Coastlines – Tutorial Script

The place where most humans spend most of their time interacting with the oceans is along the coastline. In these regions we see spectacular displays of marine life, reef development, sand migration, and coastal erosion. Let's review these processes and the features they develop by visiting a variety of coastlines from all over the world.

When a coastline is made of solid rock lifting up out of the water, the waves will attack any bits that stick out. This focused wave energy will do its best to undercut the solid rock, creating wave-cut notches below wave-cut cliffs. Only by undercutting the cliffs will the ocean succeed in its erosional task, as gravity now causes the unsupported rock to fail and fall into the ocean. When undercutting has been extensive, and the cliff is yet to fail, we get sea caves and sea arches. When the roof above a sea arch finally fails, an island is left offshore. We call these sea stacks. And where erosion in sea caves has carved holes to the surface, we get blowholes. Blowholes can be quite dangerous, because large waves will frequently push into the cave and out the blowhole taking coastal explorers unaware.

This image from Northern British Columbia shows fjords, carved by glaciers during the last ice age as they entered the ocean. One of the spectacular features of fjords is that glaciers carve straight down, so the sides of this inlet are vertical cliffs that extend in some places a few hundred feet below the surface. Boats can drive right up to the side of the fjord, reach out and grab a tree to anchor. This image is taken from the Big Island of Hawaii, where the highly resistant basalt bedrock is undercut by high waves. There are extensive caves carved out under these cliffs. Standing on the edge of these cliffs is quite dangerous, as entire sections have been known to fail and carry unsuspecting tourists with them. You can feel the power of these waves when standing here, because with each crash of the waves below, the entire rock face shakes and resonates around you. This picture of the beaches of Big Sur in central California shows large rocky headlands left behind as waves erode the uplifting granites that dominate this region. The distant dome in this picture is also a large resistant granite that erodes somewhat differently and creates an extensive rounded headland, slowly being worn down by the wave action. Erosional features are dramatic sculptures found across many coastal landscapes.

Beaches are piles of sediment that were deposited or left behind by waves. These piles are in constant flux as old sand is removed and new sand is added. We call this kind of feature a depositional feature. Others include **deltas**, where sediment is deposited as rivers enter the ocean, **spits**, where **longshore current** carries sand partially across the mouth of a harbor, **baymouth bars or bay barriers**, where the spits have completely crossed and cut off the embayments from the ocean, **tombolos**, where sand has collected behind an offshore island, and **barrier islands**, where sand piles up parallel but a distance offshore from the present coastline. These barrier islands are usually formed from spits that extend outwards along a coastline or from older beaches pushed up and inland as sea level rose after the last ice age. **Hooks** form when currents push a spit into an embayment.

Pause now.

The East Coast of the United States is dominated by depositional features, with long sandy beaches, like this one along the Atlantic Coast of Florida. Such features are found all along the East Coast between Massachusetts in the North and Florida in the South. Many barrier islands are completely covered by cities or residential communities, like this one. Normally these barrier islands would be made entirely of shifting dunes with steeper slopes on the ocean side and gentler mud-filled lagoons on the inland side. These lagoons are filled with grassy marshes in temperate climates and mangrove swamps in tropical climates as shown in this image from a lagoon inside a Florida barrier island. When embayments get completely closed off or separated from the ocean, usually by dunes, we call them lagoons. This image shows a lagoon in Pescadero, just south of San Francisco. Although the Pacific coastline is dominated by erosional features, there are a few locations such as Pescadero where we see these salt-marsh-surrounded lagoons.

Deltas are some of the largest sediment piles and depositional features in the ocean. You can see from these satellite images just how much mud these rivers carry. Because the mud particles are so small, they remain suspended in the water and are carried far offshore before settling to the bottom to create deep-sea muds.

