# PORLOCK GRAVEL BARRIER

*J. Orford*

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## Introduction

The coastal gravel barrier and beach at Porlock is the longest continuous coastal gravel barrier system on the western coast of Britain (see Figure 6.18). It is 5 km long and fronts low-lying farmland, which is being flooded daily by the tide as a result of a major breach that occurred during a severe storm in 1996. The breach has not 'healed' and has resulted in saltmarsh development and clay deposition in the back-barrier area associated with the upper elevations of a prevailing macro-tidal regime (9 m at mean high-water springs). The existence of the barrier relies upon a complex and dynamic interaction of geomorphological processes operating in an environment that is sediment-constrained and storm-wave dominated. Sporadic breaching and 'healing' events had been the natural cycle of evolution of the barrier before the onset of anthropogenic activities that attempted to stabilize the barrier and prevent it from breaching.

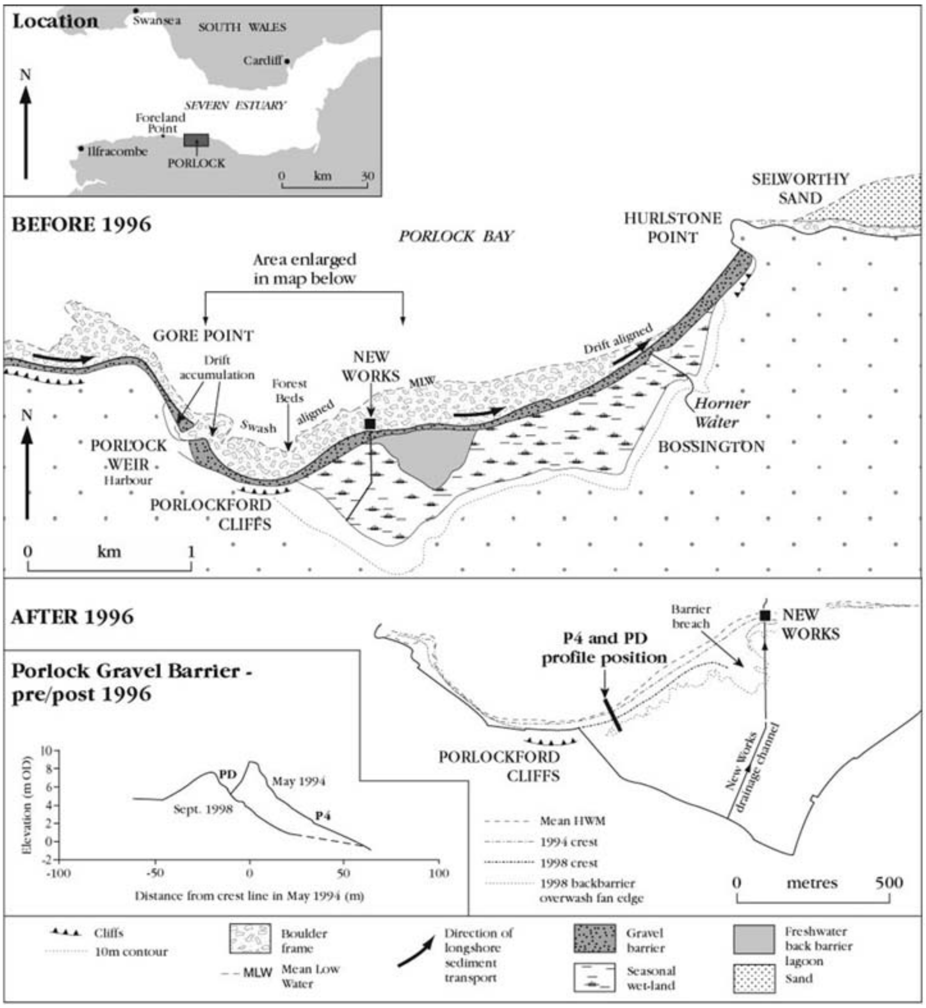


*Figure 6.18: (A) Porlock barrier and back-barrier; (B) barrier crest and back-barrier changes before and after the 1996 barrier breaching; (C) barrier profile changes due to the 1996 storm.*

The barrier shows evidence of longshore segmentation, and of sediment erosion and reworking caused by the long-term failure of longshore sediment supply, which lead to well-developed swash-aligned and drift-aligned sections that are rarely found adjacent to each other on UK gravel barriers.

