THE ENDLESS VOYAGE

"On the Coast" Episode 116

I think the coastal ocean deserves special attention in any discussion of the importance of oceanography. It's the place where mankind meets the ocean.

The biggest issue is there are six billion people on this earth. We're headed for 10 or 12. And when you have lots of people, those people have impacts and most of those impacts are concentrated near the coast.

The coastline is a very sensitive environment. It is the boundary between the entire realm of marine processes and the entire realm of terrestrial processes. Coastlines are, in a sense, nature's dipstick.

NARRATOR:
LIKE A SPARKLING RIBBON PRESSED BETWEEN LAND AND OCEAN, THE COAST DRAWS PEOPLE TO IT THE WORLD OVER. FOR MANY, IT REPRESENTS AN ESCAPE. A PLACE TO GO TO INSULATE THEMSELVES FROM THE REALITIES AND FRUSTRATIONS OF URBAN LIFE. FOR PLANET EARTH, THE COAST IS A POINT OF DEMARCATION THAT DOESN'T SO MUCH DIVIDE AS BRING TOGETHER; AN INTERSECTION AT WHICH MANKIND LEAVES HIS FOOTPRINT ON NATURE'S DOORSTEP PERHAPS MORE CLEARLY THAN ANYWHERE ELSE.

CHIP FLETCHER, Ph.D., University of Hawaii at Manoa:
On the order of 80% of the U.S. population lives in coastal counties and, since World War II there's been a national migration away from the interior of the United States out towards the coastlines. And so there's been a huge population growth on our coastal environments. There's also been the demand for coastal resources in the form of coastal groundwater, coastal fisheries, coastal recreation.

CHRISTI HILL, Ph.D., Fullerton College:
Most human impact on coastlines is negative. That doesn't mean it all has to be. But we have to make a definite effort to try to not have an impact on coastlines. In areas such as the west coast of the United States, we have people that want to build right on the coastlines.

ANTONY ORME, Ph.D., University of California, Los Angeles:
Homes were built along the Pacific coast on the coastal bluffs constructed of sediments, which are a few million years earlier had been on the seafloor anyway, and which were again inherently unstable. And surprisingly, of course, very often these homes built on coastal bluffs will slip slowly into the sea. So the prized coastal view that the homeowners wanted would suddenly appear in their living room.

JAMES O'CONNELL, Woods Hold Oceanographic Institution:
People own property. They have a right to reasonable use of their property. But since the '30s and '40s, and primarily since the '50s and '60s with the big exodus towards the shoreline, human beings are now on par with the other major natural forces, such as storms and relative sea level rising and causing erosion.

NARRATOR:
BUT THE VALUE OF COASTAL AREAS IS NOT LIMITED TO REAL ESTATE. IT IS ALSO REFLECTED IN THE EXTRAORDINARY CONTRIBUTION THE COAST MAKES TO THE MARINE ECOSYSTEM.

PETER RHINES, Ph.D., University of Washington:
So even though the coastal zone you might say is 1% or some small percentage of the total area of this World Ocean—70% of the earth's surface—it has this tremendous influence, and it has primary productivity. That's the small plant and animal life that's concentrated there by the upwelling wind systems, which the atmosphere is stressing the ocean horizontally driving ocean currents up and down coasts. And when that occurs in the right direction, it sucks up deep water and nutrients, making a ribbon of productivity, which you can see on these wonderful websites like the SEAWIFS. NASA website will show you these exquisite color images of the ribbon of life that's along the edges of the continents.

NARRATOR:
WHILE THERE IS NEAR UNIVERSAL AGREEMENT ABOUT THE VALUE OF COASTAL REGIONS, A PRECISE DEFINITION OF WHAT EXACTLY CONSTITUTES THE COAST MAY BE A BIT MORE DIFFICULT TO COME BY.

O'CONNELL:
There is no universally acceptable definition of coast. It really depends on what journal or what textbook you're reading, but in general, for example, the Corps of Engineers would define a coast as a strip of land of indefinite width that interacts with a major body of water. Other texts that you read that will try and attempt to define coast will simply define it as the area of land that actively interacts with a major body of water—be it a fresh or marine environment—and that portion of the ocean or fresh water body that interacts with the land.

ORME:
The coast is essentially a boundary between the land and the sea, but it's a broad zone rather than a single line. It is not to be identified simply with the shoreline, but it extends inland into the watersheds that contribute to the coast. It also extends out away from the actual shoreline across the continental shelf, which is also all part of the coastal zone.

