

POST-GLACIAL SEA-LEVEL CHANGES AND RESULTING COASTAL LANDSCAPES

Introduction

For the past 2 million years, during the Quaternary period, the Earth's atmosphere has fluctuated between cooler periods, when ice sheets have advanced, and warmer periods, when ice sheets have retreated (Figure 1). The Northern Hemisphere, with its greater landmass, shows evidence for these fluctuations in the shape of its coastline, due to changes in sea-level.

Some 18,000 years ago the British Isles from the Midlands northwards was covered in a great ice sheet. South of here the landscape was snow-covered for much of the year and resembled the Arctic tundra of today. The floors of the Irish Sea and southern North Sea were exposed, allowing people and animals to walk to and from Europe (Figure 2).

Sea-level at this time was 140m lower than at present, as enormous volumes of water were locked up in the ice sheets. Temperatures at this time were approximately 5°C lower than today. 16,000 years ago the glaciers began to retreat rapidly, and the water previously trapped as ice was released into the sea.

Terms list

- **Eustatic change:** Global changes in sea-level due to changes in the atmosphere.
- **Isostatic change:** Localised or regional changes in sea-level due to movements of the Earth's crust.
- **Glacial stage:** Period of cooler climate; glacial advance and marine regression or sea-level drop.
- **Interglacial stage:** Period of warmer climate; glacial retreat and marine transgression or rise in sea-level
- **Epeirogeny:** Tilting of the Earth's crust allowing sea-level to rise and fall locally.

Figure 1: Glacials and Interglacials in the Quaternary

Years before present (BP)	EPOCH	STAGE	
		Glacial	Interglacial
10,000	Holocene		Flandrian
115,000	Late Pleistocene	Devensian Wolstonian	Ipswichian (130,000 BP)
300,000	Middle Pleistocene	Anglian Beestonian	Hoxnian Cromerian (750,000 BP)
1,000,000	Lower Pleistocene	Pre-Pastonian	Pastonian
2,000,000		Bavention	Bramertonian
		Thornian	Antian Ludhamian

Note: most of the stage names are from East Anglia, where glacial sediments are preserved.

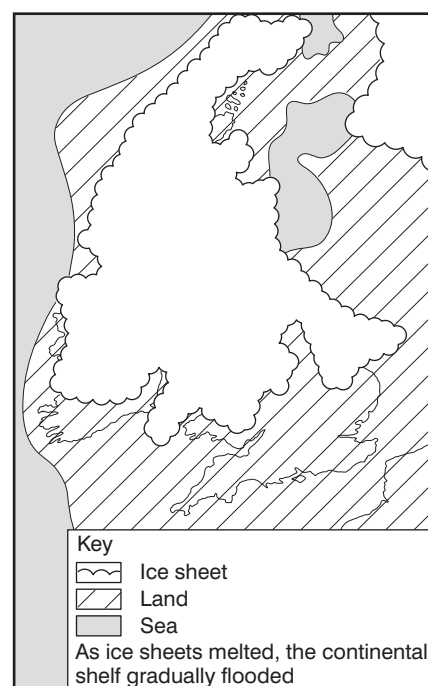
Eustatic change

The world's oceans hold 97% of the world's water; only 2% is stored as ice. Changes in this balance caused by fluctuations in the Earth's atmospheric temperature can raise or lower the volume of water in the oceans. If temperatures rise then glaciers and ice sheets melt and retreat, increasing the volume of the oceans. Seawater also expands thermally, and for every 1°C expansion raises sea-levels a further 0.8m. If temperatures fall, then glaciers and ice sheets advance and sea-levels fall. 16,000 years ago the ice sheets covering Britain started to melt dramatically as temperature rose and the climate entered the present Interglacial (Flandrian) (Figure 1). 11,000 years ago the Irish Sea basin flooded and 9,000 years ago Britain was cut off from the rest of Europe as the North Sea flooded. Sea-levels rose quickly until 6,000 years ago, when they reached approximately their present level. During the 20th century sea-levels rose by 15cm, and as the climate continues to warm, sea-levels are predicted to rise a further 50cm by 2100 (Figure 3).

