area of lm x 2m, has also been recognised in the face at the toe of the main landslide. Randomly oriented minor shears and a sub-horizontal 0.2m thick major shear zone within the landslide have been found just above beach level in the face at the toe.

On both sides of the main landslide area, at J and K (Fig. 2), a hard band in the mudstone forms a capping to the lowermost part of the cliffs. The drainage from the base of the conglomerate at L was diverted from the main landslide area towards J by the d6bris from the fall in September 1979. This drainage adds water to the conglomerate débris on the shallow slope immediately above the hard band. Sand, gravel and cobbles in a mudstone slurry flow over the hard band and onto the beach.

Mechanisms of Landsliding

Bromhead (1979) stresses that the lithology and the hydrogeological characteristics of the uppermost part of the cliff are important in determining the behaviour of coastal landslides in overconsolidated clays. At West Down Beacon the upper cliff is formed of conglomerate that is weak enough to feed débris to the landslide at a rate sufficient to keep the storm beach forward. The foot of the sea cliff is thus protected and the cliff cannot now be steepened to the extent that deep rotational slips would occur. The permeability contrast between the conglomerate and the mudstone is such that groundwater accumulates in the conglomerate. As mentioned earlier, this groundwater emerges where the cliff face intersects the low points of the base of the conglomerate. This factor would appear to be important in that, besides contributing water to the débris, it also controls where the landslides are.

It is clear from the description of the landslide area that d6bris accumulates from both the mudstone and the conglomerate and that water is directed in abundance into the débris. There is sufficient slurried mudstone for the combined conglomerate and mudstone débris to behave as a cohesive material which could move downslope as a mudslide. Because the slopes at the back of the main mudslide are too shallow, major sliding does not occur without some form of triggering. It is thought that triggering is provided by the large falls from the conglomerate in the upper cliff. A large mass suddenly reaching the upper part of the accumulated débris represents a relatively rapid loading on that débris. This undrained loading (Hutchinson and Bhandari 1971) means that the new load is perhaps almost entirely carried at first by an increase in pore-water pressure. The factor of safety against sliding may well be reduced enough to cause the main mudslide to move.

It is probable that some points of discharge of groundwater from the mudstone, similar to those visible in Fig. 1, become blocked by the débris. Wherever the débris is relatively impermeable and a higher point for the discharge has to be found, the groundwater pressure is increased. This means that, before a fall from the conglomerate, the effective stresses in the potential slip zone between the mudslide and the in situ mudstone may already be somewhat lower than expected.

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The major shear zone and the large masses of recognisable conglomerate and mudstone in the toe are further evidence for a mudslide mechanism. A mudflow would display a greater degree of internal disruption.

A minor process of mass movement, particularly during periods of wet weather, is the more or less continuous flow of débris on steep slopes.

Removal by the sea of material from the toe is thought to be of minor importance in reactivating a mudslide compared with the effect of undrained loading (Bromhead 1979). Toe erosion is nevertheless important in preventing the overall slope of the cliff reducing to a stable angle. The main mudslide at West Down Beacon appears not to be reactivated when the toe is eroded after a mudsliding event.

References

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Discussion

Mr J.R.. Merefield: What part does the clay mineralogy play in the process you describe, bearing in mind the predominantly kaolinitic matrix of the Budleigh Salterton Pebble Beds and the illitic clays of the Littleham Mudstone?

Authors' reply: The kaolinitic clay in the matrix of the conglomerate provides cohesion, bearing in mind the conglomerate provides cohesion, which helps to maintain the steepness of the upper cliff. This cohesion also partly controls the mode of failure of the upper cliff-- large falls being possible which provide the undrained loading lower down. In the lower débris piles and mudslide area, the illitic-chloritic clay of the Littleham Mudstone greatly overshadow the kaolinitic contribution from the Pebble Beds. The plasticity of the mudslide when wetted is therefore related to these minerals of moderate activity, rather than to the kaolinite of low activity.

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