1
Introduction

1.1 Coastal geomorphology

More than half the world's population lives in coastal regions, and many people visit the coast frequently. Most come for seaside recreation, but some also wonder about the origins of coastal scenery. A walk along the shore or a coastal footpath prompts questions about how such features as cliffs, rocky outcrops, beaches and dunes formed, and how and why they are changing. A coastal journey is likely to encounter estuaries, lagoons and river deltas that have evolved over longer periods, and it soon becomes clear that sea level has not always been where it is now.

Coastal geomorphology deals with the shaping of coastal features (landforms), the processes at work on them and the changes taking place. Coastal geology is concerned with the rock formations and structures seen in cliff and shore outcrops, and the sediments that have been deposited in coastal regions. It provides the background for coastal geomorphology.

Apart from incidental comments by classical Greek and Roman observers and by Leonardo da Vinci, the first systematic attempts to explain coastal landforms were by 19th century scientists such as Charles Lyell and Charles Darwin, and the pioneer American geomorphologist William Morris Davis. While a great deal of work was done in the 20th century on various parts of the world's coastline, particularly in Europe and North America, it is only in the past few decades that coastal research has become widespread, and there is still plenty of opportunity for original contributions.

Coastal geomorphology has several themes, each of which will be discussed in this book.

(a) The shaping of landforms in relation to geology, processes, variations in climate and the relative levels of land and sea.

(b) Coastline changes measured over specified periods, with analyses of their causes.

(c) Nearshore processes and responses, particularly on beaches.

(d) Evidence of geological history, notably changes in land and sea level and climatic variations.

(e) The sources and patterns of movement of coastal sediment.

(f) The array of weathering processes in the coastal zone.

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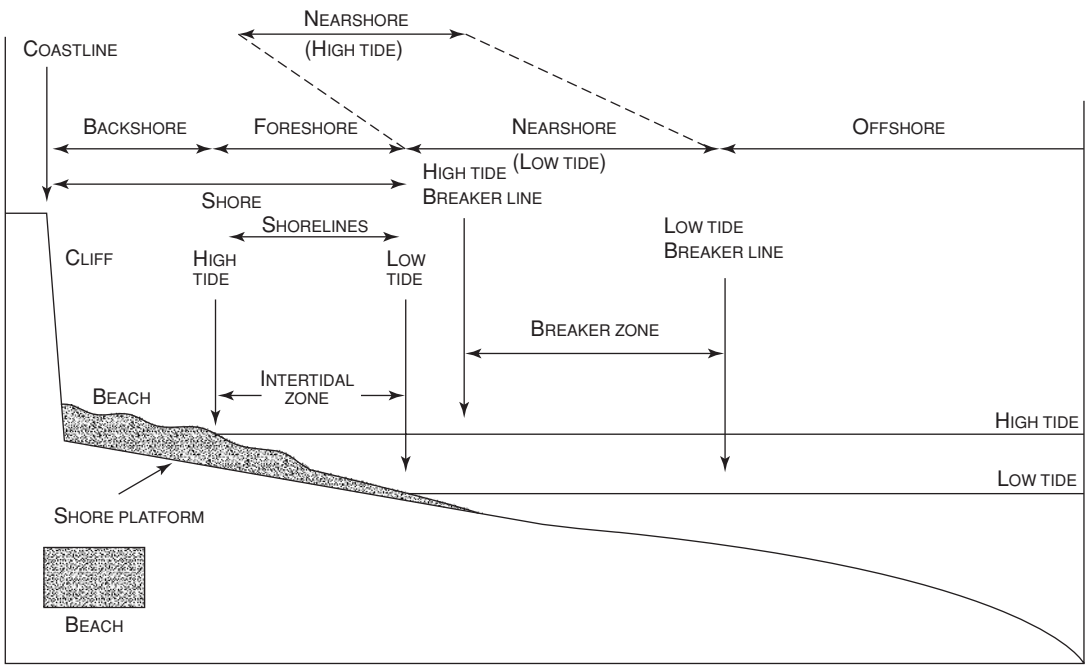


