Bursting and heaving ledges on Monmouth Beach, Lyme Regis

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Since 2004 the loss, or rather the erosional changes, in the middle foreshore ledges of Monmouth Beach, west of Lyme Regis, have been monitored using a variety of photographic techniques. The ledges appear most susceptible to change in the late summer and early autumn and while some changes can be attributed to what might be expected in such a wave dominated environment, others are not. In the summer of 2011 one ledge burst open with very obvious evidence of compression. Following that observation, a number of other compressional and extensional features have been identified, some clearly dating back many years, yet still propagating westwards. These almost certainly play a significant role in the distribution of the ledges as we see them today but the forces at work are unknown and only suggestions for their operation are described. The changes are either happening very slowly, or periodically, in response to specific conditions and monitoring is on-going in an effort to learn more.

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Introduction

The cliffs and foreshore of Monmouth Beach, west of Lyme Regis, display a world-famous succession through the Blue Lias Formation of the Lower Jurassic (House, 1993; Cope, 2015). It is a very well-visited locality for field work, geo-tourism and fossil collecting. This coastal section is a Geological Conservation Review site for Lower Jurassic stratigraphy (Simms *et al*., 2004), fossil fishes (Dineley and Metcalf, 1999), fossil reptiles (Benton and Spencer, 1995), mass movements (Cooper, 2007) and coastal geomorphology (May and Hansom, 2003) and it is one of the highlights of the Dorset and East Devon ('Jurassic Coast') World Heritage Site.

The cliffs and foreshore ledges are subject to the forces of erosion through both the direct action of the sea and landslides. Around 2004, the seemingly stable and iconic 'Ammonite pavement' or 'Top Tape', (Bed 29 of Lang, 1924) started to break up along its eastern edge, with holes appearing within the pavement itself. Photographic monitoring between 2004 and 2011 recorded the changes and the 'loss' of parts of the ammonite pavement. This recording, coupled with the observations of others (e.g., M. B. Hart, *pers. com*., 2014), has suggested that the greatest change appears to take place in the early autumn: the main break-up events were recorded in October 2006, October 2008 and October 2009.

Catastrophic changes

Sometime between the 19th and the 28th July 2011 an area in the middle of the most easterly of the extensive middle shore wave cut platforms (Grid Reference: SY33021 91243), the Specketty (Bed 19 of Lang, 1924), burst open over an 8 m by 3 m area. The jointed edges showed compression, with uplifted blocks and spalling or flaking along the surfaces adjacent to the jointing which extended into the unbroken areas of the pavement (Figure 1). The failure was progressive, continuing until the 11th August. An earlier but smaller event was observed in August 2010 and previous photographic monitoring showed that another had occurred sometime before the summer of 2008.

As the monitoring increased in response to these observations, another event was captured in October 2011. This broke off 2 m by 4 m sections of ledges in the Gumption (Bed 32, Lang, 1924), the Third Quick, (Bed 31), the Top Copper (Bed 25) and the Second Mongrel (Bed 21). Anecdotal evidence from surfers identified a wave event on the 29th September as the likely cause and the West Bay wave rider buoy, provided by the Strategic Monitoring Programme through the Plymouth Coastal Observatory (www.chanelcoast.org), recorded a 2 m swell with a 15–16 second period on a 4.6 m tide. This was an event that could typically go unnoticed. Furthermore, larger and more frequent storm and swell wave events take place in the winter and seemingly produce far less 'damage' to the ledges.

In August 2011 the failure in the Specketty (Bed 19) was captured by shooting a photographic mosaic of images and stitching them together to create a very high resolution record of the feature before it was modified by the sea. The bed had thinned very considerably in places, due to attrition of the surface and the failure appeared to be controlled by a bioturbated parting within the limestone. The Specketty is characterised by this bioturbated level, but here the limestone, which is up to 40 cm thick, was split and this level took the form of a clay parting. In places where the failure occurred, the top surface was between about 12 cm and just 3 cm thick. A simple model is proposed for the failure: attrition thins the upper limestone layer, the jointing opens up and then it fails. The cause is more problematic and will be discussed later. This event happened during a very hot spell of weather, as recorded at Bridport (www.bridportweather.co.uk/weather/index.htm), during neap tides and calm seas as recorded by the West Bay wave rider buoy.

