

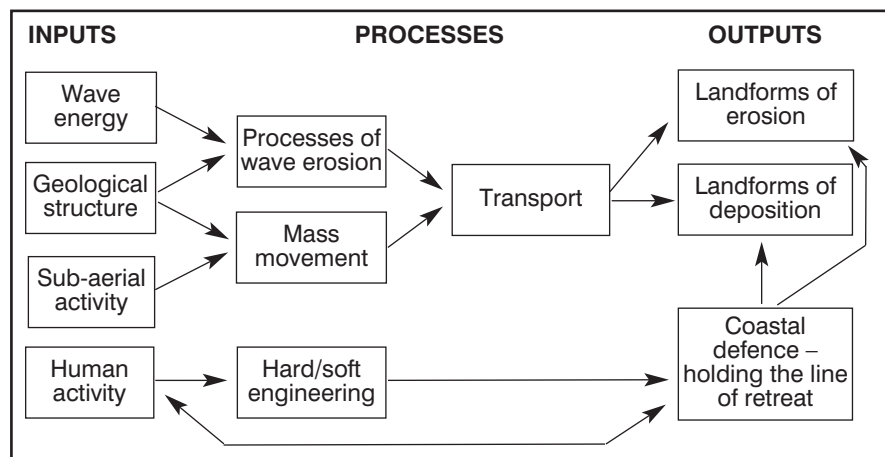
LANDFORMS OF COASTAL EROSION: EXAMPLES FROM EAST YORKSHIRE

Introduction

The coast – the interface between land and sea – is a worldwide linear zone, often only a matter of a few metres wide. In Britain we often think of the coast as being formed by the energy of the waves, largely due to their ubiquity and power; however, sub-aerial processes are also significant; sometimes climatic regimes are important and also vegetational processes on some coasts.

The coastal zone can also be viewed as a **system**, with **inputs**, **processes** and **outputs** (Figure 1).

Figure 1: Coastal systems



Wave Energy

Waves are pockets of energy generated by the wind; consequently the **fetch** of a wave is significant. In the North Sea, wind can blow from the Arctic directly southwards, generating storm waves that attack north-facing sections of the East Coast such as Whitby, Flamborough Head, and the north Norfolk coast. On a global scale, winds blow across the Atlantic Ocean from the south west, creating **swell** that reaches the Cornish coast.

Depending upon preceding weather conditions over the surrounding sea area, waves arrive at the coast with a number of characteristics: wave height, wave period, wavelength, wave velocity and wave steepness. The combination of length and height determine the amount of energy: $E = LH^2$, so a small increase in height gives a large increase in energy.

As waves approach shallow water, friction with the sea bed increases, so the height and steepness increase, causing the crest of the wave to 'fall over'; this is when the wave breaks, water rushes up the beach as the **swash** and returns by gravity as the **backwash**. Under calm conditions the frequency of waves (**wave period**) ranges from 6 to 8 per minute, but under storm conditions this increases to 10 to 14 per minute, with a commensurate increase in the amount of energy expended on erosion.

The Processes of Coastal Erosion

Waves are affected by friction as the body of water moves forward and the energy within becomes a major erosional process.

- **Abrasion** (Corrasion) Waves throw loose sand and shingle and even boulders at the cliff; this is one of the most effective methods of erosion. A hard cliff face becomes smoothed and even undercut to create a notch; a cliff face of alternating hard and soft rock becomes indented (differential erosion).
- **Attrition** This is where all movement of the water turns rocks, boulders and gravel into smooth, rounded, smaller rocks, usually between high and low tide.
- **Solution** (corrosion) This takes place where carbonic acid in sea water reacts with CaCO_3 in limestones, or the salt in sea water and spray corrodes rocks, especially if salt crystals grow and cause rocks to disintegrate.
- **Biological activity** Secretions from algae attack rocks, and some molluscs can bore holes in rock.
- **Wave pounding** (Waugh), **wave quarrying** (Knapp) Waves impact the rock face with pressures of up to 50kg/cm^2 (cf. car tyre 2kg/cm^2) (Knapp). The effect of this is to loosen blocks of rock along any weakness. This process can eventually destroy sea walls.
- **Hydraulic pressure** This is often unseen, but very effective. Waves

enter a tiny crevice or large cave and air is trapped, then forced into all the weaknesses, time after time, so that the rock can eventually collapse.

