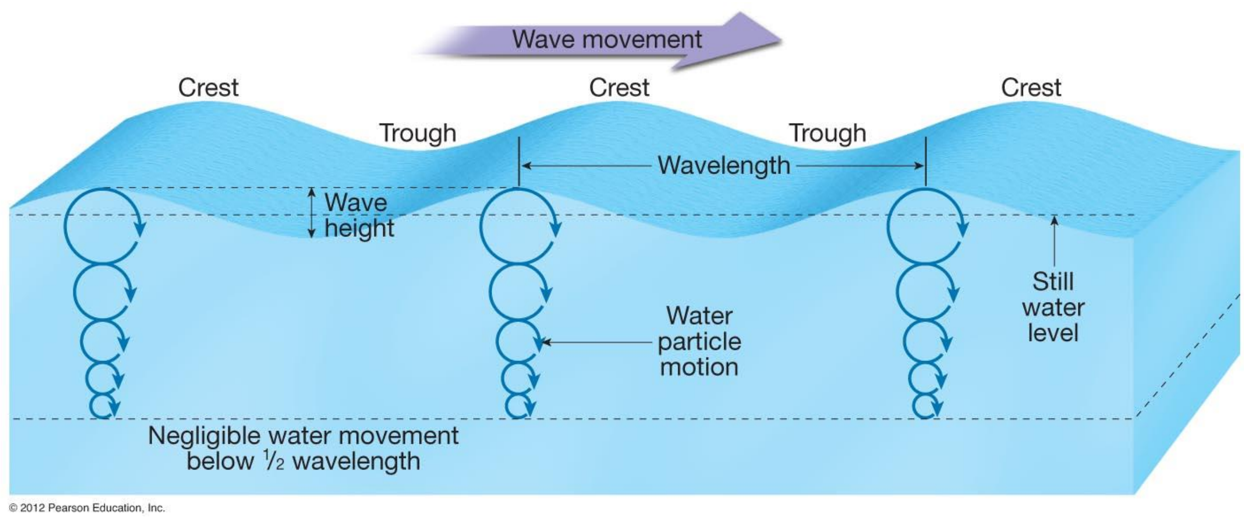
Waves and Shoreline Features

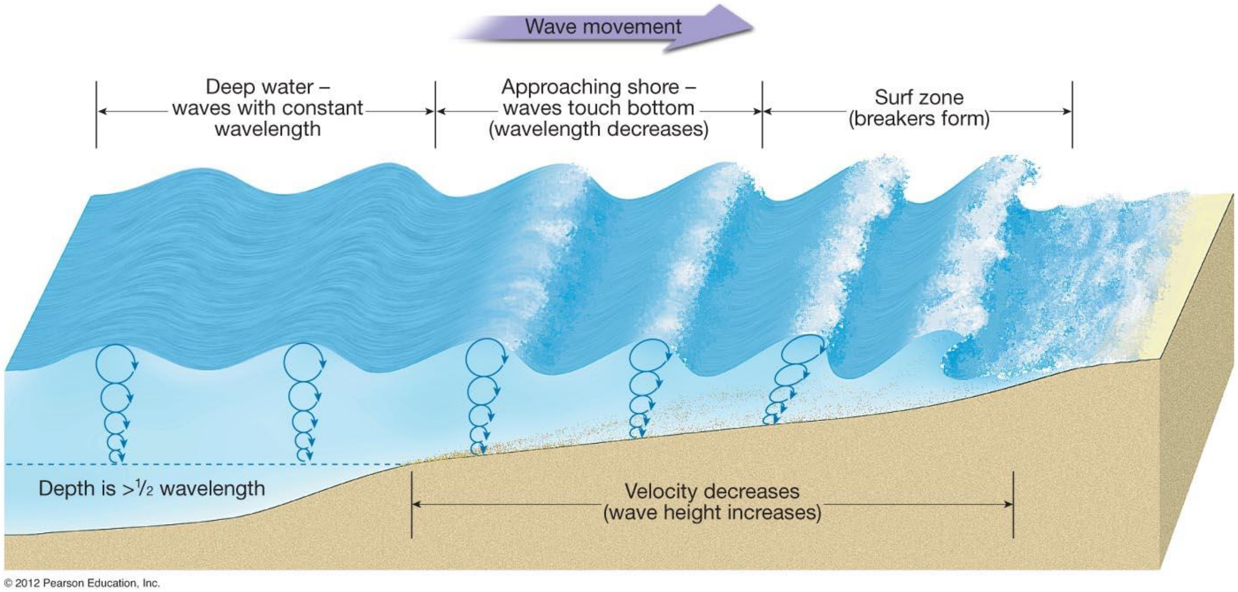
The shoreline or beach is the interface between the ocean and the continent. It is an ever-changing area whose features are largely the work of waves. These features are either the result of wave erosion or deposition from currents related to waves. It makes sense to start with an understanding of the waves themselves.

