A RECENT LARGE LANDSLIDE AT THE SPITTLES, LYME REGIS, DORSET AND ITS IMPLICATIONS FOR THE STABILITY OF THE ADJACENT URBAN AREA

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The Black Ven-Spittles landslide is an old, probably Pleistocene, complex of interacting coastal landslides that are in the process of being reactivated as a result of a combination of man-made works and marine erosion. The upper part of the complex is underlain by Cretaceous rocks and the lower part by the Jurassic Charmouth Mudstone Formation. Large-scale rotational and translational failures have occurred in the Cretaceous rocks at less than 10-year intervals during the past 60 years, almost always during or shortly after prolonged periods of rainfall. In contrast, large-scale failures have been infrequent in the Charmouth Mudstone and have been restricted to areas where a low (<1.5°) seaward dip has resulted in bedding-plane-initiated failures. Two such failures have been recorded, in 1908 and 2008, both in the same area at the western end of the landslide complex in the area closest to the Lyme Regis urban area. The first of these occurred at 1.15 pm on June 10th 1908 and involved the collapse, or partial collapse, of 450 m of cliff. It involved an estimated total of more than 300,000 tonnes of rock in what was probably the culmination of three separate failures that occurred in rapid succession. The second, involving an area of *c*. 40,000 m^2 and *c*. 500,000 tonnes of material, occurred over a period of a few hours starting at 8 pm on May 6th 2008. In addition, the new landslide intersected part of the former (*c*. 1920-1973) town rubbish tip with the result that glass, metal, other wastes and possible pollutants were deposited on the beach. Before-and-after geological surveys of the area and the availability of pre- and post-failure photographs and LiDAR surveys have made it possible to determine how the 2008 failure was initiated, and how it progressed. Both the 1908 and 2008 failures appear to have started as relatively small rock-block collapses in a fracture zone associated with a minor fault. At its western end, the new landslide is <300 m from the Lyme Regis built-up area and separated from it by similar mudstones with small faults that may be equally prone to failure.

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INTRODUCTION

Some of the most extensive landslides in Britain occur on the Devon and Dorset coasts between Sidmouth and Charmouth. In the western part of the area, where the Cretaceous Upper Greensand Formation rests unconformably on Triassic rocks, the principal failure surfaces are in thin (<10 mm thick) mudstones in the lowest part of the Upper Greensand (Gallois, 2007). In the middle and eastern parts of the area, where the Gault Formation is present, the principal failure surfaces are montmorillonite-rich mudstones close to the base of that formation. Between Lyme Regis and Charmouth shallow-seated landslides, fed by water from the overlying Upper Greensand aquifer, have occurred in the Shales-with-Beef Member of the Jurassic Charmouth Mudstone Formation. The best documented of these have been failures in Lister and Langmoor Gardens, Lyme Regis, notably in 1902, 1925 and 1962 (Lee, 1992), which necessitated extensive site-investigation and remedial works (Clark *et al*., 2000; Brunsden, 2002), and in the Spittles-Black Ven complex (Brunsden and Chandler, 1996; Conway, 1974).

In early January 1908 a collapse in the upper part of the Shales-with-Beef on the east side of Lyme Regis, in the vicinity of the eastern end of Spittles Lane (Figure 1), resulted in the accumulation of a pile of organic- and pyrite-rich mudstone debris on a terrace in the middle part of the member. Exothermic oxidation of pyrite caused smoke to emerge from the mound, and on 19th January stories of a Lyme Regis volcano appeared in the national press. The site soon became a tourist attraction that was rumoured to have been enhanced from time to time by the addition of paraffin. A description of this and a subsequent landslide was prepared by a retired Geological Survey geologist, A.C.G. Cameron who was then living at Uplyme, and passed to another Survey geologist, A.J. Jukes-Browne, who published (1908) a detailed account of the events.

At 1.15 pm on 10th June, 1908 a larger failure occurred in the terrace below the burning mound with a result that the mound split in half to reveal the burnt core looking 'like the inside of a brick kiln' (Jukes-Browne, 1908). Eye witnesses reported that 'the cliff suddenly gave way, and a large mass, weighing many thousands of tons, fell forward on to the beach …. while clouds of sulphurous smoke issued from the burning mound'. This failure was one of several that occurred more or less 'simultaneously or very soon afterwards' over a distance of *c*. 450 m. The largest of these, *c*. 210 m long (Figure 1), was the most westerly and formed a debris sheet that covered the underlying cliff of Blue Lias and ran out beyond the low water mark (Jukes-Browne, 1908). Later the same day large blocks

