Chapter 10 Coastal Landforms

The Action of Waves, Tides and Currents

The coastline, under the constant action of the waves, tides and currents, is undergoing changes from day to day. On calm days, when winds are slight, waves do little damage to the shoreline and may instead help to build up beaches and other depositional features. It is in storms that the ravages of the waves reach their greatest magnitude. The average pressure of Atlantic waves on adjacent coasts is about 600 lb. per square foot in the summer and treble that in winter. During storms, the pressure exerted is more than 6,000 lb. or 3 tons per square foot! Movements of such intensity will wear down not only the cliffs but also sea walls and buildings. *Tides and currents*, on contact with the shores, make very little direct attack on the coastline. Tides affect marine erosion mainly by extending a *line* of erosion into a zone of erosion. This zone corresponds to the area between the low water level and the high water level. Currents help to move eroded debris and deposit it as silt, sand and gravel along the coasts.

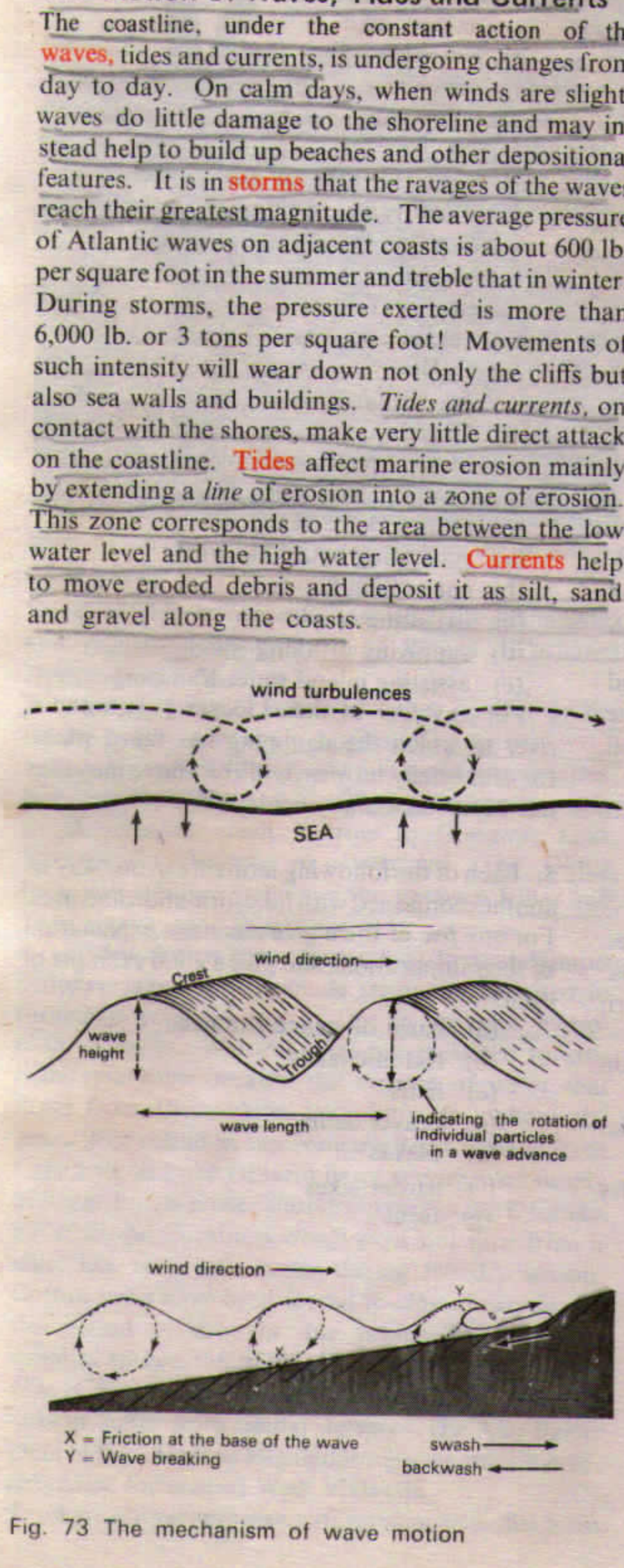

Fig. 73 The mechanism of wave motion

The Mechanism of Marine Erosion

The most powerful agents of marine erosion are waves. Their origin is due to the sweeping of winds over the water surface, which sets a series of undulating swells surging forward. These become higher and swifter. A normal wave in an open ocean may measure 20 feet high (the vertical height between the crest and the trough) and 400 feet long (the wavelength or the horizontal distance between one crest and another). During storms this is greatly increased, depending on the speed and duration of the winds. On approaching shallow water near the shores, their speed is reduced and the waves are curved or refracted against the alignment of the coast. Shallow water, when it is less than the height of the waves, checks their forward movement, the crests curl over and break into the shores in a mass of foam as breakers. The water that finally rushes up the beach and hurls rock debris against the land is termed swash. The water is sucked back and retreats as backwash. Another element in offshore drift is the undertow, which flows near the bottom away from the shore. This current exerts a pulling effect which can be dangerous to sea-bathers (Fig. 73).

Marine agents of erosion operate in the following ways to transform the coastal landscape.