Figure 1.1 Coastal terminology

1.2 Terminology

The coast consists of a number of zones (Figure 1.1). The shore is the zone between the water's edge at low tide and the upper limit of effective wave action, usually extending to the cliff base. It includes the foreshore, exposed at low tide and submerged at high tide, and the backshore, extending landward from the normal high tide limit, but inundated by exceptionally high tides or by large waves during storms. The shoreline is strictly the water's edge, migrating to and fro as the tide rises and falls.

The nearshore zone, comprising the surf zone (with breaking waves) and the swash zone (covered as each wave runs up the foreshore), also migrates to and fro as the tides rise and fall. The breaker zone (where waves are disrupted) is bordered seaward by the offshore zone, extending to an arbitrary limit in deep water. The terms offshore, onshore and longshore are also used to describe directions of flow of wind, water or sediment.

A beach is an accumulation of loose sediment, such as sand, gravel or boulders, sometimes confined to the backshore but often extending across the foreshore as well. Some beaches extend down to, and below, low tide level. Shingle is beach gravel, especially where the stones are well rounded.

The coast is a zone of varying width, including the shore and the nearshore zone, out at least to the line where waves break, and extending inland to the limit of penetration of marine influences: the crest of a cliff, the head of a tidal estuary, or the rising ground behind coastal lowlands, or dunes, lagoons and swamps. The coast is thus the zone where land, sea and air (the lithosphere, hydrosphere and atmosphere) meet and interact. It is subject to an array of processes, including tectonic movements (upward, downward or laterally) of the land margin, changes in

Panel 1.1 Coastline or shoreline?

The coastline is defined as the edge of the land at the limit of normal high spring tides; the subaerial land margin, often marked by the seaward boundary of terrestrial vegetation. On cliffed coasts it is taken as the cliff foot at high spring tide level.

The shoreline is the water's edge, moving to and fro as the tides rise and fall, so that there is a low-tide shoreline, a mid-tide shoreline and a high-tide shoreline. Shorelines thus move to and fro as the tide rises and falls, whereas coastlines are submerged only in exceptional circumstances (e.g. during storm surges).

If coastline and shoreline are regarded as synonyms this distinction is lost. There is a difficulty where the tide range is large, as in NW Australia, where tides exceed 10 m and the distance between the coastline (high spring tide shoreline) and the low spring tide shoreline is up to 8 km. However, the term shoreline is often used for the coastlines of lakes, estuaries and lagoons, where the tide range is generally small and the intertidal zone narrow or non-existent.

Many American authors have preferred the term shoreline to coastline, but there are notable exceptions: Shepard and Wanless (1971) entitled their book *Our Changing Coastlines*, and the leading American journal is called the *Journal of Coastal Research.* In the United States the term shoreline is defined legally as mean high water (MHW), as shown on nautical charts produced by the National Oceanic and Atmospheric Administration (NOAA). Shorelines at other levels are simply called lines, e.g. the mean lower low water line, which is a private property seaward boundary in some eastern states (Parker, 2001). It should be noted that the American shoreline, thus defined, is not the margin of normally dry land.

Details of work cited (Shepard and Wanless, 1971; Parker, 2001) are given in the References section (pp. 387–404).

sea level, the effects of tides, waves and currents in the sea and variations in temperature, pressure and wind action in the atmosphere. Some coasts have been shaped primarily by erosion, others by deposition. Erosion is the removal of rock material, and the term denudation is used where surface rock is removed to expose underlying rock formations and structures to further erosion.

The term coastline indicates the land margin at normal high spring tide (behind the backshore zone), and may be the base of a cliff or the seaward margin of dunes or dry land. In American literature the term shoreline (or seaboard) is often used as a synonym for coastline, while the coast is elaborated to the coastal zone. The preference here is to maintain a distinction between coastline and shoreline (Panel 1.1), acknowledging that the shoreline moves to and fro as tides rise and fall, so that one can define a low-tide shoreline, a mid-tide shoreline, and a high-tide shoreline.