Isostatic change

Isostatic changes in sea-level are caused by the Earth's crust rising or falling relative to sea-level. This can be caused by tectonic

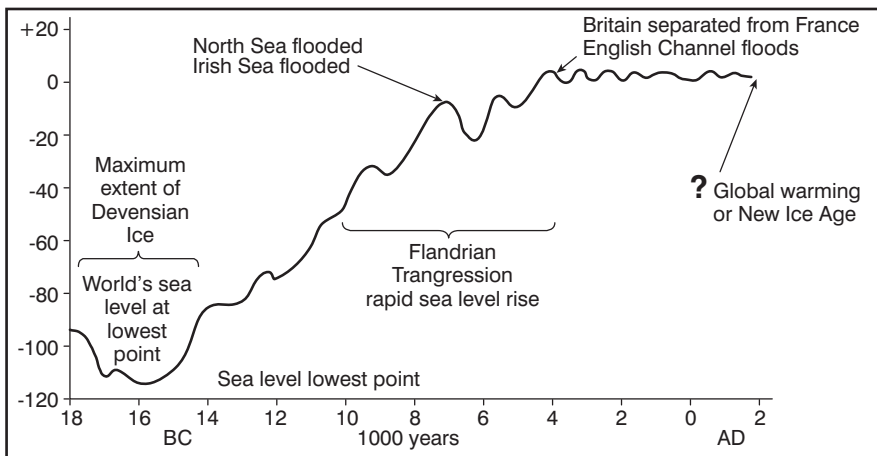
Figure 2: Approximate coastline and extent of ice around the British Isles 18,000 BP



Source: Cook et al., *Geography in Focus*

processes but also by the depression of the Earth's crust into the mantle by the weight of an ice sheet. When the ice sheet melts, the weight is released and the crust rebounds. The centre of the last ice cap in Britain lay approximately over Rannoch Moor in Scotland; this is where the greatest rebound is occurring, at 2–3mm/year. By contrast the South East of England is tilting

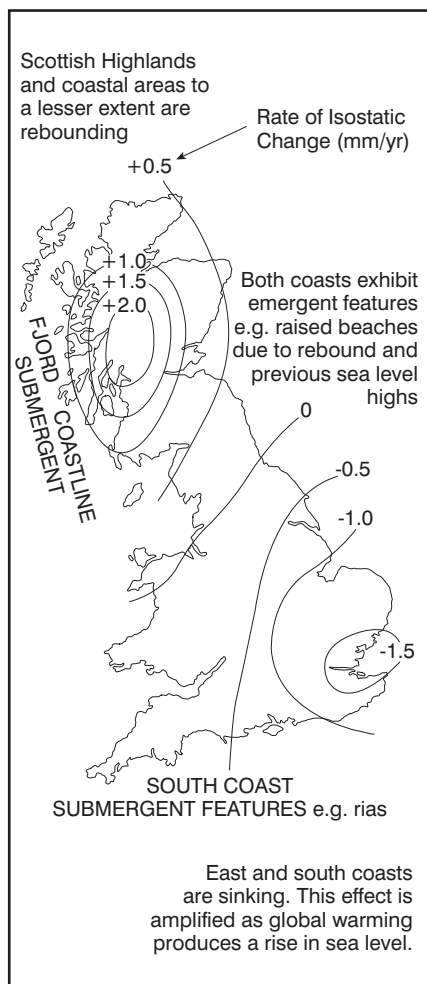
Figure 3: Sea-level change over the last 20,000 years



(Epeirogeny) or sinking by 2mm/year as the North rises up: like opposite ends of a seesaw! (Figure 4.)

Post-glacial sea-level changes therefore involve a combination of a greater volume of water from melted ice, thermal expansion and isostatic rebound or sinking. Britain has examples of emergent coastlines, where the coastline has risen relative to sea-level, and

Figure 4: Isostatic change



submergent coastlines, where the sea has drowned the former coastline.

