COASTAL EVOLUTION

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Contents

Summary

The evolution of our present coasts has taken place over a very short time in the history of the earth. Most of what we see throughout the world has formed in only the past few thousand years. It is also likely to change quite a bit in the next few thousand years. This will be controlled by a combination of sea-level change and the wave and tidal processes that impact the coast. The tectonic setting of a particular coastal reach is also a major factor in the nature of the coastal environments that develop.

Most depositional coasts are characterized by some combination of estuaries, deltas and

barrier islands whereas erosional coasts are typically high relief bedrock. Glaciated coasts and coral reef coasts are special types and have climate as a major factor in their development.

1. Introduction

The coast is a complicated and dynamic transition between the marine environment and the terrestrial environment. It includes wide range of areas, topographies, and geologic settings. Within the coast we find beaches, barrier islands, tidal inlets, coastal estuaries and lagoons, rocky coasts, and reefal and glaciated coasts. Numerous factors contribute to the nature and style of the coastal system at any given place on the globe. The ones typically associated with coastal morphodynamics are waves, tides, and wind, with the overprint of severe storms. Less commonly considered, but at least as important, are the very large-scale and slowly progressing factors of plate tectonics and sea-level change.

The global distribution of general coastal types is quite varied. The most extensive is the rocky coasts that make up about two-thirds of the world’s shorelines. This figure also includes coral reef coasts. Barrier island coasts comprise only about 10% with deltas, estuaries, and glacial coasts comprising most of the remainder. There are obvious climatic factors that determine the nature of some coasts. Glacial coasts are limited to the high latitudes and coral reef coasts are restricted to the low latitudes.

This discussion of coastal evolution will begin with those broad and slowly progressing factors and then move to those that are more local and rapidly changing. Each major coastal element will be considered in the light of these slow to rapid modifying changes.

2. Plate Tectonics and Coastal Evolution

The establishment of the concept of plate tectonics was the most important geologic discovery of the twentieth century, perhaps of all time. In addition to explaining many aspects of our Earth’s crust and surface it also provides the framework for coastal development. Most of the general relationships between plate tectonics and coastal evolution can be attributed to a single paper by D. L. Inman and C. E. Nordstrom that provided several models and rationales for coastal development. The following discussion is based largely on that paper and its general concepts.

2.1 General Considerations

The coast takes on the characteristics of its tectonic setting in much the same manner as other parts of continental plates. The presence of a water-land boundary at this location is the only major difference. As a result, the coast takes on different characteristics depending on its location at or near a plate boundary as compared to near the middle of a plate. Likewise, if the plate boundary is a collision boundary as compared to an extensional boundary, a different coastal situation will prevail. These general characteristics provide the control on the broadest-scale coastal characteristics and may extend for thousands of kilometers.

2.2 Tectonic Coastal Classification

Inman and Nordstrom's classification includes three major categories: 1) collision coasts, 2) trailing edge coasts, and 3) marginal-sea coasts. All of the world's coasts can be placed into one of these (see Figure 1).

2.2.1 Collision Coasts

When plates collide there is a combination of complex structural settings and high relief. The general situation is that one plate margin descends or is subducted below the other, which is compressed with resulting volcanism and high relief. This may occur at or near the coast and result in a specific set of morphologic and geologic features.

Collision coasts, also called leading-edge coasts, are characterized by high relief both landward and seaward of the shoreline. This typically results in a drainage divide located near the coasts thus producing small streams with steep gradients On the seaward side the continental margin is narrow, steep, and structurally complex; commonly called a continental borderland.