NARRATOR:
JUST AS DEFINITIONS OF THE COASTAL ZONE VARY, SO TOO, DO APPROACHES TO CLASSIFYING THE VARIOUS TYPES OF COASTS AROUND THE WORLD.

Coastlines are different from place to place. For instance, the east coast of the United States is a little bit different than the west coast of the United States. When you classify coastlines, typically, you can classify them one of several ways.

The first classification system and probably the most complex or comprehensive, was forwarded by Francis Shepard, a marine geologist at Scripps Institute of Oceanography in the 1960s. And he identified essentially two broad categories of coastlines: primary coastlines and secondary coastlines. Primary coastlines he defined as those which are shaped by terrestrial processes, processes originating from the land where the sea has simply come to rest against the shoreline.

The east coast would be a really good example of a primary coastline. It's an area where a couple of things are happening. You have coral reefs in the warmer areas around Florida. You also have rivers constantly pouring water and sediment into the oceans. The Gulf Coast could also be considered a primary coastline in the Gulf of Mexico, because the Mississippi River is constantly dumping sediment into the Gulf of Mexico and constantly changing the shape of the coastline. So it's renewing itself all the time. The west coast is more of a secondary coastline.

FLETCHER:
The secondary coastlines are those that are influenced from the marine side, from the ocean side. And this would include coastlines that are eroding because of marine processes. And you could have, for instance, a hard, rocky shoreline that is retreating because of erosion due to waves and currents, or you could have a coastline that's more complex, which is retreating where you have a rocky headland, but adjacent to that, you have an embayment. And the sediments that are produced by the erosion at the rocky headland are carried by currents and by waves into the adjoining embayment, and form beaches there.

Secondary coastlines are coastlines that are affected by ocean processes—wave activities and tides. Those coastlines are much older. They've already been established, their original shape has been established. And then what happens is the wave activity constantly erodes those away. They tend to be not as irregular because, as wave activity works, especially on irregular areas like headlands, they constantly wear them away and flatten out the coastline. So secondary coastlines tend to be ones that are helped more along by wave activity and ocean processes.

NARRATOR:
WHILE SOME OCEANOGRAPHERS CONTINUE TO USE THE PRIMARY AND SECONDARY DESIGNATION FOR COASTAL CLASSIFICATION, OTHERS TAKE A SOMEWHAT DIFFERENT APPROACH.

FLETCHER:
For instance, in introductory textbooks in physical geology, you find typically four types of coastlines classified: erosional coastlines, depositional coastlines, submergent

coastlines and emergent coastlines. Now the erosional and depositional coastlines basically are the same sort of thing that Shepard described and that I described earlier. Emergent and submergent coastlines are those where the relative rate of movement of the land is compared to the rate of movement of the ocean surface or sea level. And so you have either a coastline that's slowly emerging, such as we have up in the high latitudes of most of our continental areas, because they were recently glaciated. The weight of the ice pushed the continental landmasses down. Now that the ice has melted—these large continental glaciers associated with the last ice age—now that that ice has melted and the weight has been removed, the coastline, the land, is literally rebounding upwards. It's call glacial isostasy. So that is an example of an emergent coastline. For instance in the coastal areas of Norway and just in general Scandinavia, you find over the last thousand years fishing communities that have had to relocate their villages every 100 or 200 years back towards the shoreline because they find themselves getting higher and higher as the land rebounds.

NARRATOR:
SUBMERGENT COASTLINES, BY CONTRAST, ARE THOSE THAT ARE MOVING DOWNWARDS OR BEING FLOODED BY RISING SEA LEVEL. CHESAPEAKE BAY, DELAWARE BAY, AND AUSTRALIA'S SYDNEY HARBOR ARE GOOD EXAMPLES OF DROWNED COASTS. BUT THERE ARE STILL OTHER CLASSIFICATION APPROACHES THAT CAN ALSO BE USED.

REINHARD FLICK, Ph.D., Scripps Institution of Oceanography, UCSD:
Low energy and high energy is another way to classify coastlines and the terms are generally used to describe the relative height of the wave activity that impacts a particular coast.

JAMES O'CONNELL, Woods Hole Oceanographic Institution:
Areas that are inundated with significant waves are generally high energy environments, such as the Cape Cod National Seashore, a lot of the Outer Banks of North Carolina that are open ocean shores that are inundated by ocean storm waves.