1. **Corrasion.** Waves armed with rock debris of all sizes and shapes charge against the base of the cliffs, and wear them back by corrasion. On-coming currents and tides complete the work by sweeping the eroded material into the sea.

2. **Attrition.** The constantly moving waves that transport beach materials such as boulders, pebbles, shingle and fine sand also hurl these fragments against one another, until they are broken down by attrition into very small pieces. The grinding and polishing of such fragmental materials against cliff faces and against each other is largely responsible for the fine sand which forms the beaches that are so typical of the seaside resorts.

3. **Hydraulic action.** In their forward surge, waves splashing against the coast may enter joints and crevices in the rocks. The air imprisoned inside is immediately compressed. When the waves retreat, the compressed air expands with explosive violence. Such action repeated again and again soon enlarges the cracks and rock fragments are prised apart.

4. **Solvent action.** On limestone coasts, the solvent action of sea water on calcium carbonate sets up chemical changes in the rocks and disintegration takes

place. This process is limited to limestone coasts.

The rate of marine erosion depends on the nature of the rocks, the amount of rock exposed to the sea, the effects of tides and currents, and human interference in coast protection. Other effects such as vulcanicity, glaciation, earth movement and organic accumulations have also to be considered.

Coastal Features of Erosion

1. Capes and bays. On exposed coasts, the continual action of waves on rocks of varying resistance causes the coastline to be eroded irregularly. This is particularly pronounced where hard rocks, e.g. granites and limestones, occur in alternate bands with softer rocks e.g. sand and clay. The softer rocks are worn back into inlets, coves or bays and the harder ones persist as headlands, promontories or capes (Fig. 74). Along the Dorset coast of southern England, Swanage Bay and Durlston Head are examples. Even where the coast is of one rock type irregularities will be caused by variation within the

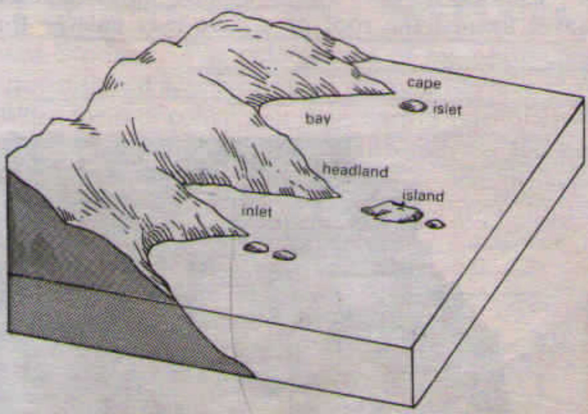

Fig. 74 Coastal features of differential erosion

rock. Thus Penang Island, made of granite, has many bays and headlands. Very large indentations such as the Persian Gulf or the Bay of Bengal are due to other causes such as submergence or earth movement.