1.3 Ancient coastlines

Coastlines have existed since oceans first formed on the surface of a cooling Earth, about 4 000 million years ago, but it is difficult to find early coastlines because most of the evidence has been removed by erosion or concealed by deposition. Table 1.1 shows the geological column (the sequence of geological periods). Deposits indicating coastlines that existed in Mesozoic and Tertiary times can be found in the stratigraphy of southern Britain. An example is seen on the Haldon Hills, east of Dartmoor in SW England, where there are pebbly sands with corals and mollusc shells that represent a beach deposited in the Cretaceous, about 110 million years ago. Other fragments of ancient coastlines have been preserved far inland. In the Czech Republic there is a quarry on Kank Hill, near Kutna Hora, about 70 km east of Prague, where it is possible to stand on the Upper Cretaceous shore. A beach resting on an irregular wave-worn surface of

Table 1.1 The geological column: the sequence of rock formations arranged by age (my – million years).

Quaternary Period:	Holocene (Recent)	
		10 000 years
	Pleistocene Epoch	
		2.3 my
Tertiary Period:	Pliocene Epoch	
		5 my
	Miocene Epoch	
		23 my
	Oligocene Epoch	
		36 my
	Eocene Epoch	
		53 my
	Palaeocene Epoch	
		65 my
Mesozoic Era	Cretaceous Period	
		144 my
	Jurassic Period	
		213 my
	Triassic Period	
		248 my
Palaeozoic Era:	Permian Period	
		290 my
	Carboniferous Period	
		360 my
	Devonian Period	
		405 my
	Silurian Period	
		436 my
	Ordovician Period	
		510 my
	Cambrian Period	
		560 my
Pre-Cambrian Era		

In North America the Carboniferous Period is divided into upper (Pennsylvanian) and lower (Mississippian) Periods.
Geologists recognise Formations within each Period, based on rock type (lithology), e.g. the Old Red Sandstone Formation in the Devonian and the Chalk Formation in the Cretaceous, and when these are shown on maps and in sections they are useful for geomorphology. Alternatively, they divide each period into a number of stages, based on their fossil content, but these may not correspond to lithological units.

Pre-Cambrian rock marks the limits of a Cretaceous sea that reached here about 95 million years ago (Ager, 1980). There have been many such transgressions of the sea over the land during geological time, probably related to changes in the size and shape of ocean basins, particularly during the splitting of the ancient supercontinent of Pangaea into several drifting continents, a process that began early in the Mesozoic era.

Evidence of former coastlines becomes clearer in the most recent of the geological periods, the Quaternary, which comprises the Pleistocene (which began about 2.3 million years ago) and the succeeding Holocene (the last 10 000 years). The Quaternary period was one of major global climate and sea level fluctuations, and Quaternary coastlines can be found above and below present sea level (Chapter 3). There are Late Pleistocene beaches and shore platforms standing above present sea level on many coasts, notably in SW England and around Scotland, while submerged Pleistocene coastlines (cliffs, shore platforms and beaches) have been detected on the sea floor, notably off California and Japan. Coastal plains built forward by deposition, as in the SE United States, may include stranded remnants of coastlines of Pleistocene and Holocene age, containing evidence of past conditions that has generally been lost on receding cliffed coasts.

During cold climate phases of the Quaternary, when glaciers and ice sheets became extensive, global sea level was much lower than it is now, and when the climate of the Ice Age gave place to milder conditions there was a major world-wide sea level rise. Existing coastal landforms have been largely shaped within the past 6000 years, when the sea has stood at or close to its present level, with global climate much as it is now. Some coasts have older (relict) features, inherited from earlier environments when the sea stood higher or lower, or when the climate was warmer or colder, wetter or drier, or stormier or calmer than it is now.