The geomorphological importance of, and wider interest in, the Porlock coastal gravel barrier has grown significantly over the last two decades, owing to debate about the effects of earlier coastal management strategies. There can be little doubt that the catastrophic breaching event of 1996 occurred as a consequence of barrier weakening through cumulative management activities (over several decades) intended to protect the coast. Although the barrier is returning to a natural state it is unlikely that the breach will heal, and part of its present-day interest is the development of the geomorphology following the breach.

## Description

The Porlock barrier fringes the seaward edge of a coastal embayment at the eastern end of the Exmoor plateau (Figure 6.18). The crest height west of Gore Point is typically 5–6m OD, and 12 m OD to the east, towards Hurlstone Point. The local lithologies west of Porlock are red-purplish or grey fine-grained sandstones, and thick flaggy grit beds interspersed with shale and pebble beds. All of these lithologies are represented in the sediment of the barrier. The pattern of sediment facies (shape and size) differentiation across the barrier (cf.Bluck, 1967) is well developed, but has been disturbed locally by recent management activity.

The coastal edge of the Exmoor plateau (*c.* 40 km long) shows a distinctive 'hog's-back' form with a 350 m fall from the plateau top to sea level, with a steep and unstable convex coastal slope (Arber, 1911) *c.* 1 km wide. Arber commented on the thick wooded cover of the coastal slope, but during the 20th century anthropogenic disturbance of this cover resulted in an increase in the frequency of coastal landslides in the unconsolidated sediment. The sediment size arriving at the hog's-back shoreline from these slides has a considerable range from blocks (>20 m) to mud. The Porlock foreshore shows a well-developed outer boulder frame in the intertidal zone for all but the last kilometre of its proximal (eastern) end, suggesting the landward retreat of sections of the barrier. The recent increase in sediment supply from landslides has not alleviated the sediment deficit characteristic of the barrier, so it is likely that the apparent surplus of sediment west of the Porlock barrier is a recent phenomenon and not the typical situation throughout late Holocene times (i.e. over the last 2000 years), although landslides will have supplied sediment episodically in the past history of the feature.

The Exmoor coastal slope was covered by Devensian solifluction sediment, forming fans that coalesced at the foot of the plateau, which have been reworked by Holocene relative sea-level rise. The present barrier is transgressing across such a fan at Porlockford, and the western end of the barrier is developing on top of the intertidal scar of an eroded fan (Gore Point).

The rising ground of the relict solifluction fan at Porlockford cliffs controls the present-day embayed position of the barrier. Fan resistance to wave action can lead to barrier segmentation around the flanks of the fan. This western foreshore shows a mixture of boulder scars as the rising sea level has eroded its way through the old fans, and a lag of large boulders (outer boulder frame) that resist swash action and incorporation into the barrier. The frame dissipates wave energy but its low position (<–1 m OD) means that it does not protect the barrier during high tides and surges. The exposed position led to attempts to build up the barrier crest east of Porlockford and New Works in the early 1990s by reshaping the profile (making it higher to *c.* 8 m OD) but thinner (Figure 6.18C; profile P4); replacing washover sediment back onto the ridge top; and renourishing the ridge sediment volume with dredge material (gravel, sand and mud) from the entrance of Porlock Weir harbour. Attempts to export down-drift gravel back to this swash-aligned section were successfully resisted by the National Trust, the landowners of the easterly drift-aligned section. The weakness of this swash-aligned bay was the core management problem in the 1990s, as potential barrier breakdown and associated back-barrier flooding were perceived to be central issues for local economic well-being and aesthetics.

Between Porlock Weir and the tidal sluice gate (New Works; Figure6.18B), the continuous easterly longshore depletion of sediment has reduced the volume of the barrier and accelerated its retreat onshore by rollover (where sediment is carried over the ridge top by storm washover), forcing the embayed barrier into a more swash-aligned structure. The Porlock barrier has retreated most at this section. Here, the barrier is low (*c.* 6–7m OD) and narrow

(<40 m wide), commensurate with the loss of volume as the barrier is 'stretched' between Porlock Weir and New Works without new material being added.

Although New Works appears to have been built at the transition between the up-drift swash-aligned and down-drift drift-aligned sections, it is unlikely that the works *per se* were of a sufficient age to have played a part in the development of this transition point. New Works was probably sited here because of its low elevation with respect to back-barrier drainage.