2. Cliffs and wave-cut platforms. Generally any very steep rock face adjoining the coast forms a cliff. The rate of recession will depend on its geological structure, that is the stratification and jointing of the rocks and their resistance to wave attack. If the beds dip seawards, large blocks of rock will be dislodged and fall into the sea. The cliff will rise in a series of 'steps' as shown in Fig. 75. On the contrary, if the beds dip landwards as illustrated in Fig. 76, the cliff will be more resistant to wave erosion. Some

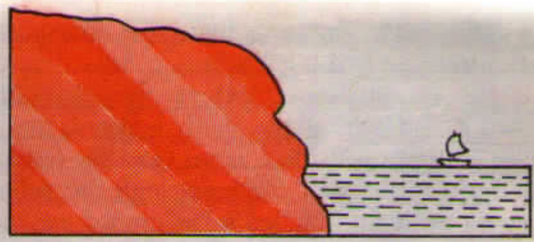

Fig. 75 Cliff beds dipping seawards

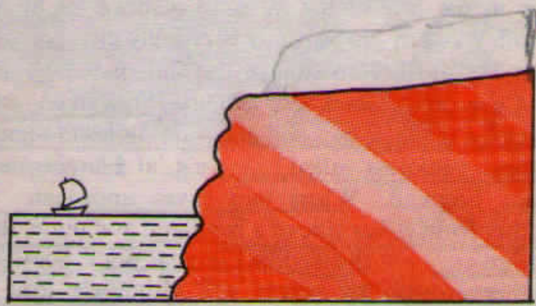

Fig. 76 Cliff beds dipping landwards

of the best known cliffs are the chalk cliffs of the English Channel and include Beachy Head which is 500 feet high, the Seven Sisters near the mouth of the Cuckmere and the 'White Cliffs' of Dover.

At the base of the cliff the sea cuts a notch, which gradually undermines the cliff so that it collapses.

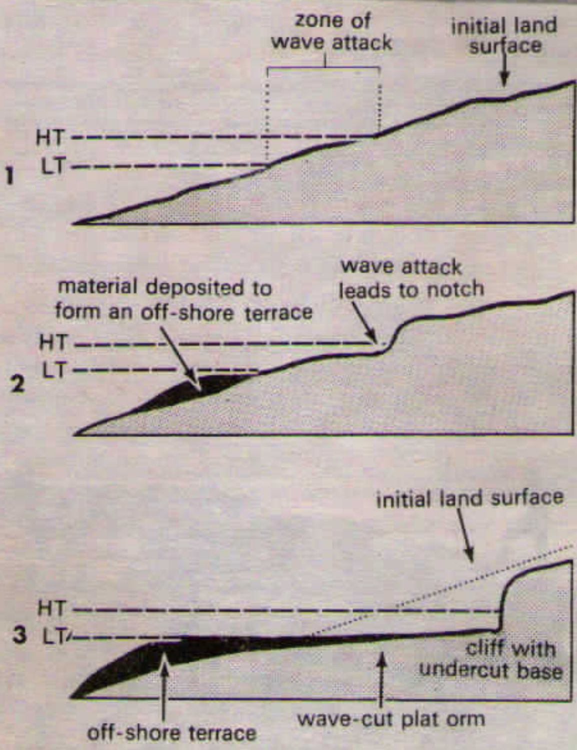

Fig. 77 The development of shore profile

As a cliff recedes landwards under the pounding of waves, an eroded base is left behind, called a **wave-cut platform**. The platform, the upper part of which is exposed at low tide, slopes gently seawards and its surface is strewn with rock debris from the receding cliff. Further abrasion continues until the pebbles are swept away into the sea. The eroded materials are deposited on the **off-shore terrace** (Fig. 77). When the platform attains a greater width (e.g. 30 miles in the case of the wave-cut platform of Strandflat off Western Norway), it is entirely covered with water and further erosion of the cliffs is negligible.