- **Subaerial weathering** This occurs most notably by rain leading to the saturation of cliff material and then the failure of the cliff by **mass movement**. This mass movement can range from soil creep, to slumping, to landslides. This is an important process on the upper part of the cliff and in softer material.

Factors Affecting Coastal Erosion

Geological structure

All rock has degrees of hardness or softness. Boulder clay is much softer than chalk, so the former will erode to form a bay, the latter will be resistant and form a headland. However, the same features will result with two similar rocks eg limestone, providing one is harder than the other.

Within the rock it is necessary to recognise some common structural features. All sedimentary rocks are laid down in layers called **beds** or **strata**, one layer being separated from the next by the **bedding plane**. Within beds are **joints**, the result of **lithification** (soft sediment turning into hard rock). Bedding planes and joints are weaknesses within the rock and are likely to be exploited by processes of weathering and erosion (Figure 2).

Figure 2: Some structural terminology

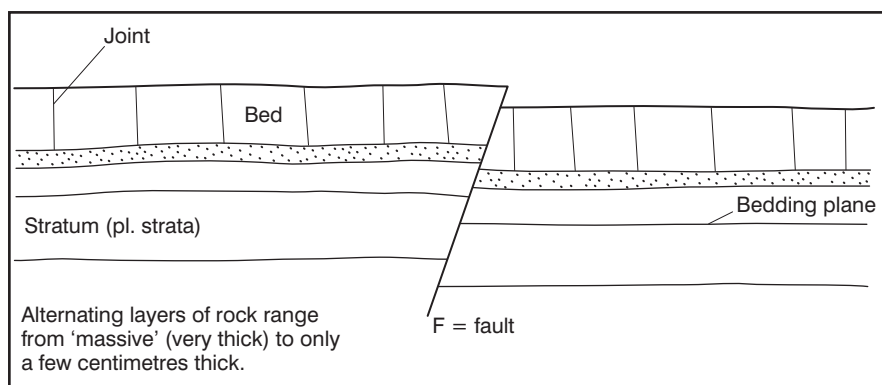
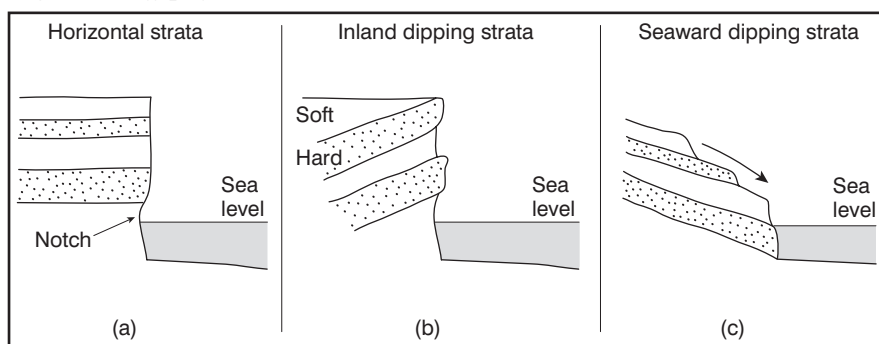


Figure 3: Cliff profiles



Igneous rocks also exhibit joint patterns, as in the hexagonal columns of basalt seen widely throughout Iceland and on the Giant's Causeway in Antrim, Northern Ireland.

Metamorphic rocks exhibit banding or lineation formed in the process of metamorphism as minerals are realigned with their long axes parallel to each other; schistosity is one of the best examples.

The cliff profile can be influenced by the dip of the rocks (Figure 3).