Emergent features

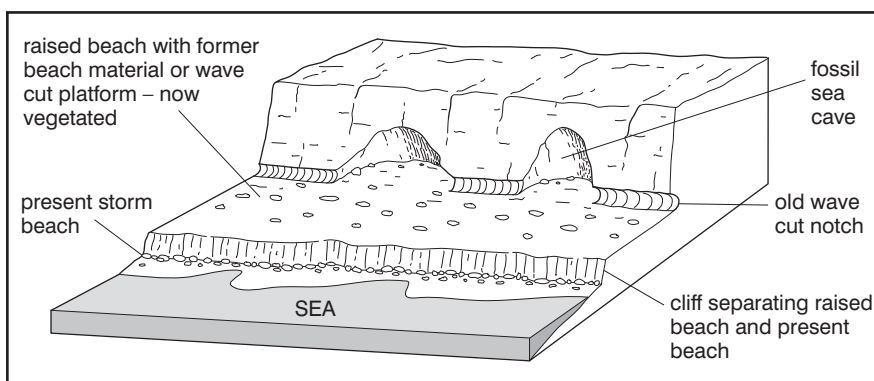
Emergent coastlines may have two origins; first, during past interglacials sea-levels were higher than today; secondly, glacial rebound, particularly in Scotland, has raised old shorelines above present sea-level.

Raised beaches

Around the coastline there is evidence of relatively higher sea-levels in the form of raised beaches. These are deposits of sand and pebbles on gently sloping platforms backed by an old cliff line, which may contain fossil sea caves, wave-cut platforms and even arches. At Westward Ho! in Devon the raised beach is 5m above present sea-level and formed during an interglacial 100,000 years ago, when sea-levels were 10m higher than at present.

In Scotland the land has rebounded by 100m since the ice sheets retreated, and with the added factor of sea-level rise the

Figure 5: Emergent coastal features



east Scottish coast near St Andrews contains many example of relic beaches, which form terraces along the coastline (Figure 5).

Base level changes/rejuvenation

If the land over which a river flows rebounds and relative sea-level falls, the river's erosive processes will be rejuvenated as it tries to erode down to a new base level. The base level of a river is the most efficient gradient for the river to flow down. This process will start from the lower reaches of the river near the sea. As the river erodes upstream, a waterfall or steep section will retreat upstream, forming a gorge or deepened valley. This active erosive point is called a knick point. Downstream of the **knick point**, terraces may form where the river has cut through the old floodplain. Entrenched meanders may occur when vertical erosion is very rapid, e.g. River Wear, Durham. Ingrown meanders occur when uplift is less rapid and the meanders are able to erode laterally.

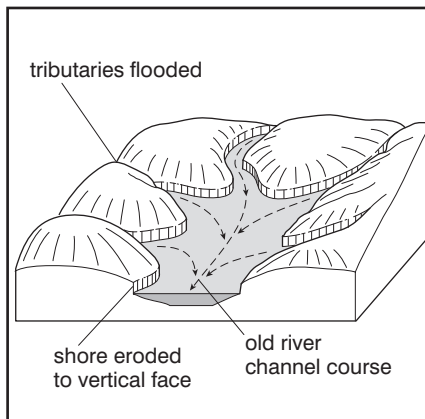
Submergent features

When sea-levels rose, many lowland valleys flooded, drowning the old coastline and creating a submergent coastline. Figure 8 shows some of the submergent features of the south coast with their map outlines.

Rias and estuaries

After the ice sheets melted, wide valleys flooded, forming very wide, tidal, sediment-rich river mouths. The Thames estuary formed at this time. Thought to have once been a tributary of the Rhine river system, the rising sea flooded the broad basin of the southern North Sea and created the present day

Figure 6: Formation of a ria, e.g. Falmouth ria



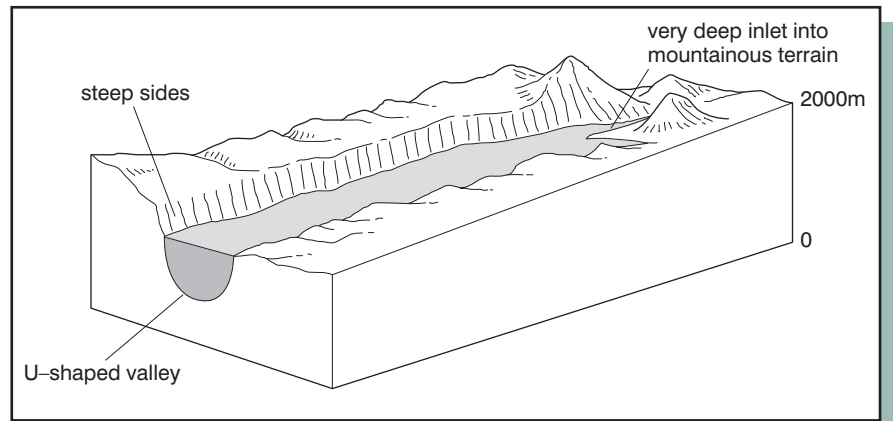
tidal estuary of the Thames. The River Solent once flowed into the sea beyond the Isle of Wight, meltwater having gouged out the valley of the river. When the sea-level rose, the Isle of Wight became an island at the mouth of the Solent. Other islands along the British coastline were also created by rising sea-levels, for example St Michael's Mount in Cornwall.