A separate, compressional, failure feature was also observed in August 2011 in the Third Quick (Bed 31) towards Seven Rock Point (SY32889 91107). Here the limestone appeared to have sheared through the middle of the bed, and large flat flakes had, or were in the process of spalling off. It took place at the end of a sinuous joint feature extending eastwards towards the edge of the limestone ledge and appeared to be a westerly

Figure 1. *The spectacular heave in Bed 19 (Lang, 1924) during July and August 2011.*

extension of it (Figure 2). Three similar, but older, features were then identified in the Bed 35, the Second Quick, nearby (GR SY32906 91112) and south and east from there where they were associated with east–west trending cracks in the ledge. These cracks do not extend into the beds below, raising the question of the origin of the jointing. Gallois (2012) described the tectonic setting for the area, and identified both N–S and E–W trending faults, which presumably control many of the jointing features in the platforms. In the same bed in this area, pull apart jointing was observed by Ian West during a trip to see these features. Here it can be seen that large sections of the northern edge of the ledge have rotated slightly, in a horizontal sense, thereby creating corresponding compressional failures (Figure 3). Similar, but larger scale features can also be seen in the Mongrel (Bed 23, Lang, 1924) at SY32971 91170. Here a long, linear crack runs east–west through the ledge, but it widens to the east. The whole ledge, therefore, has rotated and in doing so, it has compressed the northern edge, an edge that contains four gullies. The widest are on the eastern side, while the narrowest are to the west. The penultimate western one contains a block that has been displaced vertically while the most western one has the freshest cracks and jointing.

The failure in the Specketty and Third Quick are 'contained' in that the beds are continuous into the cliff face, while those in the Second Quick and Mongrel are 'unconstrained' in that the beds have been eroded into ledges that are isolated from the cliff. A final, startling and very obvious observation was made by Alan Powderham during another site visit. The surviving section of the old quarrymen's tram line probably constructed in 1908 at SY3306691279 crosses a tectonic fault with mineralised slickensides showing listric movement. The tramway was set into blocks of concrete on Bed 9, yet the two blocks straddling the fault have been tilted in opposite directions either side of the fault (Figure 4). Fresh flaking was evident along some of the jointing in the bed: this fault, or the beds around it at least, have been moving! The Channel Coast Observatory undertook a ground based LiDAR survey of this area which determined up to 45 cm of uplift in the concrete blocks.

On-going observation

In 2012, Natural England sponsored an Un-manned Aerial Vehicle (UAV) survey of the area in order to generate a very high resolution photographic record of the middle and upper shore ledges. Four surveys were flown altogether. The over-arching survey was from the eastern edge of Bed 19 to the western edge of the ledges east of Seven Rock Point, where they become obscured by landslide toe debris, and was flown at an altitude to generate an image resolution of about 12 mm: each pixel representing 12 mm on the ground. Three smaller, but higher resolution surveys of Bed 29 and parts of beds 31 and 35 were flown at 2 mm resolution. The purpose was to record what the ledges looked like prior to the next failure. However, from the winter of 2012/13, large parts of the eastern end of the survey area, including the concrete blocks, and some of the western end at Seven Rock Point, have been obscured by landslides.