Waves are generally formed by the motion of wind on water.   The kinetic energy (energy of motion) from the wind is transferred into the water, and this energy is transmitted across the oceans as water waves. The size of the waves is dependent on the speed of the wind, the length time that the wind blows, and the area of contact between the wind and the water (this is called fetch). A large, powerful, and long-lasting storm will produce large waves.

Perhaps the most surprising aspect of waves is the efficiency with which they transmit the energy. The waves we see at the beach are likely generated by storms that may have been thousands of miles distant, and yet the energy is conveyed far across the open ocean. This is because the wave transmits only energy and not water. As a wave passes the water actually moves very little, in circular orbits that decrease in size with depth.



The waves in the open ocean are waves of oscillation – the water only moves in circles as described above. However, when the wave nears the shore, the wave base touches the bottom and begins to slow. The rest of the wave does not slow and eventually falls forward or breaks. At this point the water does move appreciably, first up the beach and back and becomes a wave of translation.



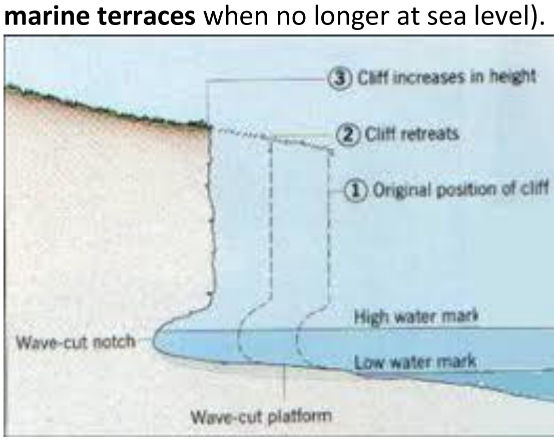
Because the wave slows where it touches the bottom if the water is not of uniform depth, waves will slow first in some areas and this causes the wave to bend. Viewed from above, the crests of the waves will actually curve or refract (when a wave form is bent it is called refraction). This will concentrate the wave force on anything sticking out from the shoreline such as a rocky **headland** (a coastal protrusion into the sea). The result in the long term is that the erosive power of the waves will eliminate the headland.