ANTONY ORME, Ph.D., University of California, Los Angeles:
And in this instance typical wave heights in shallow water may be in the range of three to five meters and sometimes more than that. And they may be quite frequent. They may be coming in every 10 seconds or so. And that would create very high energy conditions capable of generating substantial erosion, moving a lot of sediment and redistributing coastal features, particularly beach sediment, over quite long distances. If the tidal range is also great, then that high energy is expressed over a much larger range of shoreline. And you could have even more disturbance. And that would be true, for example, in the northeast Atlantic around the British Isles, in the Gulf of Alaska, where you have high-energy wave activity superimposed onto a very considerable tidal range. In contrast, low energy coasts are those characterized by fairly low waves, less than, say, two meters, often also with a low tidal range, or almost no tidal range. And the consequences of such a low energy coast would be quite minimal changes from day to day, from week to week, or even for year to year in the shape and characteristics of the shoreline. And coasts like

that, for example, would characterize the Mediterranean Basin, which has a very minimal tidal range. It would also characterize the Gulf of Mexico.

NARRATOR:
GIVEN THE NUMBER AND VARIETY OF COASTAL CLASSIFICATION METHODS, OCEANOGRAPHERS OFTEN GRAVITATE TOWARDS THE APPROACH THEY CONSIDER TO BE THE MOST USEFUL IN STUDYING COASTAL ZONES AND PROCESSES.

The most useful, I think, and the most general classification of coastlines is according to where they are in the large-scale tectonic picture of the crust of the earth. In other words, the surface of the earth can be described in terms of large plates that move around relative to each other over long periods of time over the geological history of the earth. And the classification of coastlines according to their position on these tectonic plates is really the most useful one for understanding the kinds of coastal settings that we usually find, certainly in the mid-latitudes areas, such as where we are in the United States, both the east and the west coast.

NARRATOR:
DEPENDING ON THEIR PROXIMITY TO TECTONIC ACTIVITY, COASTAL ZONES CAN BE CLASSIFIED AS EITHER ACTIVE OR PASSIVE.

ORME:
When we talk about active margins, for example, on the coast of California, the coast of New Guinea, the coast of New Zealand, the coast of Chile—all of these are active tectonic margins and the activity there is related to tectonic stresses. Passive margins, on the other hand, relate to continental margins where there's relatively little plate activity going on other than a continuing separation of plates—for example, between West Africa and South America.

CHRISTI HILL, Ph.D., Fullerton College:
Passive coastlines are the east coast of the United States, the east coast of South America, places that are far away from plate boundaries. And so they're just passively sitting there, trailing along behind the continent as it moves away from the plate boundary. Passive coastlines are also called trailing edge coastlines, because they're just trailing along and they just have time to sort of erode away without being built up or disrupted by plate tectonic processes.

NARRATOR:
SOME OCEANOGRAPHERS WOULD ARGUE THAT THE BEST WAY TO UTILIZE THE EXTENSIVE ARRAY OF COASTLINE CLASSIFICATION APPROACHES IS TO INCORPORATE ELEMENTS OF EACH.

ORME:
I often come up with a threefold classification. The first of these is that coastal origins are often related to the primary tectonics of the coastal zone, and they come into

existence as a result of plate motions over many millions of years. So you're dealing with a very coarse scale operating over a very long time period. Within that context, the more precise limits of the coast are related to sea level change. And sea level change itself functions over several thousand years. And it functions, again, often globally, but sometimes also regionally, particularly where you have ice sheet depression off coastlines. And that kind of process of sea level change operates over the width of the continental shelf up the present coastline and sometimes above it. And then, within that, further we recognize—or I recognize—a third category of coastline which is essentially a product of contemporary processes. The processes that one can reasonably see within their lifetime or within, in fact, a few minutes to a few hours—the work of waves, of tides, of currents, and the way in which they can manipulate the coastline by causing erosion, sediment transport, deposition of sediment elsewhere. And so you have a kind of a hierarchy of scales from the very core system, very longest—the tectonic scale through the intermediate sea level change scale, to the localized and very specific effects of individual waves and tidal currents, and so on

NARRATOR:
IT IS OFTEN SAID THAT NO TWO SNOWFLAKES ARE EXACTLY ALIKE. SO TOO, IS THE SHAPE OF EVERY COASTLINE UTTERLY UNIQUE. WHATEVER A COASTLINE'S SHAPE TODAY, IT WAS PROBABLY DIFFERENT YESTERDAY, AS IT WILL NO DOUBT BE TOMORROW. FOR COASTAL ZONES ARE AMONG THE MOST DYNAMIC AREAS ON EARTH, SUBJECT TO A HOST OF FACTORS THAT MAKE EVERY COAST A WORK IN PROGRESS.