1.4 Coastline morphology

Maps and charts show that few of the world's coastlines are straight: even those of simple outline are typically gently curved. An example of an almost straight coastline is the north coast of Madura in Indonesia, which may be related to a major fault line. The almost straight 800 km east coast of Madagascar could also be fault guided, but it includes depositional sandy barriers shaped by Indian Ocean swell, and has not been produced directly by faulting. Probably the best example of a fault coast is seen in California north of San Francisco, where the coastline runs along the San Andreas Fault NW to the Bolinas Lagoon, and then follows the fault along the inner (eastern) shore of the Point Reyes peninsula bordering Tomales Bay.

There are often simple relationships between coastal outlines and the geology and topography of coastal areas. Headlands and promontories generally occur where there are outcrops of resistant rock at, above or below sea level, or where higher ground comes to the coast, as on interfluves between incised valleys. Bays have been excavated where softer rock outcrops are bordered by more resistant formations, particularly where lowlands have formed. Where there have been relatively recent tectonic movements (upward or downward, tilting or folding) of the land it is likely that uplifted sectors protrude seaward and that subsided areas have become bays.

There are distinctive cliff and shore features related to certain geological formations, such as chalk or granite, where they outcrop on the coast. However, there is not always a good correlation between coastal landforms and the outcrops of rock formations shown on geological maps, particularly when geological formations have been defined by mineralogy or palaeontology, rather than by rock type (lithology). Thus the cliffs and rocky shores on the coast of Aberdeenshire bear little relationship to several mapped divisions of the Dalradian schist, classified on the basis of their mineralogy (Ritchie, 2006). Some coasts of similar geology, latitude and aspect are compared in Panel 1.2.

Panel 1.2 Comparisons of coasts of similar geologies, latitudes and aspects

It may be useful to compare features on similar geological formations in similar latitudes and with similar aspects: for example coastal landforms on glacial drift deposits in the Danish archipelago with those in New England and around Puget Sound. The features of the Normandy coast (such as the landslides at Les Vaches Noires and Longues-sur-mer) are similar to those of the south coast of England, with contrasts related to the higher wave energy on the northern side of the English Channel. Davies (1980) suggested that features on coasts of varying aspect should be compared, for example the east and west or north and south coasts of islands such as Tasmania, Ireland or Sri Lanka. Contrasts related to aspect can be studied on islands, such as the coastal blowouts and parabolic dunes on the east and west coasts of King Island in Bass Strait (Jennings, 1957). Interpretation of the major dune formations of Fraser Island and Cooloola in SE Queensland is aided by comparisons with similar dune systems in equivalent latitudes on the coasts of southern Brazil and Mozambique.

On a smaller scale, there are contrasts related to local variations in exposure: on the coast of Tahiti beaches occur only inshore of gaps in the bordering coral reefs. On the west coast of the Galloway Peninsula, in Scotland, an emerged shore platform is backed by bluffs that became bolder as exposure through the 'window' to the Atlantic (between Islay and Ulster) increases at Bellochantuy Bay.

Certain rock sequences and structures produce the same kind of landform association. Similar landforms accompany particular rock sequences, as on the south coast of England where landslides occur as the Chalk gives place laterally to Upper Greensand and Gault Clay, as at Beer in Devon, White Nothe in Dorset, Freshwater Bay and Culver Cliff on the Isle of Wight, Holywell in Sussex and Folkestone in Kent. Similar features are seen at Bempton on the east coast of England, and near Boulogne and at Sainte Adresse in northern France.

The shaping of many coastlines has been influenced by upward or downward movements of sea level (Chapter 3). Embayed coastlines with valley-mouth inlets, as on the Atlantic coasts of the United States and western Britain, are the outcome of relatively recent marine submergence (Chapter 11). Where sea level has fallen there are often emerged coastal plains and smooth coastlines where the sea floor was relatively featureless near the coast. There are exceptions where the sea floor had an irregular topography that has emerged, as in the archipelago of SW Finland.