Folding and faulting

As a result of earth movements all rocks exhibit some degree of folding which can become weaknesses. Faulting does not have to be a major movement, but merely a few millimetres, which is sufficient to dislocate the beds and create a line of weakness for the processes of weathering and erosion to exploit.

Coastal morphology

On an indented coastline, headlands and the offshore topography concentrate wave attack on that headland by the process of **wave refraction**. Many headlands have a wave-cut platform between high and low tide which can cause friction for the wave, but due to their solid nature they do not absorb energy, as a sandy beach would do, so waves can break at

the foot of the cliff, causing maximum erosion. Some waves at high tide may cross the wave-cut platform and not be much affected by friction and then refracted by the cliff, having minimal erosional impact.

In a bay, waves have to travel further, and a beach absorbs wave energy and reduces the power of the wave before it reaches the cliff. Where there is a wide, deep, sandy beach, waves may not even reach the cliff at all.

Flamborough Head and Holderness Coast

Flamborough Head in East Yorkshire is a chalk headland exhibiting classic features of coastal erosion, but also some unique features (Figures 4, 5 and 6).

The Lower Chalk zones form the highest cliffs of the headland north of Thornwick and are inaccessible. The Middle Chalk forms Thornwick Bay and the North Landing area, whilst the Upper Chalk can be seen at Selwicks Bay. Chalk in northern England is harder than that in southern England due to a higher calcite content. The Lower and Middle Chalk also contain varying amounts of flint, a secondary deposit which is very hard and brittle. The layers of chalk dip in a southerly

direction at 4°; they are well jointed and criss-crossed by minor faulting – all the necessary ingredients for erosion.

Geological history

The recent geological history of the area is important. Pre-glacially the cliffs were only made out of chalk and were about half their present height. The sea eroded caves, arches and stacks and a wave-cut platform. During the Ice Age the whole of this area was covered in ice; post-glacially, as the ice retreated, a vast deposit of Boulder Clay was left over all the area, masking pre-existing features: the caves were plugged with Boulder Clay and the bays were infilled. As the North Sea basin filled up and the waves rolled in, their first job was to excavate the Boulder Clay, to reveal many of the original features.

Selwicks Bay

In Selwicks Bay, most easily eroded by the sea are the faults, which enlarge into **caves**. In places, two caves erode back to back to form a through-cave, or a cave can erode through a small headland into a pre-existing bay, both of which are called **arches**. Some arches are so small it is only possible to crawl through them, others are large enough to sail a yacht through. Arches themselves eventually collapse; the upstanding tower of rock is a **stack** and they also eventually collapse, to leave a **stump**, only slightly proud of the **wave-cut platform**. All this erosion results in the slow, inexorable retreat of the cliff line, leaving a foundation of chalk as the wave-cut platform, one of which occupies the majority of Selwicks Bay (Figure 4).

There are two unique features. Part of Selwicks Bay is composed of a wide 'line of disturbance' where the chalk has been subjected to and contorted by severe earth movements, the friction reconstituting some of the minerals into calcite which has hardened this section of cliff, so as to form a small headland within the bay, Also at Selwicks Bay is a **blow hole**, not unique in itself, but it reflects the glaciological history of the headland. Pre-glacially it was created as a blow hole that was then infilled and covered by Boulder Clay, only to be post-glacially re-excavated and enlarged so that today, even though the water rushes in, it does not blow. The weaker clay surrounding it is actively slumping into the blow hole and forms a huge amphitheatre