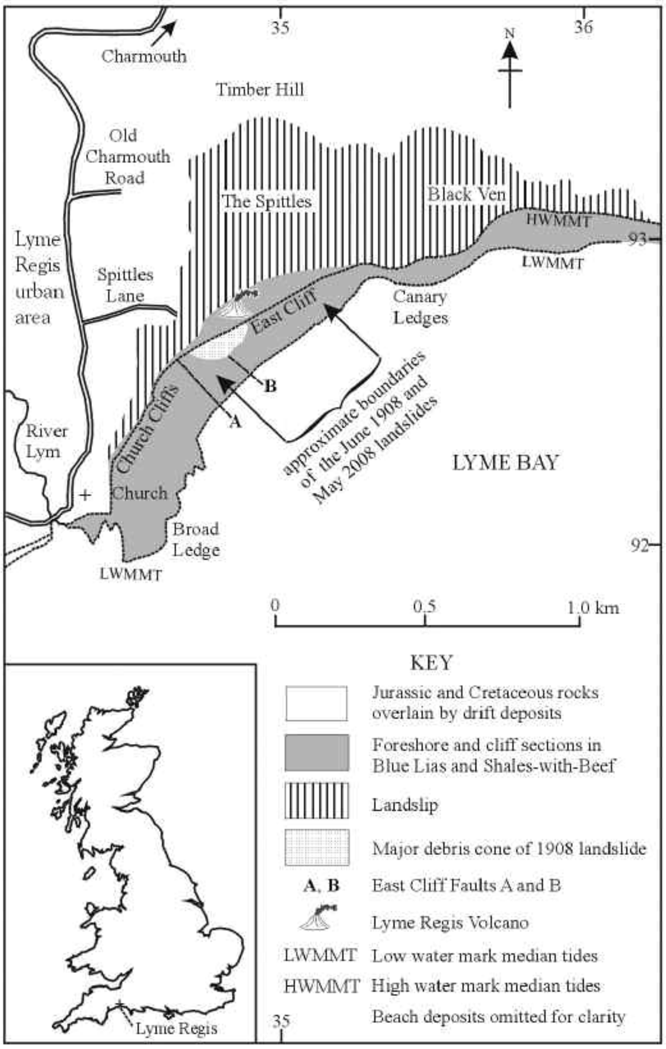

Figure 1. *Geological sketch map of the area around the June 1908 and May 2008 landslides.*

fell from the slip faces and a mass of material moved forward. A similar sequence of events occurred in the same area on May 26th, 2008 when a succession of failures occurred in the Shales-with-Beef over a distance of about 400 m to produce a landslide and debris area of *c.* 40,000 square metres that covered the full width (*c.* 85 m) of the intertidal area.

DESCRIPTION OF THE MAY 2008 LANDSLIDE

Eyewitnesses observed the initial stages of the 2008 landslide, one of whom made a video recording of the early part of the event. At about 8 pm on May 6th, Lyme Regis firefighter Mr Virgil Turner and his team were on a night exercise on the beach below Church Cliffs when the first failure occurred. They were alerted to it by the sudden noisy departure of the gulls from East Cliff, rapidly followed by a large rock fall. A succession of further falls occurred over the next 30 minutes, mostly on the west side of the initial collapse. Local resident Mr Jim Robson made a continuous video recording (2 minutes 37 seconds long) of the failure from the end of East Cliff lane [SY 3447 9242], 350 m south west of the western edge of the landslide, starting about ten minutes after the first collapse. It begins with avalanche-like flows of Shales-with-Beef mudstones (rock-block failures) mixed with waste materials from the town tip in the vicinity of a small fault (East Cliff fault B in Figure 1) that produced a temporary gully with a buttress, about 30 m high and 30 m wide, on its west side. This collapsed as a series of rock-block and toppling failures over a period of 90 seconds and deposited several thousand tonnes of material into the sea. A succession of additional collapses, mostly east of the fault, over the next 30 seconds extended the debris area about 100 m east of the fault. At the end of the recording, the debris-covered area obscured the Blue Lias cliff over a distance of about 200 m. At its eastern end, the landslide abutted against the Blue Lias and Shales-with-Beef outcrop in the eastern half of East Cliff.

Prior to the landslide, these beds cropped out below The Spittles in three terraces, each capped by a thin (mostly up to 0.3 m thick) discontinuous bed of muddy limestone (Figure 2a). In ascending order, the terraces are coincident with Grey Ledge at the top of the Blue Lias, the Devonshire Head Limestone in the middle part of the Shales-with-Beef and the Birchi Tabular Bed at the top of the Shales-with-Beef (Figure 3). After the failure, the cliff face below the Birchi Tabular Bed had retreated about 35 m and was fronted by a stepped profile of debris that stretched from the foot of the inland cliff across the Shales-with-Beef and Blue Lias outcrops and intertidal area into the shallow subtidal area (Figure 2b), a distance of over 100 m.