In hilly areas such as Cornwall and Devon, rias, or drowned river valleys, formed. The lower sections of the river valley flooded as the sea-level rose and picked out the dendritic pattern of former tributaries, forming a wide tidal inlet which can extend far inland. Falmouth and Plymouth both lie at the mouths of rias, where the sheltered expanse of water makes a safe haven for a port. The River Fal ria extends 18km inland, to Truro. Rias become deeper nearer the sea as the old river valley descends to the now submerged former coastline (Figure 6). Lulworth Cove in Dorset is thought to have formed as the sea eroded through a hard Portland limestone barrier to erode the sands and clays behind, creating the characteristic circular bay in Dorset. There is some evidence to suggest that the valley leading down to the cove originally carried a meltwater river which eroded the gap through the limestone, giving the sea a head start when sea-levels rose and drowned the lower reaches of the valley.

Fjords

Found on the West Coast of Scotland, fjords are flooded glacial U-shaped valleys or troughs. When valley glaciers erode through

Figure 7: Fjord coastline, e.g. Loch Torridon, west coast of Scotland



mountainous terrain they create a steep-sided flat-bottomed valley. As sea-levels rose the valleys were flooded, creating long inlets into the mountains with access to the sea. The valley sides are often very steep, leaving little room for habitation along the edges. Norway is famous for its fjord coastline, but Scotland also has many tidal lochs or fjords, e.g. Loch Torridon (Figure 7).

Drowned forests

After the glaciers had retreated, vegetation and forests pioneered the glacial outwash and boulder clay left behind. However, as sea-levels subsequently rose, these forests were drowned by the sea. Southampton, South Wales, Cornwall and Lancashire all have examples of drowned forests. One of the best examples is at Bexhill in East Sussex.

Shingle ridges

After the glaciers retreated, great outwash plains containing large amounts of reworked glacial material were deposited. As the sea-level rose these deposits were transported and sorted by the sea and pushed landwards by wave action. Chesil Beach in Dorset is the largest shingle ridge beach in the country, extending for 29km along the south coast and was formed in this way. The beach continued to move toward the land until the most dramatic rise in sea-level was over and the beach butted up against the land. The beach forms a tombolo with the Isle of Portland and a lagoon (the Fleet) against the old shoreline. Chesil Beach is no longer growing, as all the pebbles have been transported from offshore, leaving the beach as a fossil feature (Figure 8).