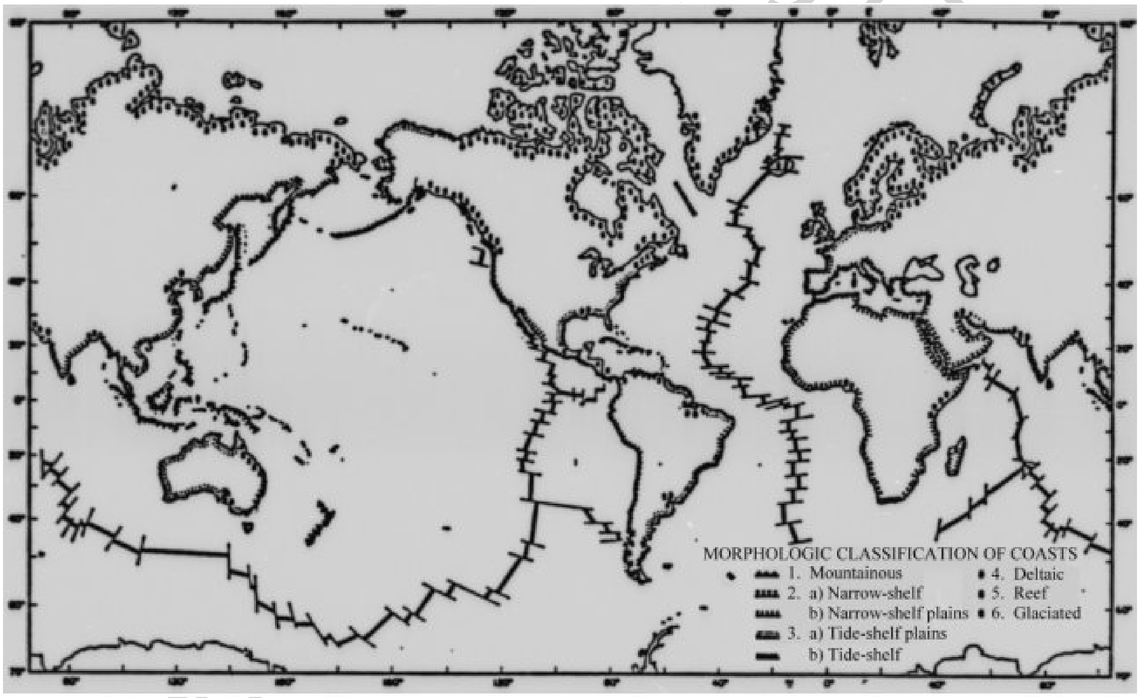

Figure 1. Distribution of various tectonic coastal types throughout the world
(from Inman and Nordstrom, 1971)

The result is that although streams may carry considerable sediment to the coast, little accumulates there as deltas or as barrier systems. The steep and narrow shoreface permits large waves to reach near the coast and carry much of the sediment to deeper water. Sediment transported alongshore may be captured by submarine canyons that have their heads in, or near the surf zone.

These factors produce a coastal zone that is mostly erosional due to high-energy wave conditions and a lack of available sediment. Collision coasts are typically dominated by bedrock bluffs and cliffs, with small estuaries and barrier spits in the bedrock re-entrants (Figure 2). Regardless of the tidal range, collision coasts tend to be wave-dominated. The best examples of this type of coast are along the west coasts of both North and South America.

2.2.2 Trailing-Edge Coasts

Coasts that develop along continental margins that are within a plate or are near the diverging portion of a crustal plate are tectonically stable. The result is that there is little relief, wide coastal plains and large drainage basins. The continental margins are wide with gently sloping continental shelves. Coasts associated with these conditions are depositional with large estuaries, well-developed barrier/inlet systems (see Figure 3), and large river deltas. They may exhibit wave-dominated or mixed energy morphologies.

Figure 2. Coast of California (USA) displaying typical rugged and high-relief features of collision coast morphology.

Inman and Nordstrom subdivided trailing edge coasts into three categories based on their age or maturity of development. These are; 1) the Amero-trailing edge coast, 2) the Afro-trailing edge coast and 3) the Neo-trailing edge coast with the first being the most mature. Amero-trailing edge coasts have well-developed and wide continental margins and adjacent coastal plains. The east coast of USA and that of South America are the best examples of this type. The next level of maturity is the Afro-trailing edge, taking its name from that continent. Here there is modest development of the continental margin and coastal plains are small. Africa is a good example with its rift valley down the backbone of the landmass and its stable margins. Fairly well-developed drainage systems and deltas are present and the coast tend to be depositional in nature. Neo-trailing edge coasts are those where separation of land masses has taken place in the recent geologic past. The Red Sea and its related rift area are the classic example (Figure 4). Here separation took place only a few million years ago and the continental margin is narrow and steep. Coasts are depositional but poorly developed.