After 1950, the ridge east of the New Works area was in constant need of remedial attention due to washover forcing the remnant ridge into a swash-aligned posture commensurate with the westward barrier. The barrier was rebuilt on several occasions: by regrading washover fans; adding new gravel (from the old recurves) to the upper beach; and installing groynes to reduce westward movement of sediment. All this activity reflected the continuing movement of gravel eastwards as the swash-aligned section was evolving further eastwards. The barrier has retreated marginally at this section since the 1980s and is currently held by old shore-parallel stone walls now being consumed by barrier rollover. This anthropogenic intervention (stopped in 1990s) makes it difficult to determine the natural position of the barrier in the decade before 1996.

During late October 1996 Hurricane Lillie moved across the North Atlantic Ocean and degenerated into a deep depression before moving across southern Ireland and the UK. Storm surge levels superimposed on the high tide exceeded the height of the managed barrier between Porlockford Cliffs and New Works on October 26th. Massive overwashing demolished the barrier crest and moved gravel onto the back-barrier area. The volume of overwashing waters was sufficient to fill the back-barrier area and during the falling tide, forced a breach west of New Works. The extent to which the gravel ridge was also pushed back has been partially identified by differences in crest surveys undertaken by Orford *et al*. (2001) in July 1994 and September 1998, and in a series of detailed measurements post-1999 by Bray and Duane (2001). In outline the original managed crest of the barrier was demolished and pushed back in the form of classic washover fans (Figure 6.18B). During February 1997, a series of major westerly cyclonic storms helped to reconsolidate the beach ridge at a new position 15–25 m farther landwards.

Since 1999, ridge changes west of New Works have been slight, the lack of movement and restructuring of the ridge into a broader and lower (*c*. 6–7 m OD) feature suggests a period of stability. The barrier will continue to retreat as a function of the elevation reached by extreme run-up of breaking waves, which will also increase with future storminess and relative sea-level rise. Past lowland management and land-use in the area has meant that there is space for barrier retreat without any overwhelming demand for coastal protection. In order to understand the development of gravel barriers that are not impeded by protection measures, Porlock is a key 'open air laboratory' site that will enable geomorphologists to better predict the outcome of management activities on gravel barriers. The freedom to evolve now will mean the site is once again moving towards a more 'natural' pathway and therefore a key site to see how a barrier naturally responds to past anthropogenic forcing.

## Interpretation

The barrier probably initially formed as a drift-aligned spit building eastwards; remnants of the recurves from this sediment-surplus phase can be identified at positions between New Works and the old limekilns near Horner Water, but there is no available dating evidence for this barrier growth phase. As sediment supply from the hog's-back area diminished owing to a reducing rate of the rise of relative sea level in mid-late Holocene times, then barrier reworking would have taken place (Orford *et al*., 1996). Barrier sediment from updrift positions (west) was transported to continue the spit growth at its eastern end, until reaching Hurlstone Point (which acted as a natural groyne) and sediment was trapped in major beach ridges. These latter forms have been steadily drift-aligned (20 m accretion between 1880 and 1980) into high (12 m OD) beach ridges. Their seaward growth means that there is no shore platform exposed at low water and thus bigger waves can approach closer inshore without dissipation, allowing storm waves at high tide to generate swash sufficient to move gravel to the crest top.

The west–east Exmoor coastal slope is the main source of gravel for the Porlock barrier. There is a net easterly beach drift system powered by Atlantic swell waves and depression-generated storm waves running from the north-west to west into the Severn Estuary. The slight shift in coastal alignment east of Foreland Point might indicate that the contemporary source area for Porlock is somewhat less than the whole Exmoor length. There is little fine-grained sediment in the Porlock barrier system because much of the sand-sized load is moved offshore, or deposited to the east of Hurlstone Point. It is feasible that Holocene relative sea-level rise has now eroded the low-elevation fans at the foot of the coastal slope and it is the reduction of this source that has now pushed Porlock's sediment budget into deficit. The 20th century rise in sediment supply (due to up-drift changing coastal slope management practice) seems only to be reaching as far as Porlock Weir. The cannibalization of the Porlock barrier and development of the major swash-aligned unit deep into the western end of the Porlock embayment means that sediment transport from the old western source area has now virtually ceased. This has not been the case in the past when the barrier was probably developed as a spit extension of the coastal plateau edge into Porlock embayment.