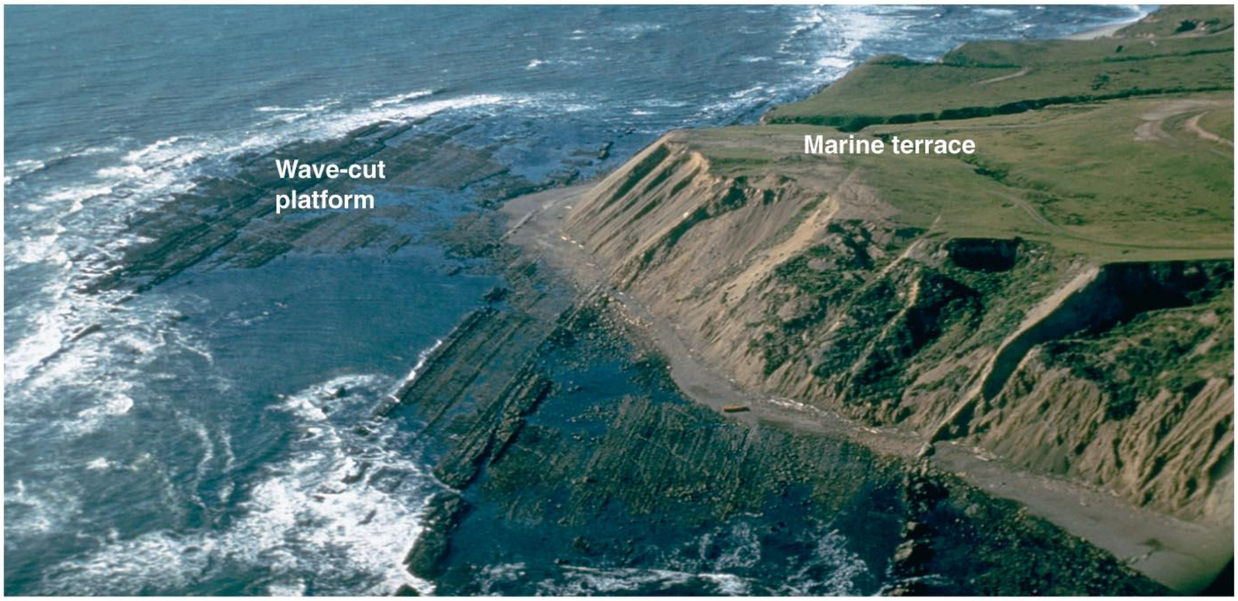
Erosional Features

As the waves impact into the shoreline they carry significant force and lots of debris. As a result waves are very erosive because the pounding water forces open cracks in the rocks breaking them apart, and because of the sand carried in the wave abrades the rocks.