Many coasts formed by deposition of sediments have simple, often gently curved beach-fringed outlines (e.g. much of the Gulf Coast of the United States), as have some cliffed coasts cut in fairly soft rock formations (e.g. Lyme Bay in Dorset, Figure 6.24). There are exceptions where deposition at a river mouth has formed protruding deltas. Other coasts with geological diversity are more intricate, with headlands and embayments (e.g. South China), branching inlets and ramifying peninsulas (e.g. Sulawesi in Indonesia and the Kimberley coast in northern Australia) or numerous islands (e.g. the Dalmatian coast).

Rounded bays have formed where the sea has penetrated into volcanic craters or calderas, as in the South Shetland Islands, a chain of volcanic islands parallel to the west coast of the Antarctic Peninsula. Here Deception Island is a partly collapsed volcanic cone with a rim rising to 580 m, overlooking a deep caldera penetrated by the sea to form a circular embayment. Similar rounded bays were formed by explosive eruptions at Santorini in the Aegean Sea and Krakatau, between Java and Sumatra, but these now contain younger volcanoes. Theoretically a rounded coastal embayment could be formed by marine submergence of a breached meteorite crater, but no example has been demonstrated. There are bays in breached and drowned sinkholes on the limestones of the NW coast of Gozo in Malta. Where a resistant geological formation running along the coast is backed landward by a weaker outcrop, penetration of the outer rampart by marine erosion may be followed by the excavation of a rounded embayment, as at Lulworth Cove on the south coast of England (Figure 4.28).

Smoothly curved coastlines have formed where incoming refracted waves have shaped the outlines of depositional coasts, as on the Ninety Mile Beach and in Discovery Bay, SE Australia. They are well developed on coasts exposed to ocean swell, but can also form on the shores of large bays and coastal lagoons (Section 6.9). On some coasts the smooth curvature extends across cliffed sectors in soft rock formations as well as along the intervening beaches, as in Hawke Bay on the east coast of North Island, New Zealand, and Te Waewae Bay in South Island, New Zealand. These are both shaped by refracted southerly ocean swell originating from storm centres in the Southern Ocean. On the south coast of England the Seven Sisters in Sussex are cliffs that truncate several valleys but are smooth in outline, with no inlets (Figure 1.2). The chalk cliffs are bordered by a gently sloping shore platform that is exposed at low tide, and has been cut across strata that dip gently seaward. At high tide this platform is submerged, and waves wash against the base of the cliff. Marine erosion has cut into the southern slopes of the South Downs to form vertical receding cliffs, the lower part of the cliff showing fresh white chalk recently scoured by waves armed with the chalk and flint boulders and cobbles that are strewn over the shore platform. In addition to wave abrasion, several other processes have contributed to the shaping of these coastal landforms. They include solution by rain water and sea spray, bioerosion by the plants and animals that inhabit the shore and frost shattering in cold winters. The cliffs undulate across dry valleys that were cut by streams when the climate was much colder during Pleistocene times. The



Figure 1.2 The Chalk cliff at Seven Sisters, Sussex

chalk surface was then disintegrated by freezing and thawing, and runoff from melting snow excavated valleys in the weathered rubble. Remnants of this rubble, known as Coombe Rock, underlie the dry valleys, and can be seen in the cliff at Birling Gap (marked by the building in the distance in Figure 1.2). See Chapter 4.

Various attempts have been made to describe the coastal outlines shown on maps and air photographs numerically, but without much success. The mathematician Mandelbrot (1967) saw coastlines as analogues of fractal curves, which retain the same general pattern regardless of how much they are magnified. Similar coastline features occur on a variety of scales. Beach cusps, for example (Section 6.10.7), maintain their shape as their dimensions increase or decrease in relation to incident wave heights, but a particular beach cusp is not subdivided into smaller, nested beach cusps, and the beaches on which they occur are not as a rule cuspate on a larger scale. It is true that coastal promontories and embayments occur on various scales from continental down to a particular headland and cove, but their pattern is not maintained hierarchically as the scale changes. The Mandelbrot observations have not led to any advance in coastal geomorphology.

