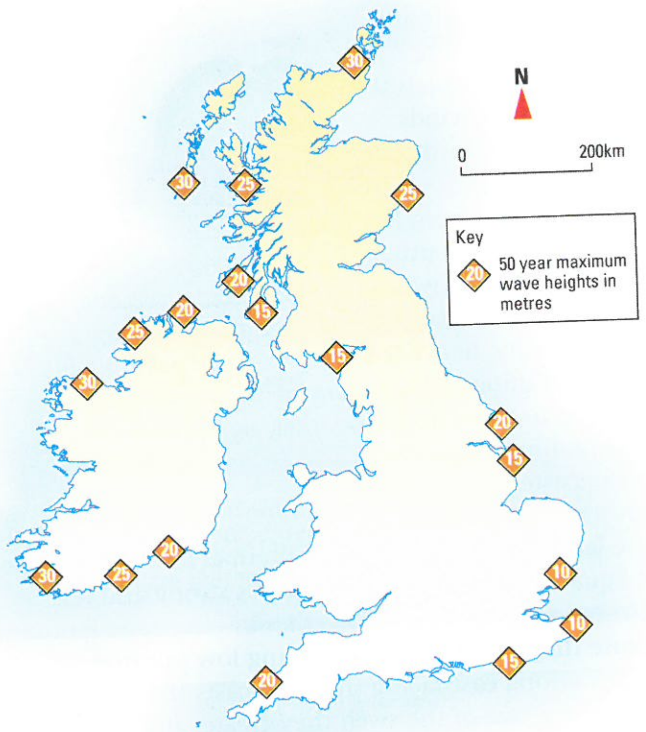
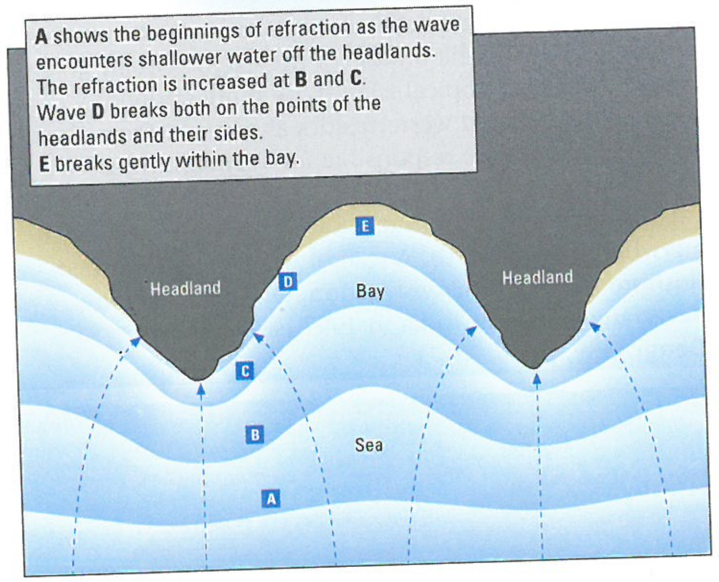
Within the UK, the west coast is a higher energy coast than the east coast. Westerly is both the prevailing and dominant wind direction; it is also the direction of longest fetch. Maximum wave heights decrease from west to east and from north to south across the British Isles away from exposure to the open ocean and onshore westerly winds (Figure 2.19). Fetch is the limiting factor for the height of waves generated by easterly winds in the North Sea. No matter how long an easterly gale blows, the waves breaking against the east coast can never reach the height of those from westerly gales along the west coast. However, with waves of fifteen and more metres in height occasionally recorded along the coast of Holderness, waves still have the power to cause considerable erosion. The shores of Europe's almost enclosed seas, such as the Mediterranean and Baltic, are low energy coasts in relation to those bordering the Atlantic and North Sea. In the Mediterranean gales occur less often since high pressure dominates the weather for a larger proportion of the year and strong low pressure systems only track south with any regularity during winter. In the Baltic Sea some of the longest examples of constructional coastal landforms in Europe have been formed, mainly because both sheltered waters and low tidal ranges are present (Figure 2.53).