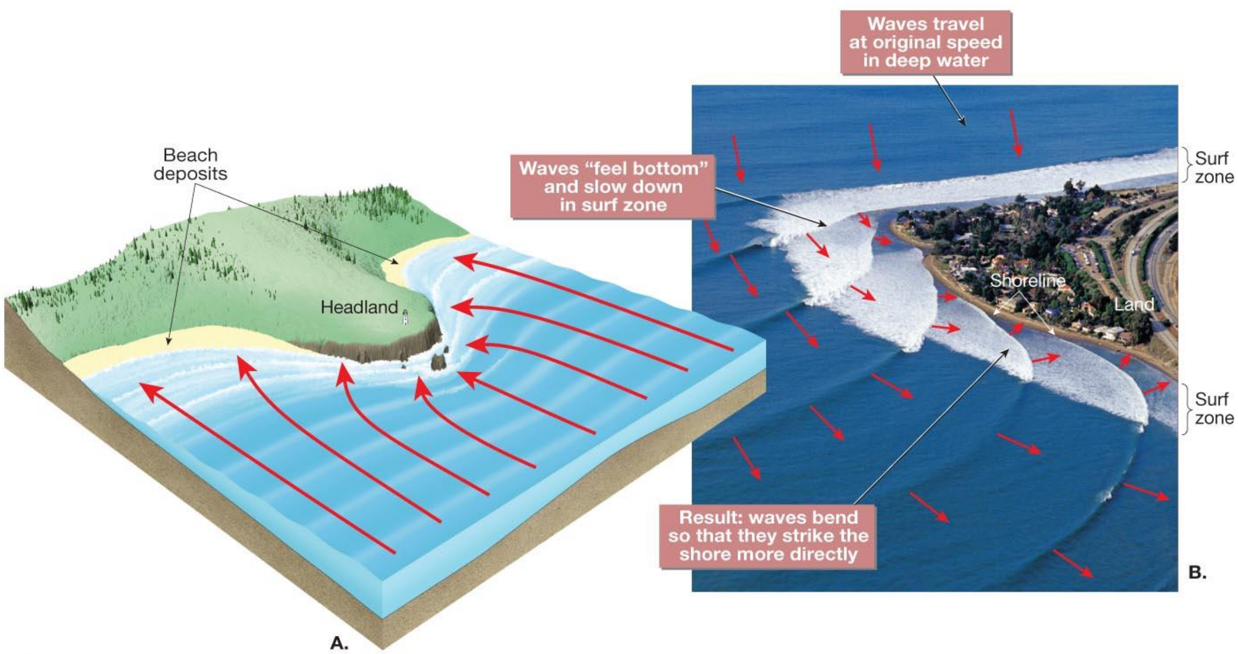
Sea Cliffs and Wave-cut Platforms

Wave force concentrated on rock will cut a notch, and undermine overlying material. Where there is a headland or rocky shoreline this can result in the formation of a **sea cliff**. As erosion progresses the cliff will recede. Note that the wave force is concentrated in making the notch; the waves erode horizontally and not vertically. This results in the formation of flat areas called **wave-cut platforms** (also called **marine terraces** when no longer at sea level).





As is mentioned above, waves will hit headlands first, and refraction results in the concentration of erosive force all around the headland.

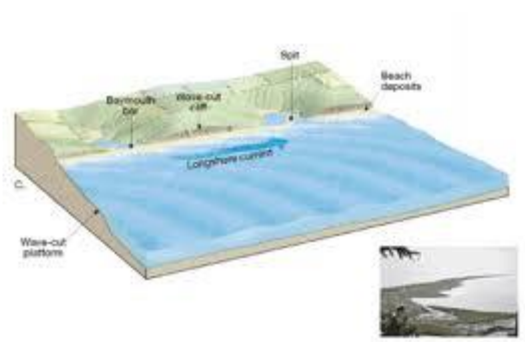


Erosional force on the sides of the headland can result is tunnels cut through by the waves. Such a feature is called a **sea arch**. Because a rock suspended over air is not stable for a long period, the arches will collapse leaving only the ends. The remnants of sea arches are called **sea stacks**.

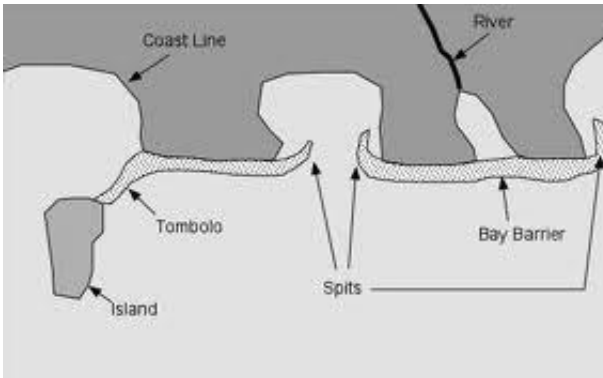
Depositional Features

Because the waves rarely hit the shoreline head-on, some of the wave motion is translated along the shoreline. This results in a current moving along the shore, and in the movement of material down the beach. For example, if the waves are coming slightly from the north, there is a net current created moving to the south. Because the waves do such a great job of stirring things up, the resultant current will contain lots of sand and other debris that will be moved along, and this is **longshore transport**. In addition, each wave will rush up the shore still moving a little toward the south, but will return straight down the slope. This results in material being moved down the beach in a zigzag fashion.