3. Cave, arch, stack and stump. Prolonged wave attack on the base of a cliff excavates holes in regions of local weakness called **caves** e.g. at Flamborough Head, England. When two caves approach one another from either side of a headland and unite, they form an **arch**, e.g. the Neddle Eye near Wick, Scotland. Further erosion by waves will ultimately lead to the total collapse of the arch. The seaward portion of the headland will remain as a pillar of rock known as a **stack**. One of the finest examples of a stack is the Old Man of Hoy in the Orkneys which is of Old Red Sandstone and is 450 feet high. Equally outstanding are the Needles, Isle of Wight, which are a group of stacks cut in chalk and diminishing in size seawards. In the course of time, these 'stubborn' stacks will gradually be removed. The vertical rock pillars are eroded, leaving behind only the **stumps** which are only just visible above the sea level, e.g. those of the St. Kilda group, off the Outer Hebrides, Scotland (Fig. 78).

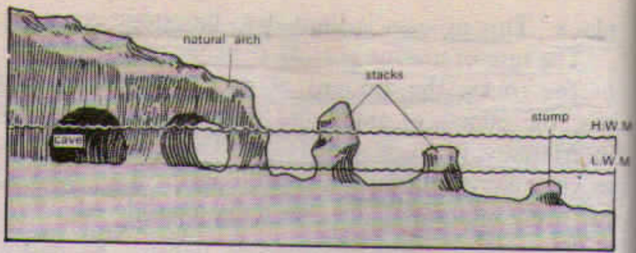

Fig. 78 Arch, stacks and stumps. Where two caves are eroded on either side of a headland they may eventually join to form a natural arch. If the top of the arch collapses stacks are formed. These are gradually worn down until they become stumps exposed only at low tide

4. Geos and gloups. The occasional splashing of the waves against the roof of a cave may enlarge the

A wave-cut platform on the Hong Kong coast *S.T. Fok*

joints when compressed air is trapped inside. A natural shaft is thus formed which may eventually pierce through to the surface. Waves breaking into the cave may force water or spray or just air out of this hole. Such a shaft is termed a gloup (from the noise made by the water gurgling inside) or blow-hole (Fig. 79). An example is at Holborn Head in Caith-

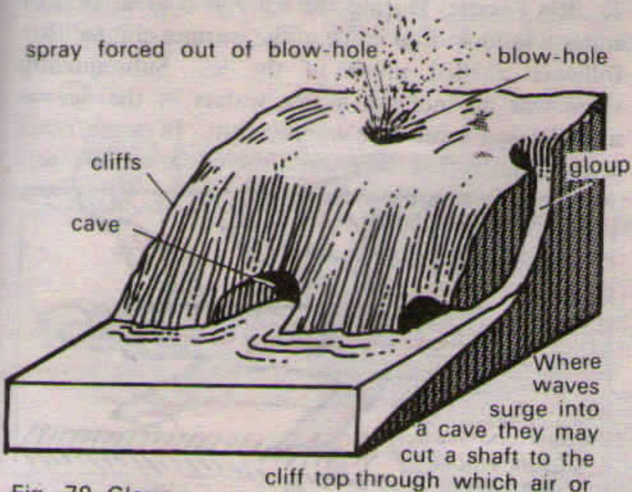

Fig. 79 Gloup

ness Scotland. The enlargement of blow-holes and the continued action of waves weakens the cave roof. When the roof collapses a long, narrow inlet or creek develops. Such deep clefts, which may be 100 feet deep and equally long, are called geos, e.g. the Wife Geo, near Duncansby Head, Scotland (Fig. 80).

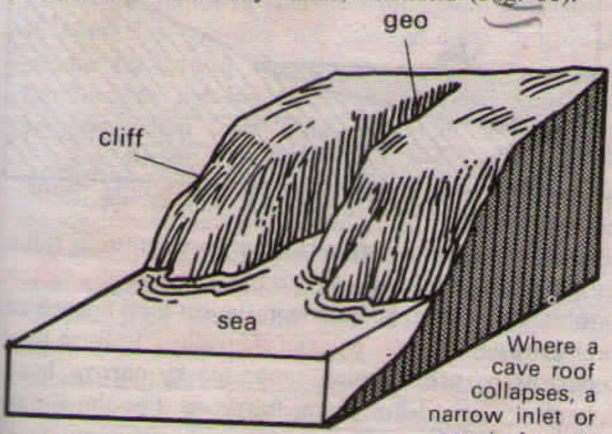

Fig. 80 Geo

Coastal Features of Deposition

1. **Beaches.** Sands and gravels loosened from the land are moved by waves to be deposited along the shore as beaches. This is the most dominant form of the constructive work of the sea. The eroded material is transported along the shore in several distinct ways. The longshore drift which comes