1.5 Coastline length

Measurements of coastline length are necessary for describing the proportions of various types of coastline around the world or the lateral extent of erosion and accretion on beaches. Such measurements can be made can be made by counting straight intercepts of a selected length (e.g. 1 km) on maps of uniform scale (e.g. 1:250 000), or by using computers to integrate the grid squares within which coastline segments occur, taking each grid square as representing a specific coastline length. It is difficult to make

Table 1.2 Coastal dimensions

Inman and Nordstrom (1971) described first-order coasts as having length, width and height dimensions of about 1000 km × 100 km × 1 km, and second-order coasts about 100 km × 10 km × 1 km. They introduced ranges (1–100 km long and 10–1000 m wide) for third-order coasts, but did not develop the series further. Suggested categories:

First-order features – about 1000 km long, 100 km wide and 10 km high (e.g. continental coasts, related to global tectonics).

Second-order features are about 100 km long, 10 km wide and 1 km high (e.g. deltas, fiords).

Third-order features about 10 km long, 1 km wide and 100 m high (e.g. coastal barriers).

Fourth-order features are about 1 km long, 100 m wide and 10 m high (e.g. foredunes).

Fifth-order features are about 100 m long, 10 m wide and 1 m high (e.g. beach berms, shore platforms, sand bars).

Sixth-order features are about 10 m long, 1 m wide and 10 cm high (e.g. beach cusps).

Seventh-order features are about 1 m long, 10 cm wide and 1 cm high (e.g. current ripples).

In each case the dimension given should be regarded as being within a range of from 50% of to five times the figure given (e.g. sixth-order features 5–50 m long, 0.5–5 m wide and 5–50 cm high).

precise measurements, and different results are obtained with variations in the starting point for segment measurements or the location of grid squares.

The total length of the world's coastline is certainly considerably longer than the figure of 439 700 km given by Inman and Nordstrom (1971) and is probably close to a million kilometres, including the coasts of the very many small islands. Information on coastline lengths is available on the Internet, and can be obtained from Wikipedia (http://en.wikipedia.org/wiki/list or from the United States Central Intelligence Agency World Factbook (https://www.cia.gov/library/publications/the-world-factbook/index.html). The latter source lists coastlines with a total length of 847 942.30 km, but as several (e.g. Finland) exclude archipelagoes and coastal indentations and several other islands are omitted the global total is probably indeed close to a million kilometres.

Table 1.2 shows a classification of coastal dimensions. Variations in geomorphology around the world's coastline were illustrated by Bird and Schwartz (1985) and documented in *The World's Coasts: Online* (Bird, 2003).

1.6 Coastal evolution

The shaping of coastal landforms has been influenced by a range of morphogenic factors. These include geology, which determines the pattern of rock outcrops on the coast, on the sea floor and in the hinterland, and movements of the Earth's crust, which result in uplift, tilting, folding, faulting and subsidence of coastal rock formations. Climatic factors have influenced the wind and wave regimes that shape coastal features, and the weathering processes that decompose and disintegrate coastal rock outcrops vary from tropical to arctic and from humid to arid environments. Climate also conditions coastal vegetation and fauna, which have produced features ranging from salt marshes and mangrove swamps to shelly beaches, coral reefs and stabilised dunes, and also the organisms that attack rock surfaces (the processes of bioerosion, Section 5.1.4).

Coastal processes include the effects of rising and falling tides and associated tidal currents, and are influenced by oceanographic factors such as sea temperature and salinity, determined by climate and the patterns of ocean currents.

The various processes are discussed in Chapter 2. Mention has been made of ancient coastlines, produced by past changes in the relative levels of land and sea, and these changes have continued to influence the evolution of existing coasts. Within historical times coastal evolution has also been modified by the effects of various human activities on the coast and in the hinterland.