Jennings *et al.* (1998) explored the relative sea-level rise identified by a palaeo-ecological reconstruction of organic deposition found exposed in the foreshore, and in the pre-1996 back-barrier marsh at Porlock. Their results fit into the broader relative sea-level rise envelope identified by Heyworth and Kidson (1982) for the Severn Estuary. Tree roots bedded into a fen-type freshwater environment are exposed on the foreshore of the western swash-aligned barrier, and cores taken from the pre-1996 seasonally wet back-barrier area (now tidally flooded) identify a mixture of environments related to whether the back-barrier area was open to intermittent tidally induced flooding and mud deposition, or was closed such that a freshwater fen environment was generated. The thesis of Jennings *et al.* (1998) was that barrier coherence (hence barrier strength to resist breaching) and potential for tidal incursions into the back-barrier area was related to the rate of relative sea-level rise. They suggested three domains of barrier activity related to relative sea-level rise, noting that as the rate of rise decreased there would be an increasing tendency for spatial stability of the barrier, a decreasing longshore sediment supply rate, and as a consequence a greater potential for the barrier to be cannibalized and disturbed sufficiently to allow storm breaching sufficient for tidal incursion. Prior to 7000 years BP, relative sea-level rise rates of *c.* >6 mm $a^{-1}$ were likely to generate high longshore sediment supply but reduce the ability of the barrier to maintain any longshore coherency sufficient to act as a barrier to tidal influence in the back-barrier area – hence the evidence of fine-grained, marine, back-barrier deposition. Between 7000 and 5000 years BP, relative sea-level rise rates of 6–2mm $a^{-1}$ allowed sufficient sediment to seal any barrier breaching, while the spatial translation of the ridge was so reduced that the barrier maintained its coherency to act as a buffer to saline influences, thus letting a back-barrier freshwater regime operate in which fen-deposition predominated. When storm breaches were intermittently open, the back-barrier area was exposed to saline waters, thus allowing thin marine mud-sequences to be inter-digitated with organic fen materials. By late Holocene times (<2000 years BP) decelerating rates of relative sea-level rise (<1 mm $a^{-1}$) reduced the longshore sediment supply allowing barrier breaches to remain open and the fen to be replaced by tidally dominated back-barrier sedimentation.

The 1996 breach is unlikely to be sealed by the existing low longshore transport rates. It has been widened and deepened with headwater erosion by tidal flows into the consolidated Holocene clays of the old back-barrier. Bray and Duane (2001) have mapped the retreat of the breach and the extension of the inlet sidebars. They have also monitored tidal elevations and associated sedimentation within the now active upper tidal frame behind the barrier. The high turbidity of the water column in the Severn Estuary and its macro-tidal regime ensure that fine-grained sediment enters behind the barrier on almost all tides. Annual deposition rates of 10 mm $a^{-1}$ measured during 1999–2000, suggest that this is a site of great potential for saltmarsh development. Whether this sedimentation rate is the initial result of a forced change in the system and will decline as the back barrier adjusts to the new tidal regime is uncertain. However the lack of coastal squeeze at this site suggests that this will be an important test site for evaluating saltmarsh growth and adjustment to accelerating relative sea-level rise in future decades. Bray and Duane (2001) also underline the potential for barrier change immediately east of New Works. The implications for further breaching in this area are intriguing, though current inlet efficiency may be reduced if more breaches occur, thus limiting more persistent breaches.

The historical state of the barrier is unknown, though the 'stabilized' barrier during the 20th century produced a local view of back-barrier stability that has not been the norm for most of its Holocene existence. The tidal sluice-gate system (New Works) indicated the measures taken to ensure the drainage of freshwater from the back barrier to allow pasture development. Even then, the pre-1996 intermittent wetlands identified a problem in fully draining the back-barrier area and the resultant small mere and fen that did develop provided the interest for the original Porlock SSSI biological designation. This past anthropogenic intervention has flavoured perspectives as to how Porlock barrier should be managed, although the latest storm-forced changes to the managed barrier section show that a natural mode of barrier evolution is now appropriate, and that this should be of prime concern in future management strategy.

## Conclusion

The Porlock barrier is central to geomorphological studies into how a freestanding gravel barrier responds to relative sea-level rise and storminess changes. The barrier is likely to remain a centre of coastal interest for its combination of evolving swash-aligned and drift-aligned longshore sections; its post-management adjustment to a stable cross-barrier profile in relation to relative sea-level rise and storm-wave climate; its rollover dynamics and washover response; its breaching behaviour; its developing tidal inlet control on barrier segmentation and longshore transport impedance; its back-barrier fine-sediment deposition and saltmarsh development. It represents one of the best UK examples of how managed 'stabilized' barriers are non-sustainable at the decade-timescale. It also exemplifies the likely mode of barrier failure, if coastal gravel-dominated barriers are not allowed to adjust freely to changing relative sea level.

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