A natural arch

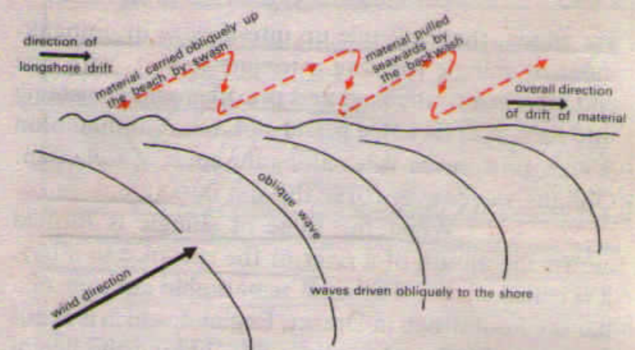

Fig. 81 Longshore drift

obliquely to the coast carries the material along the shore in the direction of the dominant wind (Fig. 81). At the same time, the backwash removes part of the material seawards along the bed of the sea, and deposits it on the off-shore terrace and even beyond. Finer materials such as silt and mud are deposited in the shallow waters of a sheltered coast.

The constant action of the waves automatically sorts out the shoreline deposits in a graded manner. The coarser materials (cobbles and boulders) are dropped by the waves at the top of the beach. The finer materials (pebbles and sand grains) which are carried down the beach by the backwash are dropped closer to the sea. On smooth lowlands, beaches may continue for miles, like those of the east coast of West Malaysia, but in upland regions where the land descends abruptly into the sea, such as the Chilean coast, long beaches are absent.

2. **Spits and bars.** The debris eroded by waves is continually moved by longshore drift and where there is an indentation in the coast, such as the mouth of a river or a bay, material may continue to be deposited across the inlet. As more materials

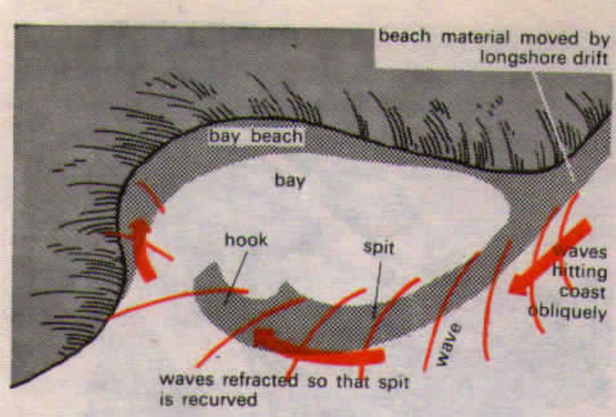

Fig. 82 Development of spit

are added, they will pile up into a ridge or embankment of shingle forming a tongue or spit, with one end attached to the land and the other end projecting into the sea (Fig. 82), e.g. Calshot Spit, Southampton Water, England or those along the coast of Kelantan. Oblique waves may curve the spit into a hook or recurved spit. When the ridge of shingle is formed across the mouth of a river or the entrance to a bay, it is called a bar. The most remarkable example of a bar is Chesil Beach in Dorset, England, which extends for over 16 miles along the coast, linking the Isle of Portland with mainland, and enclosing a lagoon called the Fleet. Such a connecting bar that joins two land masses is better known as tombolo. On the Baltic coast of Poland and Germany, large bodies of water are almost completely enclosed by long bars, locally termed nehrungs, to form marshy lagoons or haffs.