Figure 4: Sketch map of features at Selwicks Bay

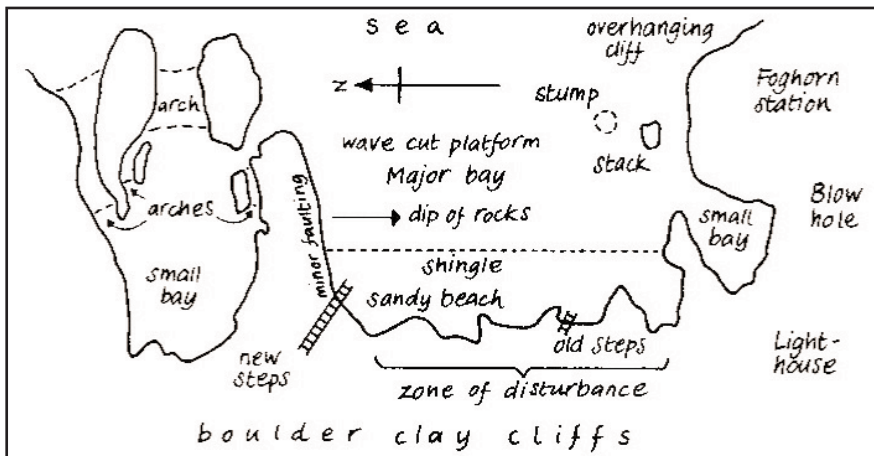


Figure 5: Sketch diagram of the west side of North Landing, Flamborough Head (pre-1984)

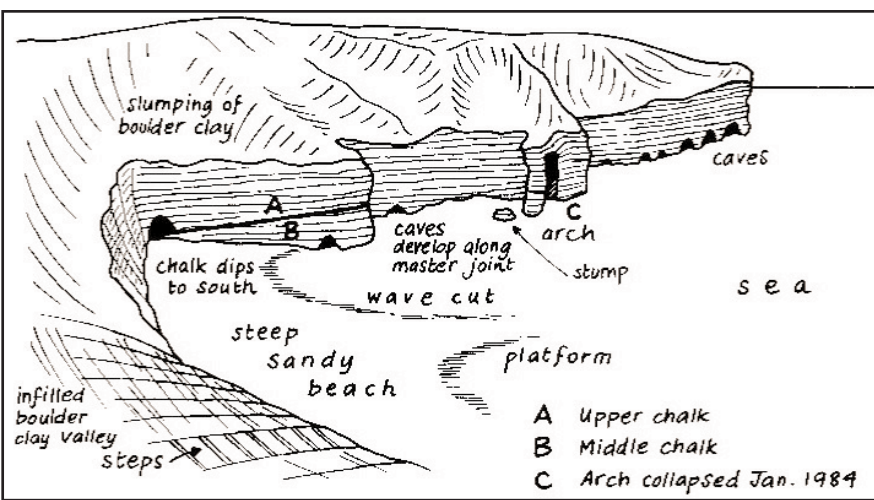
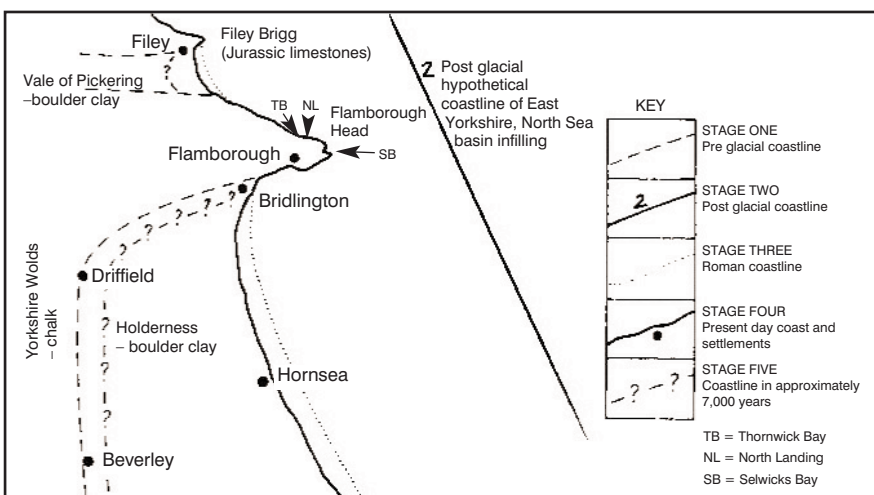


Figure 6: The sequence of East Yorkshire coastlines in pre- and post-glacial times



around the blow hole, an example of the subaerial weathering of the cliffs (Figure 7).