ORME:
Assuming sea level is reasonably stable, then shorelines change mainly in response to wave and current action and certain tidal forces. Waves, in particular, tend to focus on headlands, because the headlands protrude out further into the zone where the breakers are likely to be stronger, and, therefore, headlands tend to erode, and the materials eroded from headlands often tends to move into embayments between headlands. The net effect through time is often to cut back the headlands while filling in the embayment. And this does lead to a somewhat of a straightening of the shoreline.

ERIC TERRILL, Ph.D., Scripps Institution of Oceanography, UCSD:
Straight coastlines can, in fact, result from being a very old coastline when erosion has been acting upon it for quite some time period. As the erosion has taken place over time, you could think of the wave energy essentially carving out all the bumps and curves of the coastline in creating a straight coast. And so that's essentially why on the east coast, when we have these older coastlines—'cause it's not a very geologically active area, as a result of that, because they're much older, as opposed to, say, our younger coastlines here in California, that have lots of curves to them and the waves haven't been acting on them as long or the waves and the tides haven't been acting on them as long.

NARRATOR:
EXPOSURE TO VARYING AMOUNTS OF GEOLOGIC ACTIVITY IS ONE OF THE MAIN REASONS WHY EACH OF THE UNITED STATES COASTAL ZONES IS SO DISTINCT.

ORME:
There's a fundamental distinction within the United States between the Atlantic and Gulf Coasts on the one hand, and the Pacific Coast on the other. The Atlantic and Gulf Coasts are tectonically at passive margins. They're characterized by very broad continental shelves. They're characterized by extensive coastal plains inland from the present shoreline, and they have been characterized by very substantial lateral changes in sea level. And not necessarily vertical so much, but lateral changes in sea level over the last say, 20,000 years. The result is that a lot of wave energy is expended far out on the shelf and even when it approaches the shoreline, it generally deposits material offshore of the mainland coast in such a way as to build up barrier islands and barrier beaches.

CHIP FLETCHER, Ph.D., University of Hawaii at Manoa:
There is a whole type of coastal system known as a barrier island or barrier coast system. A very strong example we have in the U.S. is the Outer Banks of North Carolina, but you can find these barrier island systems all around the world.

They're islands that are naturally occurring, and if you were to leave them untouched, they actually migrate. As sea level rises, they move closer to the mainland. As see level drops, they move farther away from the mainland. They're typically made of sand and are very mobile.

O'CONNELL:
There are several theories that suggest the formation of barrier islands. Barrier islands are formed in one way through that long shore sediment transport as the sand accumulates on the terminal end of a mainland, you end up with a barrier spit. As the barrier spit extends in length, it causes the hydraulic head—a buildup of water in the bay or estuary. If it finds a low point in that barrier spit, it will break through, and when it breaks through, it leaves a stand-alone spit that's not connected to the mainland on either end. That would be a barrier island. And one of the other theories of barrier island formation are old sand deposits. Old paleodeltas that exist offshore. In a major storm you'll have sand moving landward from these old paleodeltas and, if the sand accumulates to a point where it protrudes above the level of the ocean, sand will continue to accumulate and form a barrier island in that way as well. And then long shore sediment transport will take over as a main process and extend that barrier island.

FLETCHER:
A barrier island system first and foremost is sand rich, at least the beach and the island itself are uniformly made up of a large percentage of sand. What's interesting, though, is we find that as you move offshore from these barrier islands, the shelf—the shallow seafloor actually in many places is sand-starved. And so the islands themselves appear to

be physical accumulations of sand, rather than simply an isolated portion of a broad sand-rich system.

NARRATOR:
ALTHOUGH BARRIER ISLANDS AND SPITS CAN AT TIMES BE SUBJECT TO SIGNIFICANT DISTURBANCES, THE ATLANTIC AND GULF COASTS ARE USUALLY CONSIDERED QUITE CALM, AT LEAST WHEN THERE'S NOT A HURRICANE IN THE VICINITY. THE PACIFIC COAST, ON THE OTHER HAND, IS SOMETHING ALTOGETHER DIFFERENT.