The only changes identified so far are minor modifications of joint bound blocks along the edges of some ledges, the sort of failures one might expect to see in response to sea conditions. The Ammonite Pavement is experiencing the greatest change

Figure 2. *Compressional and flaking features in Bed 31 towards Seven Rock Point, August 2011.*

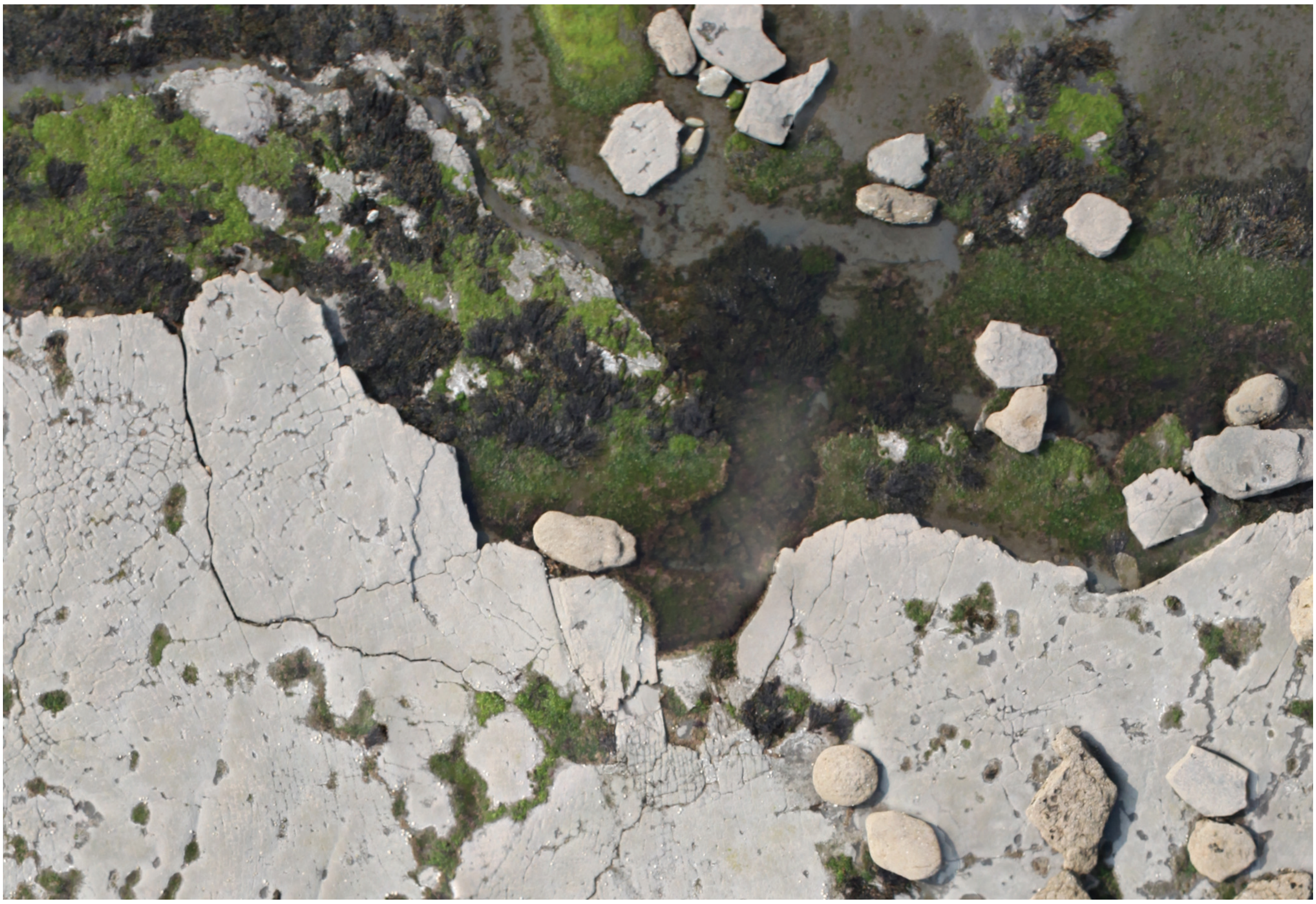

Figure 3. *Horizontal rotation of a block of limestone (left) and subsequent compression (middle), northern edge of Bed 35, Seven Rock Point. The image covers approximately 8 m on the ground.*

Figure 4. *The remains of the old tramline with concrete blocks tilted in opposite directions over a fault. The rail tracks can be seen in the distance.*

with the eastern edge breaking away during winter storms and the holes through it are now in the process of joining up. There is some evidence of spalling and flaking within them.