A prominent feature within the debris area was a strip of calcareous mudstone (Bed SB 8 in Figure 3) capped by the Devonshire Head Limestone that had been pushed forward and upward to produce a prominent steep-sided ridge that was separated from the *in situ* Shales-with-Beef by a graben-like feature (Figure 4a-c). The Blue Lias cliff was almost wholly obscured by Shales-with-Beef debris, but enough of it was still visible to show that the cliff had remained intact and that the Blue Lias had not been involved in the landslide (Figures 2b and 4d). At its western end, the landslide intersected the southern edge of the Lyme Regis town tip (*c.* 1920 to 1973) with the result that a large quantity of burnt waste, glass bottles, domestic appliances and other materials poured over the cliff and became mixed with the mudstone debris. Over the next few days, waste continued to fall as the loose debris in the 'tumble zone' at the seaward edge of the tip became stabilised at a reduced slope angle of *c.* 30°. By May 8th, the top of the debris face had retreated *c.* 50 m from its pre-landslide position and caused a mature tree (A in Figure 2) to slide down the cliff to a mixture of cheers and groans from a large audience on the beach (Figure 4e). Over the next few months the whole of the debris area slowly became degraded. In the middle part of the landslide, the inland ridge and graben were replaced by an undulating slope as the Shales-with-Beef debris crept seaward and spread out for up to 85 m beyond the Blue Lias cliff. At its maximum prior to the removal of the finer grained material by the sea, the debris covered an area of *c.* 50,000 m^2 (Figure 5).

LANDSLIDE MECHANISMS 1908 AND 2008

There are close similarities in the geological succession, geographical location and manner of progression of the 1908 and 2008 landslides. Both landslides appear to have been initiated by the collapse (rock-block and toppling failures) of weathered and fractured Shales-with-Beef in the vicinity of East Cliff Fault B (Figure 4f). This produced a temporary valley that destabilised the Shales-with-Beef outcrop on either side of it, and this, in turn, gave rise to a series of translational landslides that progressed eastwards. Jukes-Browne's description of the 1908 landslide includes a map (1908, Plate 1) that shows the gullies in the intertidal area that mark the fracture zones adjacent to East Cliff faults A and B. The second of these is in line with the centre of the initial failure (Figure 1).

He attributed the initiation of the 1908 landslide to two main causes, quarrying of the Blue Lias limestones in the ledges in front of the sea cliff, and water flowing from higher ground into fractures in the mudstones. He suggested that the removal of the limestone ledges caused waves to break against the foot of the cliff with greater force and weaken it. The workings almost certainly contributed to an increase in the rate of retreat of the Blue Lias cliffs at East Cliff and the adjacent Church Cliffs, but they did so by inducing relatively small rock-block failures.