Why is the East Coast of the United States dominated by depositional features while the West Coast is dominated by erosional features? The East Coast must be sinking, while the West Coast is uplifting. Why? Do you remember from the Plate Tectonics video tutorial, what the plate tectonics differences are between these two coasts? The East Coast is a passive margin in the middle of the North American Plate. The only activity on the coastline is the slow steady piling up of sediment eroded from the mountains and carried to the beaches. As this sediment collects and adds weight to the crust, the land isostatically sinks below the surface. Sediment piles up, and we get barrier islands, spits, and deltas. Along the west coast, the land is uplifting. In some places, such as Washington, Oregon, and Northern California, the coast is also a subduction zone, and that explains the uplift. But what about the rest of California? Even though there's no longer subduction here and hasn't been for almost 60 million years, there is still uplift associated with small amounts of compression that still exist along the North American and Pacific plate boundary—a boundary that is now primarily characterized by transform stresses and the San Andreas Fault System. The uplift carries new, resistant rock above the waves to be eroded and sculpted leaving behind cliffs, terraces, and caves.

Let's take a close-up tour along these two coastlines using Google Earth. This video shows us moving North along the California Coast. Notice the spectacular cliffs and headlands. This video shows us moving North along the Florida, Georgia, and South Carolina coasts. Notice the spectacular beaches and barrier islands.

The East Coast beaches are especially vulnerable to seawater encroachment, not just because the land is sinking isostatically under the weight of all the sediment, but also because sea level is rising. Rising sea level has a much greater impact on flat lands with little vertical relief. Remember from past video tutorials that sea level changes globally due to three major processes. We call global changes to sea level, **eustatic sea level change**. Can you remember what processes cause sea level to rise?

Pause now.

The reverse of all three of these causes sea level to drop – expanding glaciers, cooling ocean temperatures, and increasing the size of ocean basins.

This graph shows how sea level has changed over the past 800,000 years of Earth's history. We get these data from studying seafloor sediment and ice cores. Sea level has fluctuated consistently during this period of Earth's history known as the Pleistocene. The Pleistocene began 2 million years ago and is marked by a rapid drop in Earth's temperature and subsequent oscillation in and out of ice ages. In this chart, the peaks represent interglacials, warm periods such as we are experiencing today, when sea level rises. The low points of the graph represent ice ages, when sea level drops. Looking even closer, to just the last 24,000 years since the last ice age ended, we see a slow steady rise of sea level until about 8,000 years ago, after which it's maintained a pretty flat level. This next image highlights just the last 8,000 years, and we can see there is still an increase, but it's quite gradual. That is until the last 130 years. This close up demonstrates that at about 1900, sea level started rising faster than it had for thousands of years prior. This rise in sea level corresponds to a rise in global ocean temperatures. Scientists have calculated that sea level is currently rising at a rate of 3.4 mm/yr. What would that mean for sea level in 2100? It would be 2 feet higher than it is today. That would mean the loss of many hundreds of miles of coastlines in areas of the world where coastal lands are flat and already near or under sea level. Ocean temperature increases of even a single degree Celsius can lead to a significant increase in sea level. This image shows what the San Francisco Bay Area looked like 15,000 years ago during the height of the last ice age, and the animation shows how the area has changed with the sea level rise that has happened since. Notice that 15,000 years ago, sea level was about 125 meters lower than it is today, and the entire continental shelf was exposed. These animations show in blue what Northern California, New York, and Florida will look like in the future after sea level has risen 30 meters.

Most of the world's population lives within a few feet of sea level, and rising sea levels across the planet will have a huge impact on human civilizations and economies.

Pause now.

For more information and more detail, continue on to the next video in this series.

[end credits]

Coastal Video Series:
Part I: Coastlines
Part II: Beaches and Sand Migration
Part III: Estuarine Mixing
Part IV: San Francisco Bay

Coastlines
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**Satellite Imagery of Coastlines in New York and East Coast – Google Earth (Data from SIO, NOAA, U. S. Navy, NGA, GEBCO; Images: NOAA, Terrametrics, Landsat, USGS)*
**Sea Level Change graphs, all scales -- NOAA*
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