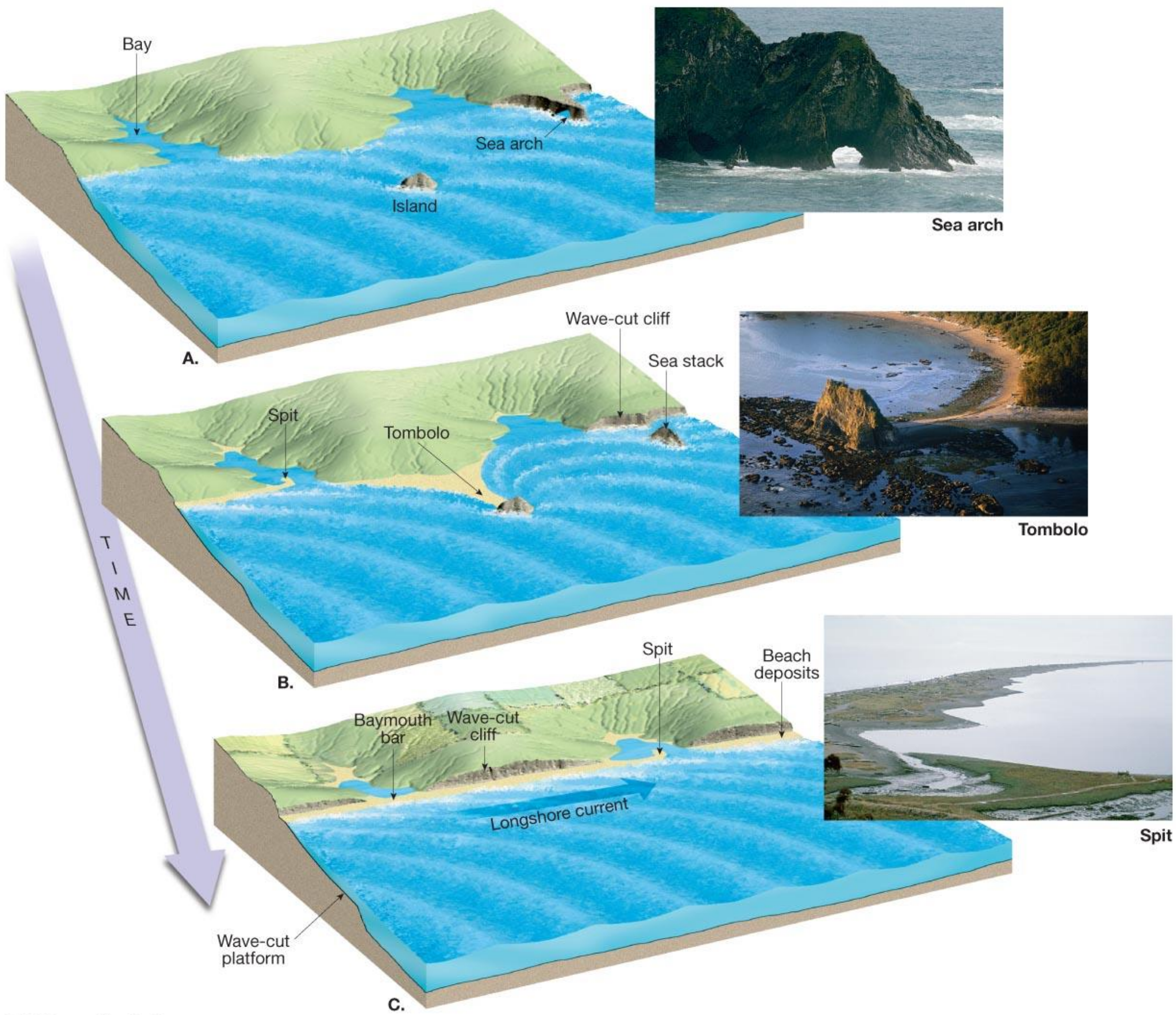
The combination of beach movement and longshore transport create depositional features along the coastline. Where the longshore current begins to cross an inlet or bay, deposition can result in the formation of a sand bar parallel to the shoreline and across the inlet. This feature is called a **spit**. As deposition continues the spit can eventually grow across the inlet forming a **baymouth bar**. The body of water landward of the bar is called a **lagoon**.



Where an offshore obstruction breaks up the current, it will deposit sand between the shore and the obstruction. This connection is called a **tombolo**.



The illustration below joins all of these features over time, showing coastal evolution.



Sea Level Changes and Coastline Features

Sea level is not constant. Changes can occur worldwide such as might be caused by an ice age. During and ice age a significant amount of water is held in ice resulting in a lower sea level worldwide. At the end of an ice age (or with global warming) the melting of ice caps will result in a global rise in sea level. Changes can also occur locally due to tectonic movements locally raising or lowering coastal areas. Some of the coastal features allow us to spot these changes and to determine if a particular coastline shows a rising or falling seal level.