3. Marine dunes and dune Belts. With the force of on-shore winds, a large amount of coastal sand is driven landwards forming extensive marine dunes that stretch into dune belts. Their advance inland may engulf farms, roads and even entire villages. The dunes of the Landes, south-west France, cover 6,000 square miles; the crests of the dunes are over 130 feet high. Dunes are common in the coastlands of Belgium, Denmark and the Netherlands. To arrest the migration of the dunes, sand-binding species of grass and shrubs, such as marram grass, and pines are planted.

Types of Coasts

Despite a great variety of coastal features coastlines may be divided into two basic types.

1. Coastlines of submergence. These are due to the sinking of the land or the rise of the sea, including such coasts as ria coasts, fiord coasts, estuarine coasts and Dalmatian or longitudinal coasts.

2. Coastlines of emergence. These are due to the uplift of the land or a fall in the sea level. They are less common and are represented by the uplifted lowland coast and the emergent upland coast.

Coastlines of Submergence

1. Ria coasts. During the Ice Age a great deal of water was locked up in ice. The warmer climate that followed melted much of the ice. Subsequently there was an increase in the waters of the oceans and the sea level rose appreciably. In some cases it is estimated that there was a rise of almost 300 feet!

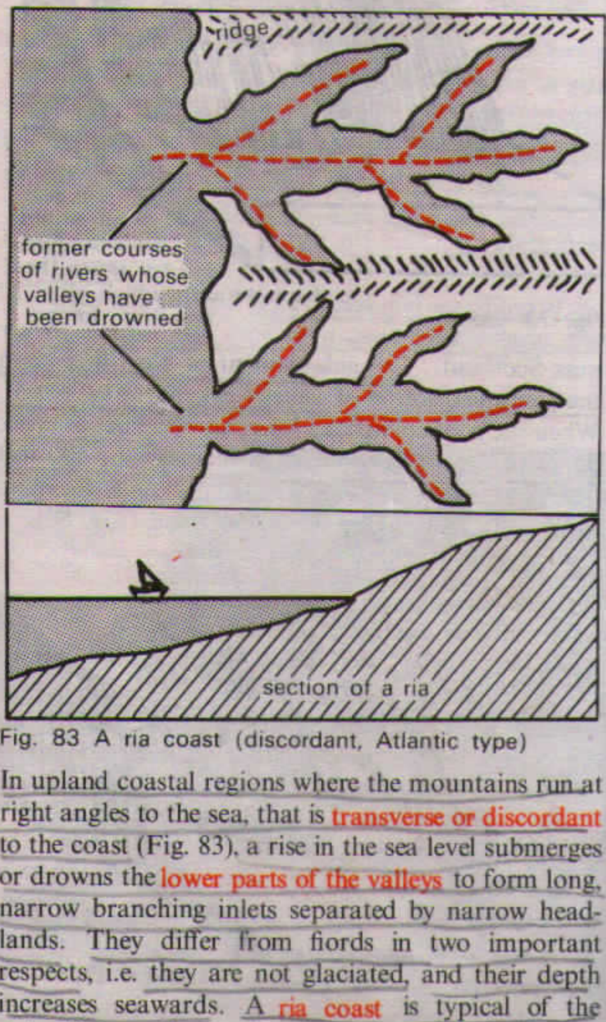

Fig. 83 A ria coast (discordant, Atlantic type)

In upland coastal regions where the mountains run at right angles to the sea, that is transverse or discordant to the coast (Fig. 83), a rise in the sea level submerges or drowns the lower parts of the valleys to form long, narrow branching inlets separated by narrow headlands. They differ from fiords in two important respects, i.e. they are not glaciated, and their depth increases seawards. A ria coast is typical of the Atlantic type of coast like those of north-west France, north-west Spain, south-west Ireland, Devon and Cornwall. As rias are generally backed by highland, they support few large commercial ports though they have deep water and offer sheltered anchorage. They have been extensively used for siting fishing ports and naval bases such as Plymouth and Brest.

