Coastal Geomorphology of England (CST-GME-EG)

Block Description

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Introduction

This GCR Block encompasses coastal landforms and geomorphology as developed in England. Many factors interplay to create the changing face of the coast that we see today: geology, glaciation, sea-level change, sediment supply, wind, wave, tide, and, increasingly, human activities.

One of the characteristics of the coastline of Great Britain is its state of continual change. Such geomorphological change may be slow and gradual, such as that which occurs where the geological inheritance has produced a resistant rocky coast, or it may also be extremely rapid, such as the almost instantaneous erosional impact of storm waves on a sand beach.

The geological background

The pattern of geological outcrops along the British coast has a fundamental control on the character of the coastline. Broad connections between outcrop pattern and the outline of the coast can be traced, and local geological variations control the detailed pattern of coastal form at local levels. Thus while there are differences between the older and generally far more resistant rocks of northern and western Britain and the younger and weaker rocks found in east and southern England, within each of these zones local contrasts dominate the coastal geomorphology. From Flamborough Head in Yorkshire southwards and westwards to the Exe estuary in Devon, the Chalk and sandstones that form the cuestas of the scarpland and vale landscape also form the major coastal headlands (Flamborough Head, North Foreland in Kent, Beachy Head in Sussex, and the Needles on the Isle of Wight, for example, all on Chalk) and between them on the intervening clays or on till-covered littoral plateaux, wide bays, locally fronted by saltmarshes and sand dunes, alternate with low cliffs cut into the low till-capped plateaux of Holderness, Norfolk and Suffolk.

Geological influence on sediment supply into the coastal system

A further influence of geology on coastal geomorphology is in the provision of sediment – from offshore as well as from retreating cliffs – that can be incorporated into beaches. Boulders and coarse gravel are derived from erosion of resistant rocks in areas such as Scotland and parts of the Welsh coast; flints form the commonest pebbles and cobbles on beaches in the south of England. Many ‘shingle’ (gravel) beaches have been built from offshore gravels, swept ashore as sea level rose during the Holocene marine transgression, and former sea-floor sediment has contributed to many beaches elsewhere. In places, flints are derived from erosion of the Chalk in which they occur. Farther north in England, a large proportion of the gravel has been eroded from glacial gravels and till cropping out along the coast or offshore.

In Scotland and Wales, by far the greatest source of gravel and sediment has been derived from glaciogenic sources, deposited both inland and on the adjacent shelf by either glaciers or glacial meltwater. As a result, the sediments are as varied as the rocks that were originally eroded by ice.

Some coarse sediments are brought to the coast by rivers, especially in Scotland and Wales, where gradients are steep and coarse-grained material is readily transported by floods. In contrast, very little sediment other than mud (clay and silt) is now brought down the rivers of lowland Britain to the coast.

The coastal marine environment: tides, waves, surges and currents

In global terms, the British Isles have unusually high tides and unusually stormy conditions; thus they have a very dynamic coast, one of the reasons why British coastal research has made such an important contribution to the world literature.

However, each of these influences also varies greatly around Great Britain. Tidal range is highest at the head of inlets such as the Bristol Channel, and lowest on the English Channel coast between Start Point and Portsmouth, on the East Anglian coast within the North Sea, Cardigan Bay in Wales, and in Shetland in Scotland. Wave energy is highest on coasts exposed to the strong winds of western Britain and the North Atlantic swell; it is lower in such relatively sheltered areas as the Irish Sea and the North Sea. Given its western exposure to the Atlantic Ocean, the English Channel coast tends to fall into an intermediate category.

Both tidal movements and the advance of waves into shallow water create currents and these move sediment in the nearshore zone, shaping sandbanks, which in turn can affect the local conditions, for example, by forcing larger waves to break and so lose energy as they touch bottom on submerged banks, or even to break against them at low tide. In constricted bedrock channels, perhaps the best example is the Pentland Firth, the tides create extremely strong currents, and where they are channelled between sandbanks as in the Thames estuary or off Great Yarmouth, the patterns of ebb and flow (often dominating different channels) run much faster than in the open sea.