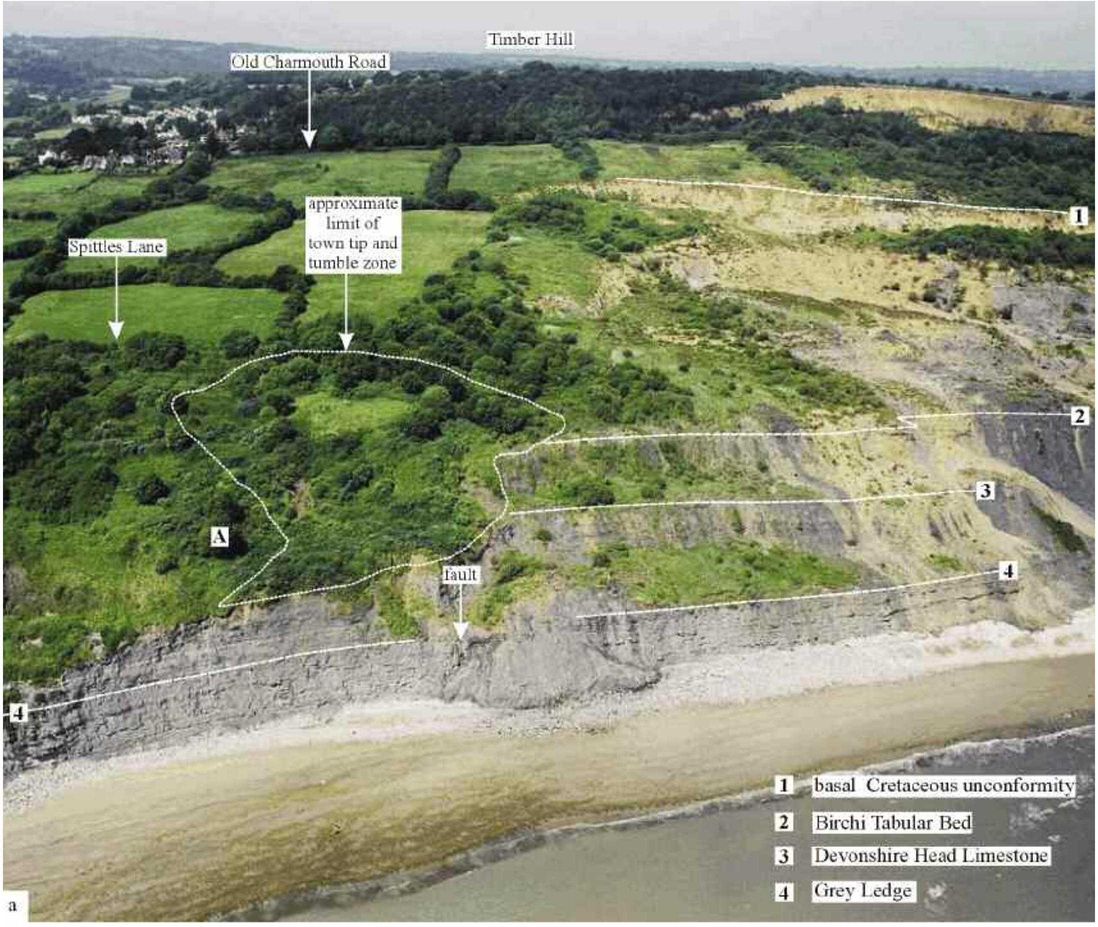

Figure 2. *Before-and-after photographs of the May 2008 landslide. (**a**) Oblique air photograph of The Spittles and adjacent areas in July 2003, view north at about mid tide. West Dorset District Council (WDDC) Frame D01000001, copyright WDDC. (**b**) Approximately the same view taken on May 8th, two days after the landslide, at high tide. The red-brown material at the west end of the landslide is material from the town tip. Photographed by the Maritime and Coastguard Agency (MCA), copyright MCA. The approximate position of the boundary of the Lyme Regis Town Tip and the tumble zone are based on Anon (2007).*

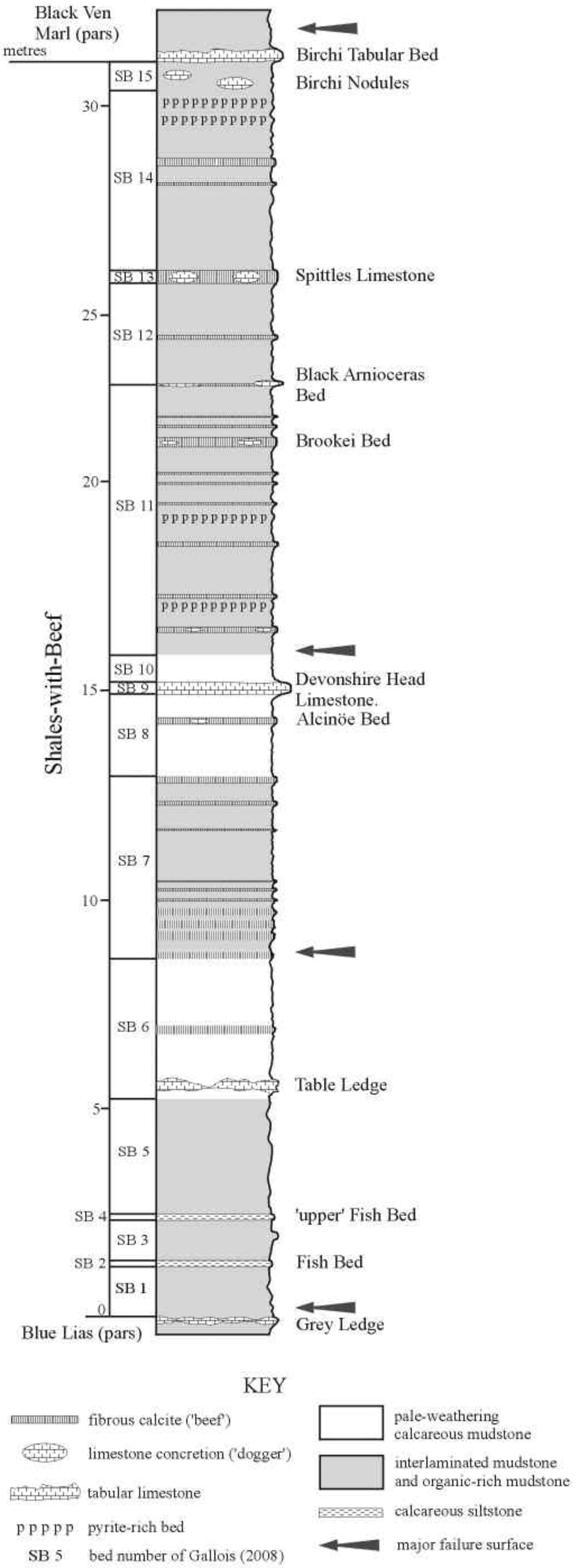

Figure 3. *Generalised vertical section for the Shales-with-Beef below The Spittles.*

Marine erosion has continued to the present day at East Cliff and below Devonshire Head on the west side of Lyme Regis, eighty years after the quarrying ceased, with no record of a major landslide in the Blue Lias. Contemporary photographs show that the Blue Lias in East Cliff was over-ridden by landslide debris from the Shales-with-Beef in 1908, but it did not fail.