A separate exercise was undertaken to compare Lang's mapping of the beds (Lang, 1932) with what can be seen today but this uncovered a number of problems. Features on the foreshore today, such as faults and folds, are identified in the Series 1 Ordnance Survey map but do not match up well with modern mapping. This has probably led to over estimates of cliff recession in previous studies. A useful reference point is provided by the remains of the tramway line including the location of a 'blondon', a tower structure that was used to support an aerial ropeway to take the quarried stone from the end of the tramway over the beach to the cement factory which was located near what is now the boat building academy. This was in operation from 1908 to 1914 and photographs in Lyme Regis Museum's collection show it to be a very considerable distance from the cliff with little change to the cliff profile.

Lang's mapping also appears to be inaccurate as the remaining rails of the tram line sit on Bed 9, but Lang has them on Bed 19. What we can say is that the beds have 'migrated' in a westerly direction, and this is what would be expected. The significance of these observations, however, is that the long linear features with associated flaking, have controlled the erosion patterns of the middle foreshore ledges and continue to do so. Whatever that process is, it is happening either very slowly or sporadically in response to specific conditions.

Ccomparable observations and drivers for change

While De La Beche (1839) was the first to identify wave cut platforms and consider how they formed around Lyme Regis, there appears to be very little comparable observations or discussion of the issue in the literature. Kanyaya and Trenhaile, (2005) have discussed tidal wetting and drying of foreshore ledges, while Kennedy *et al*. (2011), Stephenson and Kirk (2000a), Trenhaile (2008) and Trenhaile and Porter (2007) have explored the role of waves and other subaerial processes. Naylor and Stephenson (2010) and Naylor *et al*. (2011) have investigated the role of marine organisms as a driver for erosion. None appear to identify anything resembling the specific features identified on Monmouth Beach.

As to the cause of the movement in the ledges, the most obvious would be unloading. The strata have been deeply buried for millions of years and now, as they are being eroded, the contained stresses are being released. The problem with this hypothesis is that it is not seen anywhere else where the Blue Lias Formation is exposed. On the east side of Lyme Regis, the exact same beds form the middle foreshore yet there is no evidence of movement or the compressional features seen at Monmouth Beach. Swelling clays could be another driver, but again, the movement recorded is specific to Monmouth Beach. The observed events take place during hot weather, yet the well jointed limestones should have ample space to accommodate thermal expansion and again, this is not seen elsewhere. A weakening of the limestone/clay contact could account for the greater storm damage in the autumn but, again, why Monmouth Beach only? One possibility could be that quarrying along Monmouth Beach in the nineteenth and early twentieth centuries has left the middle and upper shore at a slightly higher position than elsewhere. These ledge are, therefore, exposed longer when the tide is out. A final suggestion, put forward at the Ussher meeting in 2015, was that evaporation and salt displacement could be the driver, and this would fit well with a higher foreshore. The wildcard is a massive, creeping landslide with a failure surface deep below the beach. The Plateau Landslide further west within the Undercliffs is clearly developed on a failure surface within the Jurassic or Triassic strata, as the Jurassic beds, complete with the unconformity, are rotated and exposed in the foreshore toe. That said, there is no obvious evidence to support a major landslide as the cause at Monmouth Beach, in Ware Cliffs above or on the sea bed bathymetry offshore, provided by the strategic monitoring programme. Further on-going observation is required.

Summary

The ledges along Monmouth Beach are moving, albeit slowly – and perhaps sporadically – in response to specific conditions that have, as yet, not been identified. The cause is unknown, while these features appear to be unusual in terms of the morphology of wave cut platforms. The photographic monitoring provides a baseline against which to measure future change and on-going observation is required to understand the processes.

Postscript

Between the 16th and 17th December 2016, a 9 m by 6 m section of the ammonite pavement failed in response to a 2 m swell wave event.

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