Tidal range has an effect on coastal landforms. Barrier beaches, behind which saltmarshes form, tend to be restricted to areas with relatively low tidal range, such as the north Norfolk coast. Such areas also have spits, which in some cases grow to many kilometres in length, for example, Blakeney Point and Orfordness.

High tidal-ranges can occur towards the head of estuaries (or Firths in Scotland), and here saltmarshes also develop, though compared with areas of low tidal range they are generally steeper and show much stronger zonation of vegetation, such as in the Bristol Channel–Severn estuary.

The waves reaching the coast are mainly generated by winds offshore. In the case of the semi-enclosed seas of the Irish Sea and the North Sea, most waves are generated by winds blowing across relatively restricted fetches, and so have a short wave-length, short period, and are relatively steep. Thus along the coasts of these seas, the varying pattern of length of fetch is an important control over wave energies from all directions offshore as well as the frequency with which winds blow from any one direction.

In the North Sea waves from a northerly direction are generally the largest, with a secondary maximum in East Anglia for waves from the south-east. In the Irish Sea, a west-facing beach like Blackpool, Lancashire, gets its largest waves from a westerly direction, but these are always short-period waves and so put rather small volumes of water onto the beach as they break. As a result, the wide, sandy beach at Blackpool generally consists of a series of ridges and intervening runnels; the seaward slopes of the ridges may be in equilibrium with the short-period waves.

Locally on the North Sea coast, ridge-and-runnel beaches are found in the shelter of a headland, limiting waves reaching the beach to those from the east or south-east; an example is in Bridlington Bay, which is protected from the larger northerly waves by Flamborough Head, Yorkshire.

On those parts of coast exposed to North Atlantic storm and swell waves, energies are much higher and the long-period waves put large volumes of water onto the beach as they break. Thus such wave conditions often produce very wide beaches with a gentle slope, for example Rhossili in South Wales, the beaches of the Western Isles and in some of the more exposed Cornish bays. Where strong regional winds build large waves, energies are very high, but it is also possible for long-period swell generated far offshore, even in the South Atlantic, to reach the western beaches. Such swell loses height as it moves across the ocean, but it can be distinguished by its typically long period. Beaches exposed to the Atlantic Ocean tend to be dominated by the high energies associated with longperiod waves, even where the exposure is indirect and the waves reach the coast after refraction.

High wave-energies can cause considerable erosion even of resistant rocks, and will exploit structural weaknesses such as faults, joints and bedding planes. Narrow inlets, caves, stacks and natural arches are found along our higher-energy coasts even in the most resistant rocks. Good examples of such forms, eroded into resistant lithologies, are found almost everywhere on the islands of the St Kilda group and in the Shetland Islands, such as Foula and Papa Stour. They can also be found in weaker rocks where wave energies are lower, for example, the Chalk cliffs of Thanet, Kent. Waves are also responsible for the longshore drift of sediment along the coast.

Coastal sediment transport

The alongshore transport of sediment (littoral or longshore drift) is achieved by waves and the currents they induce within the breaker zone. In England particularly, the widespread construction of groynes, revetments and walls has interfered with coastal sediment movement and the coastal sediment balance.

The direction is determined largely by the angle of wave approach, i.e. it is related to the dominant fetch. Thus the general direction of transport is southwards on the eastern coast of England, and eastwards on the Channel coast.

In the northern North Sea, the pattern is westward movement along the Moray Firth and mainly southward movement along the Aberdeenshire and Angus coast. The pattern around the Irish Sea is a little more complicated since it is not open to the north as is the North Sea.