Jukes-Browne (1908) noted that the landslide had occurred during dry weather and surmised that when a period of wet weather was followed by a dry period, the wetting and drying of the mudstones caused alternate expansion and contraction that could result in the collapse of a mass of fissured rock. He noted that a wet April 1908 had been followed by dry sunny weather in late May and early June and concluded that contraction was the final cause of the detachment. The rainfall records for Pinhay House, 3.3 km south west of The Spittles, show that for the period September 1907 to March 1908 the total precipitation was about 20% less than the average for the same months between 1868 and 1998. The total for April was close to the long-term average: those for May and June were markedly less. Similarly, the 2008 landslide was not preceded by a period of unusually wet weather, nor did it occur during an especially dry spell. The total rainfall (467 mm) for the period September 2007 to March 2008 at Lyme Regis, and that for the months of April and May 2008 were similar to the averages at Pinhay for 1868-2005.

The initial movements in the 2008 landslide were a rapid succession of rock-block and toppling failures in fractured, and probably in part chemically weathered, mudstones in the Shales-with-Beef Member in the vicinity of a fault (East Cliff Fault B in Figure 5) below the town tip. These collapses produced a temporary gully that was bounded by almost vertical, unstable faces of Shales-with-Beef. These faces collapsed within a few minutes of the initial failure. That on the western side triggered small collapses in the Shales-with-Beef over a distance of *c.* 50 m. On the eastern side, a succession of failures was observed to progress steadily eastwards until dusk (*c.* 9.20 pm), and had reached their full extent by dawn (*c.* 5 am) the next morning.

The presumed sequence of failure mechanisms in the central and western parts of the landslide, based on the stratigraphical succession in the Shales-with-Beef and the distribution of the debris in the landslide, is summarised in Figure 7. The video recording shows that east of East Cliff Fault B, the first failures were in the beds above Table Ledge, and that the debris flowed out over the lowest part of the Shales-with-Beef and the Blue Lias. For several days after this, prior to the collapse of the ridge and graben, all the debris visible at the surface came from horizons above Table Ledge. Much of the finer material in the lower part of the debris field was removed by marine erosion within a few weeks of the failure to leave a residue of the more resistant materials including large slabs of Fish Bed and Table Ledge. This indicated that failures had also occurred in the fissile mudstones immediately above Grey Ledge at the top of the Blue Lias. None of the debris included any Blue Lias lithologies.

SUMMARY AND CONCLUSIONS

The Lyme Regis urban area is bordered by large-scale, active landslide complexes. On its west side, the Undercliffs complex comprises a series of coalescing landslides in which the initial movements were bedding-plane failures in a thin bed of montmorillonite-rich mudstone close to the base of the Cretaceous succession (Gallois, 2007). In the east, in the Black Ven-Spittles complex, similar failures have occurred in the Cretaceous rocks at less than 10 year intervals, usually during or shortly after periods of high rainfall (Brunsden and Chandler, 1996). Many of these have given rise to secondary failures, mostly mudflows, in the underlying Jurassic Charmouth Mudstone. There are descriptive and photographic records of numerous landslides in the Charmouth Mudstone itself, almost all of which have been confined to the Shales-with-Beef