2.2.3 Marginal Sea Coasts

Some parts of the world have collision plate margins and their associated geologic features such as volcanic island arcs protect stable continental margins. These fetch-limited basins have been called marginal seas and they show a variety of coastal schemes.

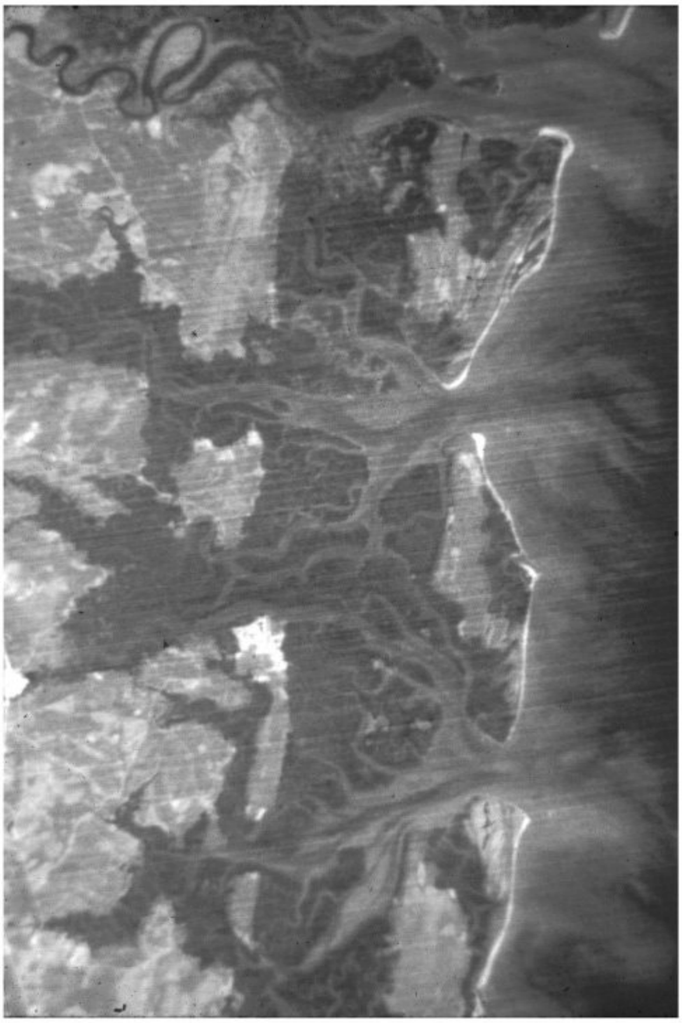

Figure 3. Satellite image of the coast of Georgia (USA) showing barrier islands and extensive marshes—typical trailing edge coast morphology

Figure 4. Example of a neo-trailing edge coast along the Red Sea on the left, and the Gulf of Aqaba on the right *(NASA photograph)*

They are typically associated with the same geologic settings as trailing edge coasts, thus they display well-developed continental margins and coastal plains, and they tend to have large river deltas. These depositional coasts may range from wave-dominated to tide-dominated depending on the relationship between sediment supply and wave energy.

Examples include the Gulf of Mexico (see Figure 5) where river deltas are present along with extensive barrier/inlet systems. Here the entire spectrum of morphodynamics settings is present. Another different example is off the coast of China where the Japanese archipelago protects the coast.

Here the combination of huge sediment discharge from rivers and high tidal ranges in the absence of an energetic wave climate produces many extensive reaches of tide-dominated conditions.

Figure 5. Example of a marginal sea coast from Texas, USA. The morphology of this coastal type is much like that of the mature trailing edges.

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Biographical Sketch

Richard A. Davis, Jr. is Distinguished University Professor Emeritus at the University of South Florida and is Director of the Coastal Research Laboratory in the Department of Geology. His research has concentrated on barrier/inlet coastal systems, beach and nearshore dynamics and Holocene history of the Florida Gulf Coast. His current research deals with inlet morphodynamics and chronic beach erosion problems in Florida. Davis has been a visiting professor in Australia, New Zealand, Denmark, The Netherlands and Spain. He has been a Senior Fulbright Fellow to Australia. Davis has authored or edited fourteen books dealing with oceanography, coastal geology, and depositonal systems.