Evolution of coastal landforms can be considered in terms of morphogenic (morphodynamic) systems, within which various factors influence the processes acting upon the coast (Short, 1999). There is an input of energy (e.g. wind, tide, living organisms) and materials (e.g. water, rock, sediment) that interact to generate the coastal landforms, and there is feedback in the sense that the developing morphology modifies geomorphological processes, and thus becomes a factor influencing subsequent changes. These can be studied in terms of response to various coastal processes operating over specified periods: that is, as process-response systems. Attempts have been made to quantify the various inputs and to describe and analyse the interactions mathematically (Scheidegger, 1991), but the ideal of a complete quantitative understanding of a coastal system is more easily advocated than achieved. It is realistic to formulate and attempt to solve specific problems, and establish empirical relationships between process and change that can be put to practical use in coastal management.

1.7 Changing coastlines

While some coastlines have changed little over the past 6000 years, most have advanced or retreated, and some have shown alternations of advance and retreat. A coastline advances where the deposition of sediment exceeds the rate of erosion, or where there is emergence due to uplift of the land or a fall in sea level, and retreats as the result of erosion exceeding deposition, or where there is submergence due to land subsidence or a sea level rise (Figure 1.3). The high

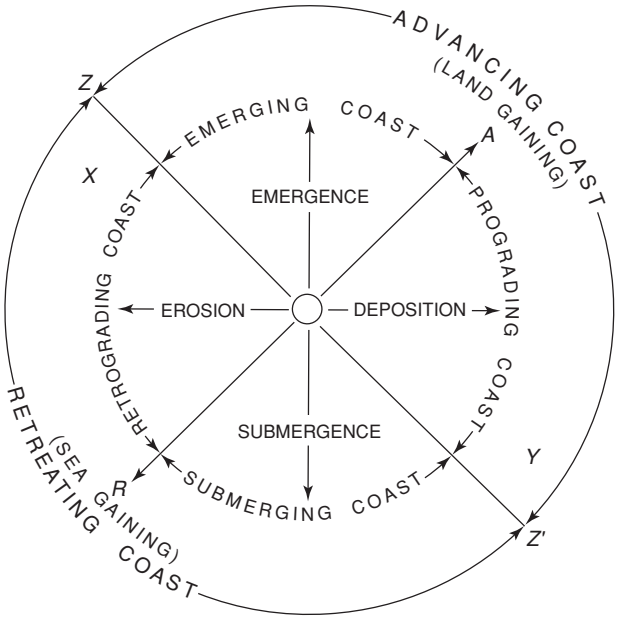


Figure 1.3 Analysis of coastline changes in terms of emergence and submergence, progradation and retrogradation, as proposed by Valentin (1952)

tide shoreline may advance or retreat independently of the low tide shoreline as the intertidal zone widens or narrows and the transverse gradient flattens or steepens.

Coastlines have changed at varying rates in response to coastal processes, with sudden changes during storms, earthquakes and volcanic eruptions (these attract media attention), and more gradual changes over quieter intervening periods (apt to pass unnoticed until someone produces historical photographs that can be used to demonstrate them). Coastline changes can be measured over various timescales, ranging from the past few thousand years down through recent centuries or decades to the annual or seasonal fluctuations and short term changes related to the various tidal cycles or caused by particular weather events. Some changes are cyclic over varying periods; others continue as erosion or deposition proceeds.

Measurement of coastline changes can be made by comparing historical maps and charts, providing these were based on accurate surveys, with the configuration shown on modern maps, air photographs or satellite imagery. Maps and charts of sufficient accuracy are available for parts of western Europe and North America for the past two centuries, but for much of the world's coastline there is little information preceding the era of air photography in the past few decades. A coastal tour on Google Earth is instructive, although the attempt to provide oblique views can be deceptive. Much useful information has been documented by people who become interested in coastline changes and collect photographs with a record of the date and the state of weather and tide: undocumented recollections are unreliable. Evidence of global coastline changes over the past century has been summarised by Bird (1985a).