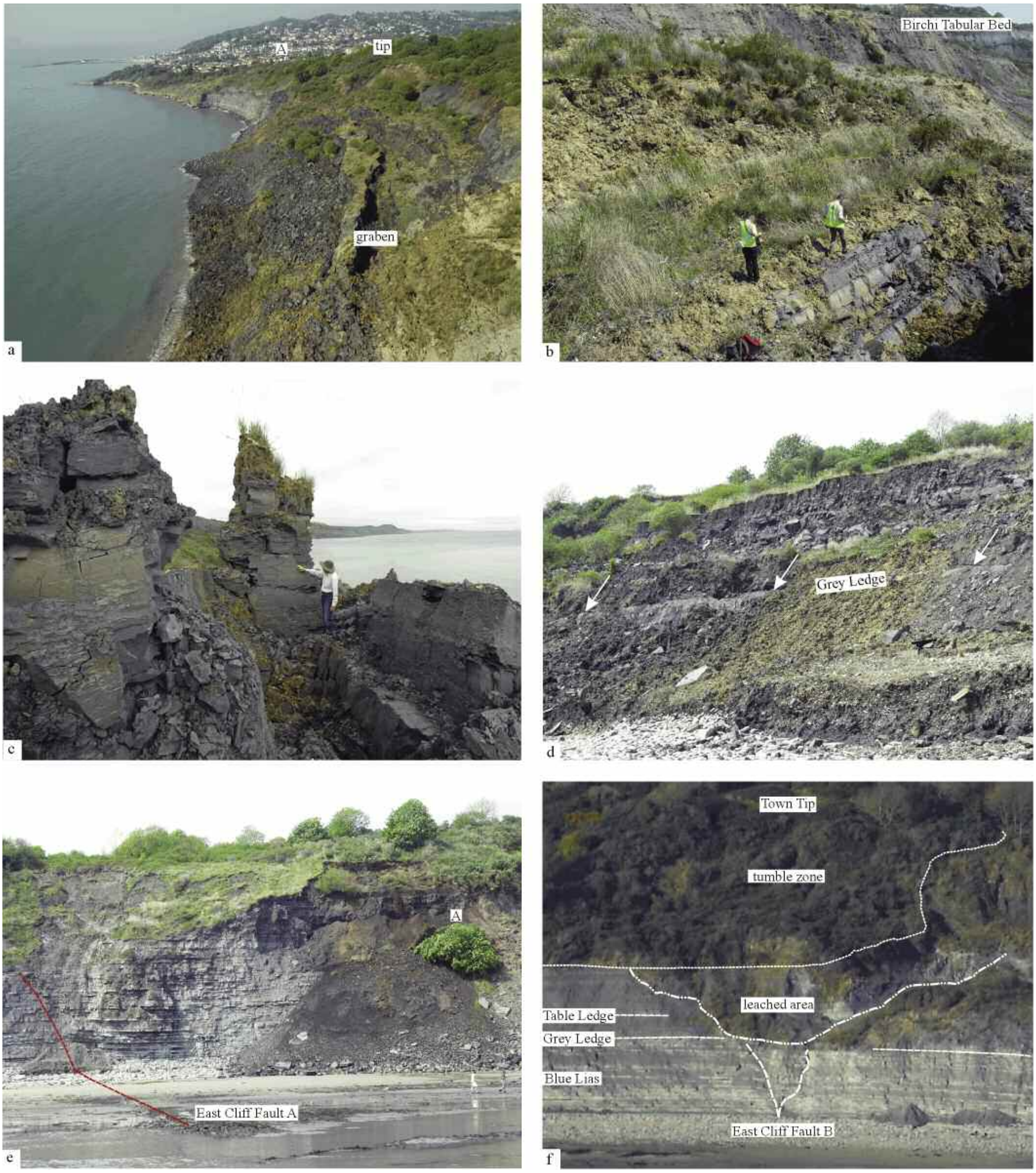

Figure 4. *Views of the 2008 landslide on May 8 and 12th, 2 and 6 days after the event. (**a**) Oblique aerial view west towards Lyme Regis across the landslide showing the temporary ridge and graben. Photographed by the Maritime and Coastguard Agency on May 8th: copyright MCA. (**b**) The graben in the middle part of the landslide viewed from the top of the temporary ridge on May 12th. (**c**) The temporary ridge, composed of blocky calcareous mudstone in the middle part of the Shales-with-Beef (Bed SB 11) that had been pushed forward and upward. Photograph by Richard Edmonds, World Heritage Team, May 12th. (**d**) Blocky calcareous mudstone debris from the middle part of the Shales-with-Beef overlying fissile mudstones in the lower part of the member that overlie undisturbed Blue Lias. Eastern part of East Cliff, May 8th. (**e**) Western end of the landslide on May 8th shortly after the mature tree (A in Figure 2a) fell down the cliff. Fifty metres west of the new landslide the fracture zone associated with East Cliff Fault A has given rise to instability in the Shales-with-Beef. (**f**) Oblique air photograph taken by Paul Whitney, BGS in February 2008 showing the triangular fracture zone in the Blue Lias associated with East Cliff Fault B overlain by a zone of weathered Shales-with-Beef that had been weakened by water flow and leachates from the town tip. Copyright NERC.*