ANTONY ORME, Ph.D., University of California, Los Angeles:
Along the Pacific Coast we have a very active tectonic margin. We have a very steep offshore area, often with little or no continental shelf. That is certainly true in Southern California, where we don't even talk of a continental shelf. We talk of a continental borderland, and wave action generated in the Pacific work its way very quickly inshore. And, as it works its way inshore, of course, the waves will be bashing against a rather steep coastline, a coastline that until relatively recently in geological terms, was often on the seafloor itself. The sediments and other rocks that comprise the coastal zone are often weakly consolidated. They often are rich in marine clays, and these can slip and be pummeled quite readily by wave action. And therefore we have a lot of activity on this essentially steep coast, quite different from the Atlantic and Gulf Coasts.

NARRATOR:
WHILE THE ATLANTIC AND GULF COASTS ARE CONSIDERED TO BE RELATIVELY GENTLE COASTLINES, EROSIONAL FORCES CAN POSE PROBLEMS IN THESE AREAS, JUST AS THEY DO ON THE WEST COAST. IN MASSACHUSETTS, FOR EXAMPLE, THE COMBINATION OF EROSION AND SEA LEVEL RISE IS ESPECIALLY CHALLENGING.

JAMES O'CONNELL, Woods Hole Oceanographic Institution:
What do we do with the built environment? Many of these houses have been there for decades, if not centuries. But eventually, as a result of sea level rise and storms, the shoreline is going to catch up with these structures. Are we going to move the buildings? Are we going to elevate the buildings? Often times, with small structures, they have been relocated several times in response to erosion. And that's the most sensible way to deal with the shore. Because once you stop erosion of a sediment source, you will increase erosion of somebody else's property. So the best thing to do is to think about relocation ahead of time. That's one of the most important uses of shoreline change data—is to look into the future and start to plan, to minimize adverse impacts of human activities along the shore.

There should be a master plan for the management of the coast and on paper there is. But it applies really at different levels, and that is the problem. The human use and misuse of the coast was really one for many generations of exploitation and resource development. It wasn't until the 1960s that people started to become seriously interested in coastal conservation and protection.

NARRATOR:
YET EVEN WITH THIS INCREASED INTEREST IN PROTECTING THE COASTAL ENVIRONMENT, THE CHALLENGE OF ACTUALLY DOING SO HAS PROVED DIFFICULT.

We have a national—indeed it's a global problem with the development of our shoreline in a way that's not really compatible with coastal processes. This takes two forms. One is that we are building expensive infrastructure sewage delivery systems, highways, and we also are building our homes and cities in the pathway of very high energy, dangerous marine processes, such as hurricanes, tsunamis, and those that are not quite so life threatening, such as erosion, passive coastal erosion that takes place, and of course future sea level rise. There is a convergence. In fact, you could characterize it as a head-on collision between the nature of human development in the coastal zone, and the natural processes that call for natural migration and flexibility of coastal environments to move laterally and vertically through space and time. So we're now finding coastal managers and along with them coastal scientists and engineers looking more closely at ways to develop the shoreline that are more compatible with the long-term changes that we see coming over the next century or two.

ERIC TERRILL, Ph.D., Scripps Institution of Oceanography, UCSD:
People who are in the seats of making policy decisions are really going to be pressed with having to make decisions based on the scientific input that's provided to them providing a happy medium between the ocean and the coastal population.

And certainly the Federal Government is involved. The E.P.A. is involved. The Corps of Engineers are often involved. But often it's up to local authorities to actually initiate and specify what is and is not possible. Ultimately, plans for development come from individuals or from groups. And then they are presented to, say, the Coastal Commission in California, where they are reviewed by perhaps an understaffed body of individuals who are always under pressure to develop from the developers and under pressure to protect from the conservationists. But eventually, despite the goodwill of all these agencies and the individuals concerned, very often such is the nature of the system and the rights of property owners that some degree of development all seems to be involved in the end even if it's a compromise. So that, whereas one might have a fine, grand plan, and one might have the mechanisms in place to evaluate various proposals, ultimately, there's a fairly steady nibbling away at our coastal resources, certainly slower than it was say, prior to 1970, but still going on at the present time.

I think a happy medium can be found. It's just trying to figure out that road that we're going to have to go down. So it's only recent that people have realized that the ocean isn't a limitless resource, and that we do need to make decisions, say growth decisions, based on what we're doing to the coastal environment.

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