2. Fiord coasts. Fiords are *submerged U-shaped* glacial troughs. They mark the paths of glaciers that plunged down from the highlands. They have **steep walls,** often rising straight from the sea, with tributary branches joining the main inlet at right angles. Due to the greater intensity of ice erosion fiords are deep for great distances inland but there is a shallow section at the seaward end formed by a ridge of rock and called the **threshold** (Fig. 84). Off the fiord coast are

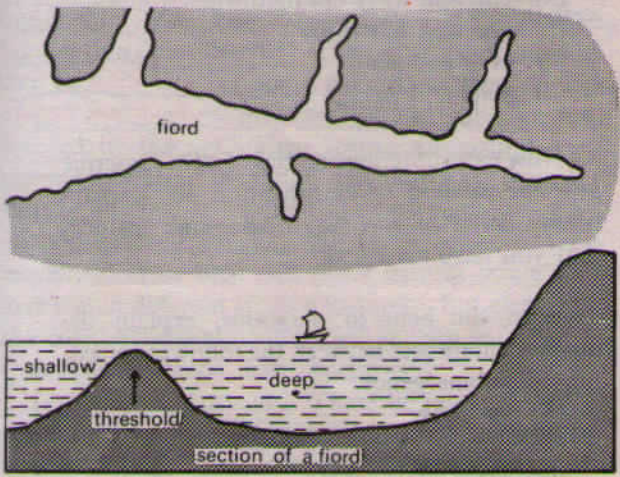

Fig. 84 A fiord coast (submergent and glaciated)

numerous islands or skerries which, with the shallow thresholds, sometimes only 200 feet deep, complicate coastal navigation. Fiord coasts are almost entirely confined to the higher latitudes of the temperate regions which were once glaciated e.g. Norway, Alaska, British Columbia, southern Chile and the South Island of New Zealand. Some of the large fiords are extremely long and deep. For example the **Sogne Fiord** of Norway is 110 miles long, 4 miles wide and almost 4,000 feet deep in its mid-channel. Despite their deep and sheltered water, few large ports are located in fiords. Their mountainous background with poor accessibility inland, attract few settlements. Agriculture is confined to the **deltaic fans,** built up where streams flow down to the fiords. The few towns that exist either as fishing or market centres e.g. Trondheim, are only of local importance.

3. Dalmatian coast. This is the longitudinal coast where mountains run **parallel or concordant** to the coast. The name is taken from the coast of Dalmatia, Yugoslavia, along the Adriatic Sea, where the submergence of the coastline produces long, narrow inlets with a chain of islands parallel to the coast. The

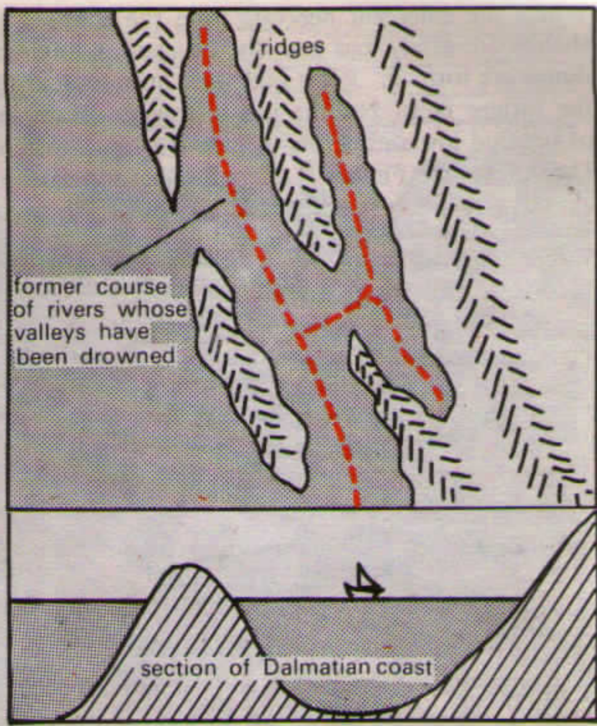

Fig. 85 A Dalmatian coast (concordant, Pacific type)

elongated islands are the crests of former ranges and the narrow **sounds** were the former longitudinal valleys (Fig. 85). The Dalmatian type of coast is also typical of the Pacific coast where the ranges are parallel to the coast e.g. western coasts of North and South America but there the coastline is more regular. Like the ria and fiord coasts, the mountainous nature of the Dalmatian coastline hinders communication inland. It has deep, sheltered harbours but no distinguished ports. On the Pacific coast, however, there are some important ports such as San Francisco.