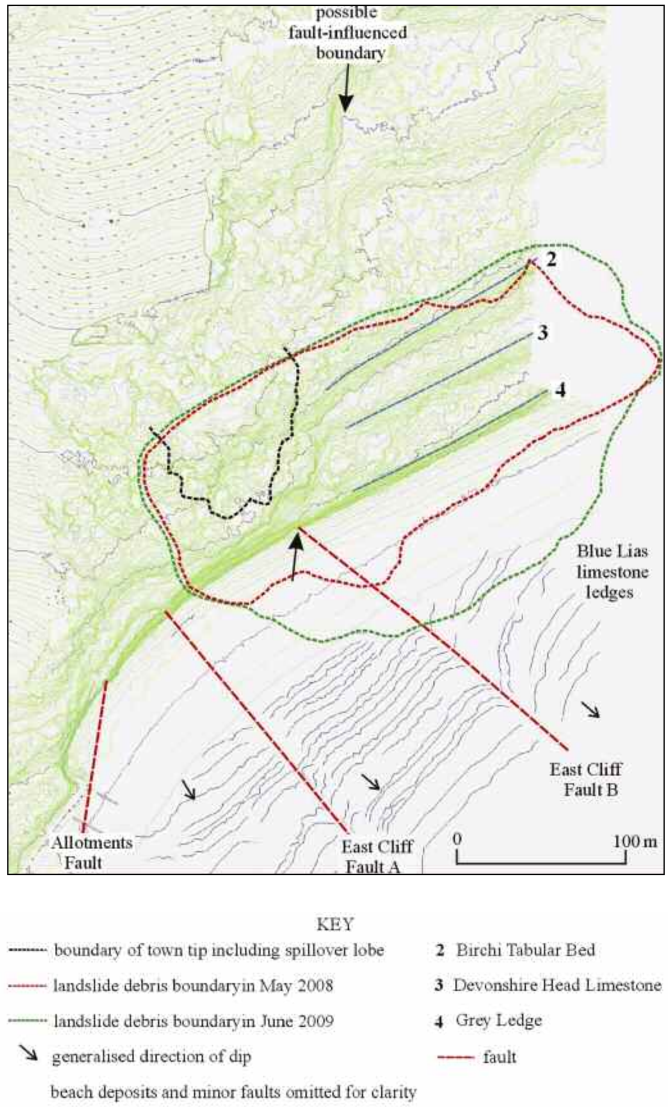

Figure 5. Topography of The Spittles and adjacent areas depicted as contours based on a 2006 LiDAR image. Landslide boundaries based on GPS surveys by Rob Clarke, West Dorset District Council. Published by permission WDDC.

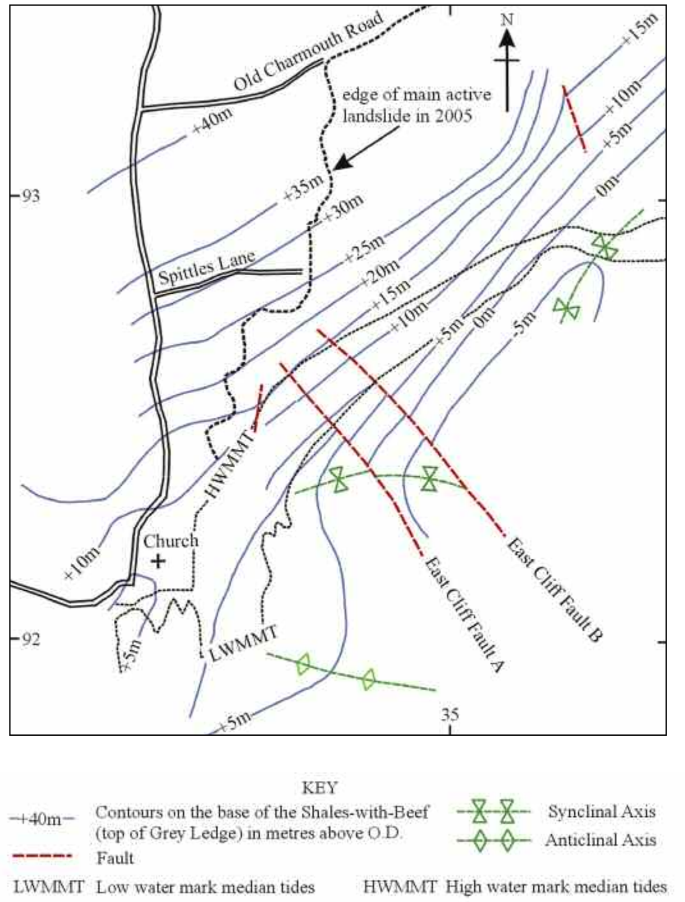

Figure 6. Geological structure of the Jurassic rocks of The Spittles onshore, intertidal and nearshore areas.

Member and have been relatively small (mostly <5000 tonnes). They include rock-block and toppling failures in bedded and jointed mudstones in actively eroding sea cliffs, and bedding-plane failures in slopes underlain by deeply weathered mudstones. The former include rock falls at Devonshire Head and East Cliff, and the latter a series of failures in Langmoor and Lister Gardens in Lyme Regis itself (Clark *et al*., 2000).

Only two primary large-scale failures have been recorded in the Shales-with-Beef, in June 1908 and in May 2008. Both appear to have been initiated by a rock-block failure in heavily fractured mudstones adjacent to a small fault (East Cliff Fault B in Figure 5). In comparison with the westward expansion of the Cretaceous part of the Black Ven-Spittles complex, the western edge of the Jurassic part has remained relatively stable during the past 60 years (Gallois, 2001, figure 1). The roughly linear nature of this boundary suggests that it might be fault bounded and related to the inland continuation of East Cliff Fault B (Figure 5). To the south west, East Cliff is intersected by similar faults. East Cliff Fault A intersects the cliff at a high angle (Figure 4d) at 115 m from Fault B, and a third fault (here named the Allotments Fault) intersects the cliff at an angle of about 30° a further 70 m south west of Fault A (Figure 5). Both have small throws, but relatively wide fracture zones that have given rise to inverted cone-shaped collapse features in the Shales-with-Beef. These are similar to that observed adjacent to east Cliff Fault B prior to the May 2008 failure (Figure 4f). The projection of the Allotments Fault inland suggests that it intersects Fault A about 45 m north west of the face of East Cliff, within the Shales-with-Beef outcrop. The next major landslide in the area is therefore likely, in the author's opinion, to occur in the Shales-with-Beef between this intersection and Fault B. This would involve much of the waste material that remains in the town tip, and it would bring the western edge of the active landslide complex to within 130 m of the urban area. Its western edge would then be close to or abut against an old (late 19th Century) landslide that was intermittently active in the 20th Century (Conway and Culshaw, 1974). It has been partially stabilised by remedial drainage and piling works.