Emergent Coastline

Where sea level has dropped (either locally or on a global scale) it is referred to as an **emergent coastline**. Recall the sea cliffs and marine terraces that result from wave erosion. If we were to see these features elevated above the current ocean level, we would have to conclude that sea level had fallen or the coastline had emerged.

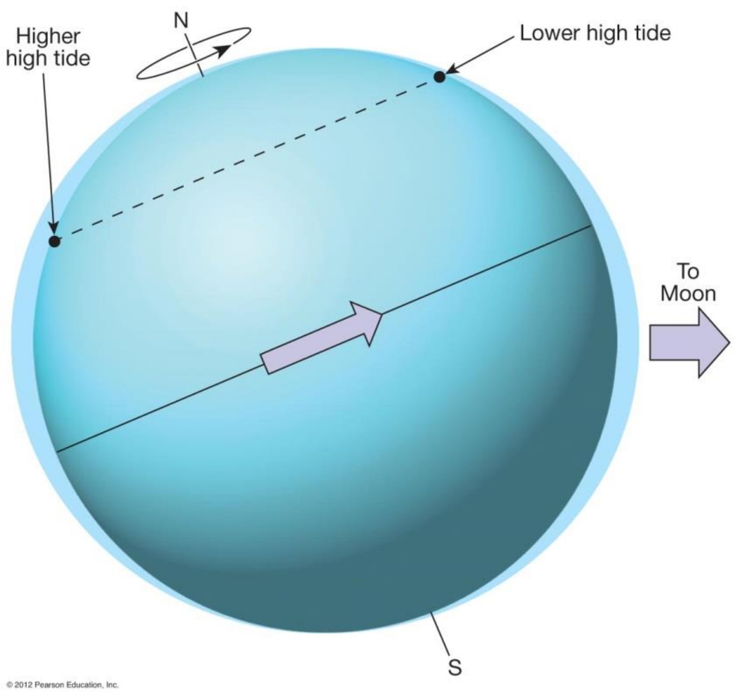
Submergent Coastline

Where sea level has risen, it will have inundated coastal features (either locally or on a global scale) and this is referred to as a **submergent coastline**. One of the easiest features to see is a drowned river valley or **estuary**.