4. Estuarine coasts. In submerged lowlands, the mouths of rivers are drowned so that funnel-shaped **estuaries** are formed. If their entrances are not silted by moving sand-banks, they make excellent sites for ports, e.g. the estuaries of the Thames, Elbe and Plate are the sites of such great seaports as London, Hamburg and Buenos Aires. Tidal effects further enhance the value of the ports and even when there is a little silting, modern dredges help to keep the ports open all the time.

Coastlines of Emergence

1. Uplifted lowland coast. The uplift of part of the continental shelf produces a smooth, *gently sloping coastal lowland* (Fig. 86). The offshore waters are shallow with **lagoons, salt-marshes and mud-flats.**

Where the emergent deposits from the continental shelves are sandy and gravelly, beaches and marine dunes are formed. Ports that were once located on the former coast become inland towns. Examples of uplifted lowland coasts include the south-eastern U.S.A., western Finland, eastern Sweden and parts of coastal Argentina south of the Rio de la Plata.

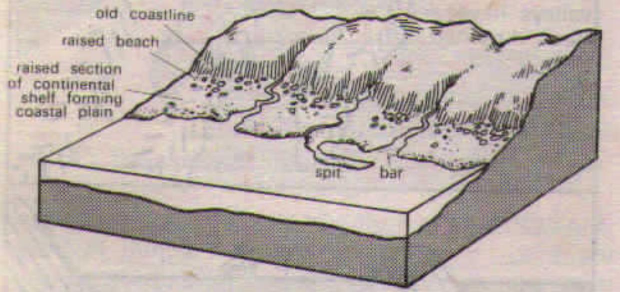

Fig. 86 Lowland coastline of emergence

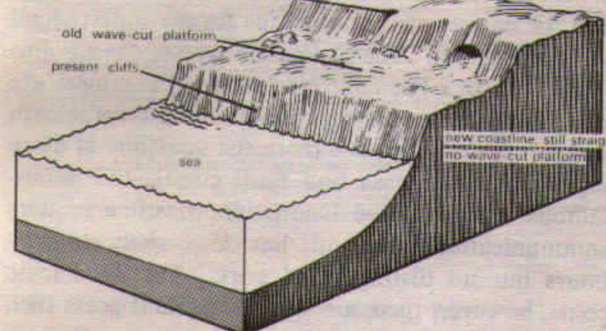

Fig. 87 Upland emergent coastline

2. Emergent upland coast. Faulting and earth movement may thrust up coastal plateaux so that the whole region is raised, with consequent emergent features. A raised beach is the most prominent. The raised beach is beyond the reach of the waves, though it may still possess arches, stacks and other coastal features. The emergent upland coast is quite straight with steep cliffs and deeper off-shore water, for the waves have not yet eroded lines of weakness or carved a wave-cut platform (Fig. 87). It has little potential for good port sites. Examples of emergent upland coasts are found in Scotland, the western coast of the Deccan, India and the western Arabian coast facing the Red Sea.

QUESTIONS AND EXERCISES

1. By reference to specific examples describe some of the major coastal features resulting from the constructive and destructive work of the sea.

2. With the aid of annotated diagrams, describe the appearance and formation of any *three* of the following pairs of features of coastal landforms.
   (a) cliff and wave-cut platform
   (b) geo and blowhole
   (c) arch and stack
   (d) spits and bars

3. How can shorelines be classified? Describe any *one* method of classification and explain briefly some of the major shoreline features that you have classified.

4. With the help of diagrams, explain the distinct differences between the following coastlines of submergence.
   (a) ria coast
   (b) fiord coast
   (c) Dalmatian coast
   (d) estuarine coast

5. Choose any *three* of the following terms connected with marine landscape. Explain the meaning of each and state its role in transforming the coastline.
   (a) longshore drift
   (b) undertow
   (c) concordant coast
   (d) raised beach
   (e) tombolo