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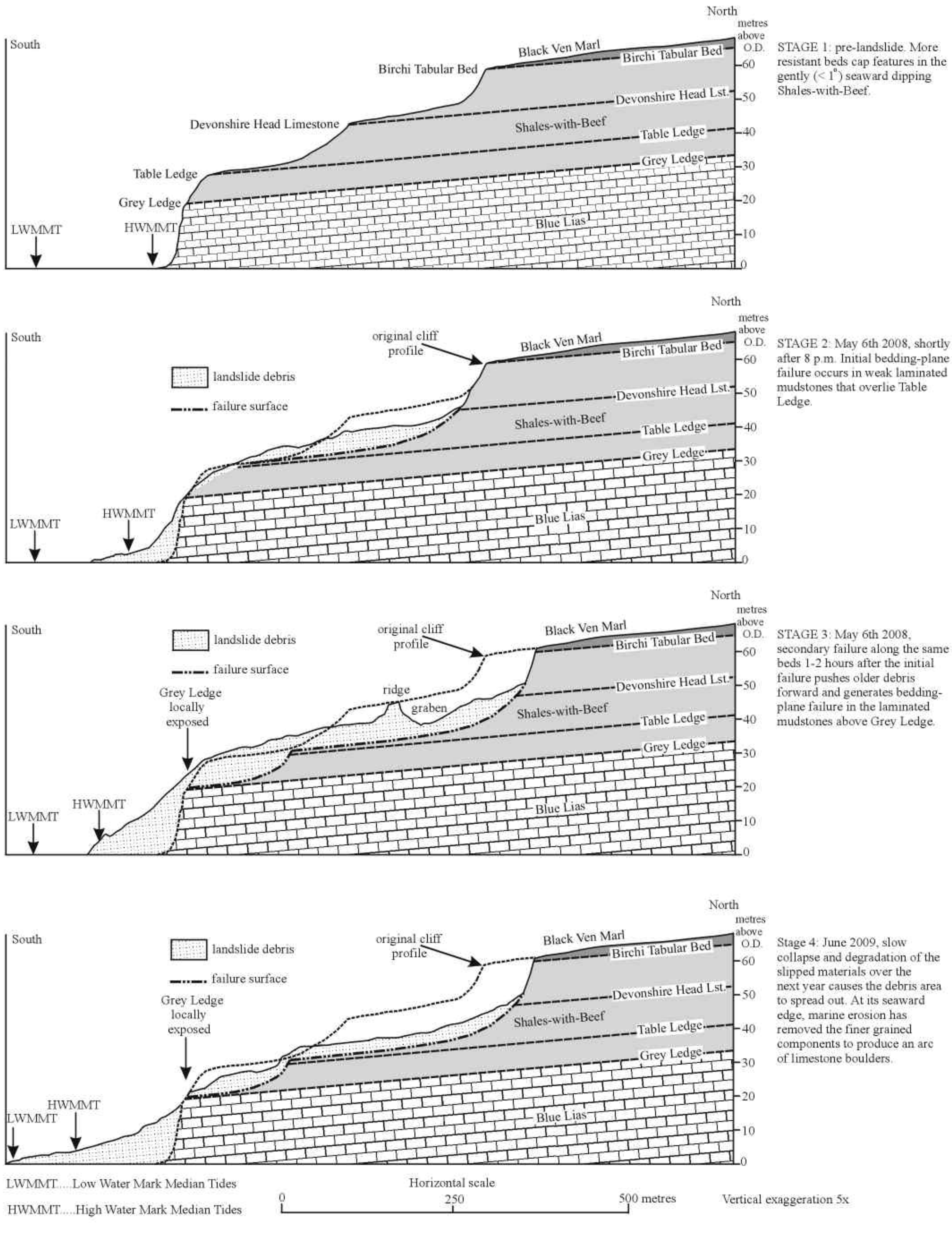

Figure 7. *Geological sketch sections through the central part of the landslide showing the postulated sequence of events.*

and for the use of their data. The rainfall data for Pinhay House was kindly supplied by Mr George Allhusen and that for Lyme Regis by local resident Mr Frank Lestner. The MCA (Figures 2b and 4a), Richard Edmonds (Figure 4c), BGS (Figure 4f) and WDDC (Figures 2a and 5) are thanked for permission to reproduce their photographs. The reviewers Andy Gibson and Peter Hobbs are thanked for their suggested improvements to the first draft of this account.

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