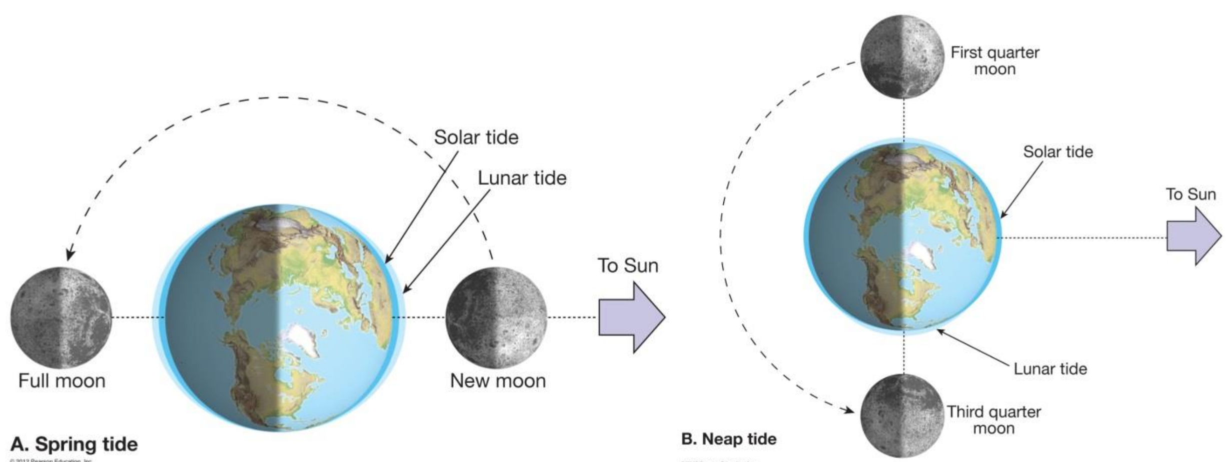
Tidal Forces and Features

Each day, coastlines experience two high, and two low tides, each resulting in some change in sea level from centimeters to meters. Just like in the formation of the solar system and the evolution of suns, gravity is the force behind these changes. The surface of earth, including land and water is under the influence of gravitational pull from the moon and the sun. This is primarily expressed in ocean tides, where essentially the water is pulled into a bulge by the other body. Although the sun has far greater mass, it is also a lot further away, so the greatest effect on gravity is from our moon.

Just for illustration, consider an Earth with no land but only an ocean, and our moon with its gravitational pull. Gravitational attraction to the moon will pull a bulge in the ocean closest to it. Because gravity decreases with distance, another identical tidal bulge will form on the opposite side of the earth. The water level not in line with the moon is correspondingly shallow. On any day the moon's location is essentially stationary and so are the bulges. Because the earth rotates on its axis each day, a spot on the equator will rotate through both highs and both lows. Because the Earth's axis is tilted, and because there really are land masses in the way, the high and low water levels vary quite a bit from location to location and seasonally.



Although most of the tidal effect is from the moon, the sun also affects the tides. When moon and sun align the tides have higher highs and lower lows (maximum tidal range), and this is called a **spring tide**. Because the moon orbits the Earth on a monthly cycle the moon and sun are in alignment and a spring tide occurs twice a month. When the moon and sun are at opposites, lower high tides, and higher low tides (minimum tidal range), will result and this is called a **neap tide**.



Generally speaking, the tides do not influence geological features except where the tidal range is very large or where the tidal currents are constrained such in a narrow **tidal inlet**. In such places the currents are strong enough to move sediment and result in the formation of **tidal deltas**.

Objectives
The student will understand the motion of waves
The student will understand erosional and depositional coastal features
The student will understand the formation and features of emergent and submergent coastlines
The student will understand the nature of tides

Terms
Sea cliffs
Wave-cut platforms, marine terrace
Headlands
Sea arch
Sea stack
Longshore transport
Beach
Spit
Baymouth bar
Lagoon
Tombolo
Elevated marine terrace
Emergent coastline
Estuary
Submergent coastline
Tidal inlet
Tidal delta

Exercises
Drakes Bay, California 7.5' Topographic Quadrangle Map

1. What type of feature is Drakes Estero?

2. How did it form?

3. Is this an emergent or submergent coastline?

4. What is your evidence?

5. What is Limantour Spit made of?

6. How did Limantour Spit Form?

Morro Bay South, California 7.5' Topographic Quadrangle Map

1. What is the feature labeled “Montana de Oro State Park”?

2. What would it become if the harbor were not dredged?

3. What direction is the longshore current flowing in this area?

4. What feature connects Morro Rock to the mainland?

5. Look very carefully at the south end of the map and you will see areas where the contour lines are widely spaced indicating broad flat platforms. What are these features?

6. Is this area an emergent or submergent coastline?

7. What is your evidence?

8. Consider your answer to Question 6 above and your answer to Question 3 in the previous section. If they are different, what does that imply about sea level changes in Drakes Bay and Morro Bay which are less that 450 km apart?

9. If the sea level changes are different, how is this possible?

Air Photo Books
Photo #32 Red Fish Pass

1. What feature do you see at 1.7, B.7?

2. What is the body of water at the top of the photo?

3. What feature is formed at 3.0, B.7?

4. What force formed this feature?

Anacapa Island
Take a look at the picture below. This is from Anacapa Island, one of the Channel Islands in California.

1. What is the prominent feature to the right of the photo?

2. How did it form?

3. What is the other feature in the picture (there are 2 on the left side)?

4. How did it (they) form?