Sea-Level History

At the time of the last glacial maximum, some 18 000 years ago, the abstraction of water from the oceans to build the great land-based ice caps reduced global sea level to some 120–140 m below that of the present day.By the beginning of the Holocene Epoch, 10 000 years before present (BP), sea level was some 40 m below present, and as it continued to rise (the Holocene marine transgression) was within 10 m of its present stand at about 5000 years ago, and close to present level by 4000 years BP. However, the precise changes at any one site will depart from this pattern for many reasons, including crustal stability (tectonic changes, the effects of loading or removal of load by ice sheets and the oceans themselves, local sedimentation) and tidal changes as the coastal configuration has changed, as well as many other lesser effects that may lead to local departures from the general pattern of sea-level rise.

GCR site selection

The GCR site-selection exercise for coastal geomorphology followed four categories (‘GCR Blocks’), one for each of England, Scotland and Wales and one for ‘Saltmarsh Geomorphology’; although three of the ‘Blocks’ are country based, comparisons were made to ensure that certain types of site occurring in each were not over-represented in a Great Britain-wide context.

In some cases, ‘representative’ sites were selected for the GCR as part of a group of related sites. Such a group of sites may show different aspects of one type of phenomenon, which shows significant regional variations in its characteristics, for example, sites with similar landforms have been selected from areas having different tidal ranges.

Most of the GCR sites are dominated by one coastal landform, especially in terms of their associated research significance. However, the selected GCR sites include a number that are complex in their assemblage of linked geomorphological forms, and so they have been classified as ‘Coastal Assemblages’.

The geomorphology of the coastline is controlled by a complex interaction of factors – the dynamics of the coastal ‘cell’, geological controls (e.g. rock type and structures), the Pleistocene inheritance (isostatic and eustatic effects), sediment ‘budget’, tidal regimes as well as anthropogenic influence. It is the intention within the ‘representativeness’ rationale of the GCR to be able to demonstrate the interplay of these themes and their manifestations from the evidence present in the selected GCR sites. These themes can be thought of as providing a basis for GCR Networks, which link clusters of representative sites.

Ultimately, some 26 networks were identified for the GCR project.

A. Cliffed coasts

1. Large-scale structural control: longitudinal and transverse coasts

2. Small-scale structural control: caves, arches, stacks, geos, zawns

3. Cliff forms and processes: plunging cliffs, slope-over-wall, hog's back, variety of rates of cliff retreat, differential erosion

4. Exhumed and emerged forms: cliffs, benches

5. Karstic development

B. Shore platforms (including both contemporary and emerged features)

6. Structurally controlled

7. Erosionally dominated

C. Beaches and intertidal sediments

8. Beach orientation: relation to wave direction, swell-dominated beaches

9. Beaches undergoing erosion

10. Prograding beaches

11. Beach phases

12. Pre-existing sediment sources, including pre-existing clasts

13. Emerged ('raised') beaches

14. Cliff-foot beaches

15. Dunes: rock-based, gravel-based, restricted sources, sand plains

16. Spits

17. Barrier beaches

18. Cuspate forelands and nesses

19. Tombolos and tied islands

20. Intertidal sediments

21. Mudflats, ridge and runnel forms

22. Saltmarsh morphology – creeks, saltpans, piping

23. Machair

D. Coastal valleys

24. Chines, truncated valleys, coastal waterfalls

E. Inlets and submerged coasts

25. Fjords, rias, estuaries

F. Semi-enclosed bays

26. Restricted sediment sources and transfers, submarine barriers, sediment sorting

Clearly, any one site may be helpful in elucidating several of these themes and therefore may contribute to more than one GCR Network (for example, Culbin, on the Moray Firth, provides information on sea-level change as well as gravel delivery data over the Holocene Epoch at a site characterized by well-developed dunes situated on top of spit structures).

The GCR sites encompassed by this GCR Block exclude major coastal landslides, such as Folkestone Warren; which are covered by the Mass Movements GCR Block. Also, sites that are of interest for coastal features that are particularly important for elucidating the Pleistocene history of Britain are described in the Quaternary GCR Blocks.