On long-settled coasts changes have been determined from historical and archaeological evidence, as around the Mediterranean Sea, where it is locally possible to detect the advance or retreat of parts of the coastline over at least 2000 years (Kraft, Aschenbrenner and Rapp, 1988) (Figure 1.4). Changes since present sea level was established (within the past 6000 years) may be determined from evidence of the preceding land surface intersecting the sea floor (Section 4.9) or from stratigraphical and sedimentological analyses of coastal depositional formations, using radiometric and other forms of dating as well as palaeontological and archaeological evidence (Carter and Woodroffe, 1994).

Traditional methods of observing, mapping and measuring changes on the coast and the processes that cause them have recently been supplemented by new techniques, including various electronic measuring instruments and the application of modelling. Computers are used to process and extend field survey data, generating serial models of beach or coastal dune topography from which the pattern of gains and losses can be mapped and quantified (Section 6.14). Air photographs have been used for some time as an aid to the mapping and measurement of coastal changes, and colour photography has extended these studies to the nearshore sea floor. Satellite imagery has been used to trace coastline changes over the past three decades. Short term changes, which range from a few minutes to a few hours (as on beaches or dunes during a storm), require monitoring by repeated field surveys, the use of micro-erosion meters, serial photo-recording or photogrammetry. Ground surveys of coastal landforms can be made using a global positioning system (GPS) in traverses that can be translated into morphological maps by computer.

In recent years increasing use has been made of remote sensing techniques such as airborne laser terrain mapping (ALTM) and light detection and ranging (LIDAR) to measure short term changes on beaches, dunes, marshland and intertidal and nearshore areas. Reflection time is used to calculate altitudes that are related to a selected datum such as the high tide



Figure 1.4 Archaeological evidence of coastline change

shoreline. Vertical changes of as little as ±10 cm have been measured (Leatherman, Whitman and Zhang, 2005; Davidson-Arnott, 2005; Finkl, 2005).

Some coastline changes have resulted from human activities, such as reclamation (also known as land claim), the making of new ground by enclosing or filling nearshore areas, which in places has advanced the coastline several kilometres (French, 1997). The Netherlands has a long history of winning land from the sea by building dykes (sea walls) to enclose areas that were previously beneath the sea (at least at high tide) and draining these to form polder lands, thereby advancing the coastline seaward. New land has also been created on densely populated coasts in SE Asia, as in Tokyo Bay and Hong Kong, and Singapore has increased its land area by 10% in recent decades by landfill.

Coastlines have also been modified by the introduction of structures such as groynes and breakwaters, intended to stabilise features that were changing in ways considered unacceptable, notably where erosion threatened seaside towns, ports, or other developed coastal areas. The dredging of harbour entrances and the dumping of material on the coast and offshore have also modified coastal topography. In consequence, many coastlines have become largely or entirely artificial, and the extent of these is increasing rapidly. Appropriate coastal management may succeed in maintaining or enhancing the coastal environment, but there have been mistakes that could have been avoided if those concerned had understood the principles of coastal geomorphology.

1.8 Summary

Coastal geomorphology deals with the shaping of coastal landforms, the processes at work on

them and the changes taking place. It uses a defined set of terms to describe coastal features, past and present. Former coastlines exist above (emerged) and below (submerged) present sea level. Coastal outlines are related to geology and processes of erosion and deposition. Coastline length can be measured by such methods as 1 km intercepts: the world's coastline is about a million kilometres long. Coastal evolution is treated in terms of geology, climate, organisms, changes in land and sea level and processes in coastal waters. Coastline changes resulting from erosion or deposition and changes in sea level relative to the land can be studied over various timescales, and are ongoing. Some are directly or indirectly due to human activities, notably land reclamation and the building of artificial structures such as sea walls and breakwaters. An understanding of coastal evolution is an essential basis for coastal management.