On a smaller scale some estuaries, inlets and bays provide more sheltered environments in which the average wave energy is lower than on the headlands and the more exposed coastal zones are on both sides of them. A change in coastal direction can also reduce average energy levels. Along coastlines that are irregular, waves approaching the headland feel the effects of frictional drag at their base before those which approach the bay. Those in the bay continue to move relatively freely shorewards for longer. Waves around the headland turn inwards and concentrate their attack upon them (this bending of the waves around a headland so that they approach almost parallel to the coast is known as wave refraction, Figure 2.20); whereas waves in the bays spread outwards and dissipate their energy. Differences in wave energy levels are thereby created at the local scale. However, the size of the differences changes with time; as headlands are worn back, less shelter is offered to bays and wave energy again increases.

▼ **Figure 2.19** Maximum wave heights recorded around the British Isles





▲ **Figure 2.20** Wave refraction

Other factors influencing coastal erosion

A strong association between high energy coastal environments and high rates of coastal erosion exists. However, wave power alone is insufficient to explain the varying rates of retreat of cliffs and coastlines. Of the other factors that need to be taken into account, rock type is the most important. Is the rock hard or soft? Is it well jointed or well bedded, or is it massive? Is it consolidated or unconsolidated? Is the rock susceptible or not to chemical weathering? There are many permutations. A well-jointed hard rock can be as vulnerable to erosion as an inherently much softer rock which outcrops in a massive block without significant weaknesses. Ancient igneous and metamorphic rocks outcrop along much of the high energy Atlantic coast of the British Isles. These have only survived in their present positions due to their resistance to erosion; otherwise the islands which make up the British Isles would have disappeared millions of years ago. Younger and generally weaker sedimentary rocks outcrop around the coasts of lowland Britain. Of these, chalk resists erosion longer and more successfully than most of the others; weakest of all are the unconsolidated deposits such as boulder clay.

Figure 2.21 Cliff extremes

▶ **a** Land's End, one of the most exposed places to the high energy of Atlantic storm waves. The granite rock is well jointed. It might be expected to be the site of rapid coastal erosion, but the rate of retreat is probably a matter of a few centimetres a year because granite is a hard and tough rock.

▶ **b** Part of the coast of Yorkshire, where the weak boulder clay (glacial till) cliffs are being undercut by waves from below and washed away from above. Annual rates of retreat are measured in metres rather than centimetres.

Structure is another factor. Where major structural weaknesses exist along the west coast, large coastal indentations can be seen. The great inlet of the Bristol Channel occupies a structural depression which has been eroded and infilled by younger sediments, most recently from rivers such as the Severn. To the north, the Pembrokeshire peninsula shows the influence of old hard rocks and powerful folding in the Hercynian mountain building period. To the south, there is the South West peninsula with its strong backbone of granite. In north-west Scotland the presence of faults helps to account for the size of some of the lochs and the separation of the Hebridean islands from the mainland.

Other physical factors that affect rates of marine erosion are cliff height and coastal alignment. The higher the cliff, the greater the pile of loose material is left at its base after every cliff fall. This rock debris offers protection to the base of the cliff preventing further undercutting by the waves until all of it has been removed. Stretches of coast which are aligned so that they face onshore prevailing winds are likely to suffer attack from storm waves more frequently than those which face only dominant winds. This is especially true of west-facing locations where the direction of the prevailing wind and longest fetch coincide. At the local scale humans can speed up erosion. Extending jetties, breakwaters and groynes out to sea deprives the litoral (along the shore) waves of load and increases their potential to erode coasts further down drift.

▲ **Figure 2.22**
Recent rockfall near Ramsgate in Kent affording temporary protection to that part of the cliff against further wave attack

Questions

1 a Make a list of the physical factors that affect rates of marine erosion.
  b Explain why
    i the British Isles is an area of the world associated with high energy coasts
    ii coasts with the highest energy are located on the western sides of the British Isles
    iii some of the highest rates of cliff erosion are recorded along the east coast of England.

2 Where and why are low energy coasts present
  a within the UK
  b elsewhere in Europe, and
  c in other parts of the world?

3 **Extended prose**

Explain the causes and effects of spatial and temporal variations in wave energy.