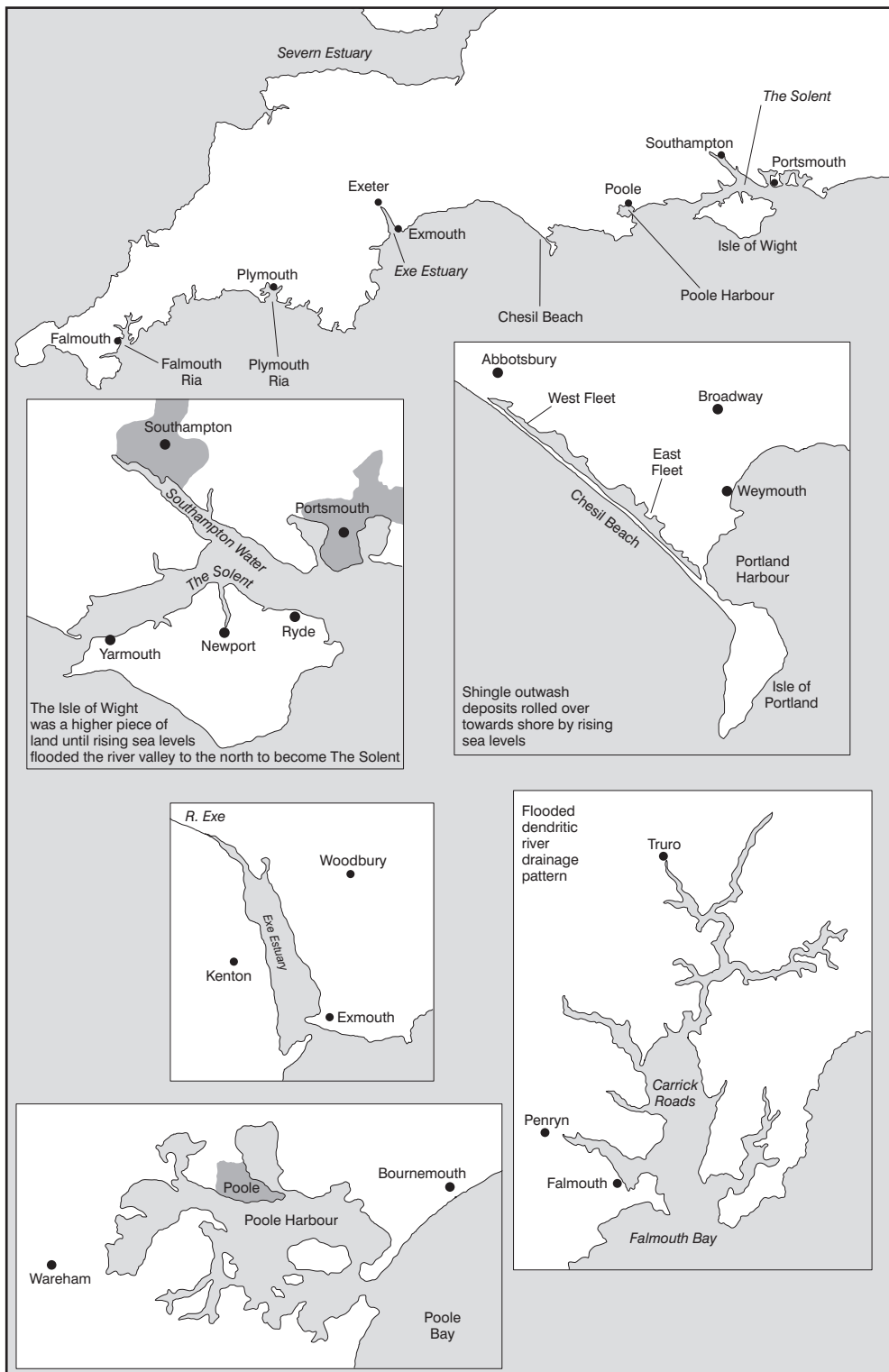
The future of the British coastline

The research behind global warming has shown that sea-levels are rising as the atmosphere warms; however, the climate of Britain in past interglacials has been warmer and sea-levels higher. As southern and eastern Britain slowly tilt by 2mm into the sea each year, Scotland is rebounding. If sea-levels continue to rise it will be the subsiding coastlines which will become more prone to flooding and erosion, as there are two effects causing the relative rise in sea-level. The coast of Scotland, which is undergoing a rebound rate of 1mm/year, may keep better pace with the rise in sea-level from global warming. Rock type and terrain will be important in the shaping of the coastline caused by higher sea-levels and it is the soft glacial sediments, low-lying estuaries and marshes which the ice sheets originally created, which will be most vulnerable. The question remains whether sea-levels will keep rising as the climate warms, or will fall as the next ice age puts Britain back in the deep freeze. The next ice age is already overdue.

Bibliography

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- Cook *et al.* (2000) *Geography in Focus*, Causeway Press.

Figure 8: Submergent features on the south coast of England



FOCUS QUESTIONS

1. Explain the differences between submergent and emergent coastlines.
2. What influence have relative rises in sea-level had on the British coastline?
3. Investigate the south coast of England from Land's End to the Thames estuary. What submergent features can you identify in addition to those in this Geofile? Draw a fully annotated sketch map to identify and explain the outline of the coastline. To extend this task, think about the geology along this coastline. What influences has it had on the features?