North Landing

At North Landing in the Middle Chalk, the layers of chalk are much thinner, there is a lot of flint, the jointing is very close so the whole rock is highly fragmented, there is a

lot of faulting and the bay, being open to the north, is subjected to attack by the storm waves from the Arctic. Caves abound and one fault has been enlarged into a long narrow inlet, called a *geo*. On the west side of the bay there was once a series of arches. Figure 8 shows an arch that is no longer there – it collapsed one night in January 1984. Two to three metres

from the base it was quite narrow and it is tempting to suggest that storm waves battered it to bits, but the roof of the arch had been under pressure for many years, with two major right-angled cracks and overhead pressure bending the layers of chalk. The overlying weight of saturated Boulder Clay caused the eventual collapse, a result of sub-aerial processes; marine erosion removed most of the collapsed debris within about three months (Figure 9). Currently there are two stumps being abraded, one from a pre-existing arch that collapsed long ago and a second stump from the 1984 arch collapse. They both now form part of the wave cut platform.

A retreating coastline

The Holderness coast is well known as one of the most rapidly eroding coasts in the world. As shown in Figure 6, Holderness did not exist pre-glacially and the chalk formed a coastline that stretched from Sewerby (just north of Bridlington) to Driffield and south to Beverley (Stage One). At the last onset of the ice, glaciers rode over the existing cliff and pushed their way up the Vale of Pickering, over Flamborough Head and up the lower slopes of the Yorkshire Wolds. As they melted and retreated they covered the landscape in a thick layer of Boulder Clay (Stage Two). The North Sea Basin became the North Sea and waves began to attack the clay deposits, rolling the cliff line westwards. The offshore gradient of Bridlington Bay is very gentle, but the beach sand near Holderness cliffs is very thin and underlain by a platform of impermeable Boulder Clay; most tides except summer neap tides, reach the base of the cliffs and in storm conditions waves break on the soft clay of the cliff. It is estimated that the coastline has retreated by 4 km since Roman times (Stages Three and Four).

Villages are still under threat, such as Mappleton, which at great expense has been protected. The cost of protection for rural areas is just too high – saving farmland that is valued at a few thousand pounds per acre with protection that costs millions of pounds. The storm surge of January 31/February 1 1953 was of such ferocity that the concrete promenades at Hornsea and Withernsea were smashed to bits. All our engineering ability may combat 'normal' waves or even some storm surges, but if we are to continue to experience sea level rise and further storm surges, then coastal

defences as they exist will not suffice; managed retreat is the only option, but what about towns like Hornsea and Withernsea? In the past few years both have had their coastal protection substantially upgraded, but what will happen when a whole village is next threatened? (Stage Five).

Conclusion

Throughout the world, coastal features are ubiquitous and the sea relentlessly erodes the edge of the land, but where waves attack upstanding coasts the resultant features can be impressive.

Wave energy, geological structure and sub-aerial activity are the major inputs influencing cliff formation. These cliffs are attacked by the processes of wave erosion and modified by the processes of mass movement which result in a variety of coastal landforms, both depositional and erosional.

Human activity is cyclical. As soon as hard or soft engineering is used, especially the former, it has an interruptive effect on the processes. Coastal defences often have to be modified in the light of experience.

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 See also **Geofile** No. 388, September 2000, N. Punnett: 'Coastal Erosion – Back to Nature'.

Figure 7: The blow hole at Flamborough Head, adjacent to the Lighthouse and Selwicks Bay



Figure 8: Arch at North Landing, prior to collapse. Note not only the narrowing of the column, but more importantly the weakness at the top of the arch caused by the overlying weight



Figure 9: Taken only three months after the arch collapsed in 1984. Most of the debris has already disappeared



FOCUS QUESTIONS

1. How can a coastline demonstrate the inter-relationship between process, structure and stage of development?
2. Develop arguments for and against protecting coastlines subject to rapid erosion referring to hard and soft engineering techniques
3. Discuss the assertion that it is not possible to understand the present day landscape without reference to past geomorphological processes.