

Seafloor Features & Landforms – Tutorial Script

Now that we have the understanding of Plate Tectonics that we developed in last week's lecture, let's go down to the bottom of the seafloor and explore its depths a little further. First, it's important to note that less than 1% of the surface of the seafloor has ever been directly sampled. What we know about the seafloor is, for the most part, determined through indirect sampling techniques such as determining from the sea surface the magnetism of seafloor rocks below, which we used to determine the rocks' age, as discussed in our last lecture. **Bathymetry** is the term we use to describe the vertical relief present on the floor that underlies a body of water. Topography is the term we use to describe vertical relief on land. Satellites cannot determine seafloor bathymetry remotely, because of the overlying seawater. However, indirectly we can approximate bathymetry of the seafloor by using satellites to measure the strength of gravity, which can then be correlated directly to seafloor high and low elevations or depths. The most accurate and direct way to learn about the ocean floor bathymetry is to use sonar or sound waves, which are sent down from a ship atop the water. These waves then reflect off the seafloor and return to the surface, providing us depth based on the time the waves took to travel. Seismic waves can be similarly used to tell us more about crustal rock layer thickness. Both of these techniques – **sonar and seismic waves** – require that a ship move over the seafloor that is being imaged – both sending out the waves and receiving the reflections back. This image here was taken using sidescan sonar technology by the U.S. Geological Survey. It was developed as part of a larger many-year-long project to map the continental shelf offshore of U.S. states and territories. To get these images, scientists had to drag a sonar sled behind their boat and then travel back and forth across the surface of the ocean, like mowing a lawn, piecing together all the strips of information into a larger map – a long and tedious process! However, the effort provides us with detailed maps, like this one that clearly shows the bathymetry under the Golden Gate Bridge, with the deepest areas in blue, and the shallowest in yellow. Most of the seafloor images that you will see in this class were developed using some kind of sonar technique.

So where to start our seafloor explorations? Let's begin at the coast where humans interact most commonly and directly with the oceans. Moving across the flat and shallow **continental shelf**, we reach the edge or **break** before falling down the slope to the base of the deep sea floor below or **abyssal plain**. The continental shelf is made from **sediment** that collects along the coast by rivers and gravity carrying it to the oceans. Sediment is just another way of saying debris – bits and pieces of rock, mineral, and organic material that collects atop low-lying areas. Since the ocean is the lowest-lying area in the world, it should be completely covered with the constant raining down and piling up of this debris or sediment. And it is! The more sediment that is carried to the coast, the bigger and wider the continental shelf becomes. Remember, the continental shelf is an extremely flat, shallow, currently flooded extension of the continent. It's basically just a big pile of debris that sloughs off the edges of our continent and accumulates.

Where plate boundaries coincide with these edges or **margins** of the continents, the shelves are narrow. **Trenches** are found just offshore, and the sediment that piles up on the shelf and periodically falls in slides, will partially or completely fill the trenches depending on the size. We call this type of margin (where the edge of the continent meets a subducting ocean plate) **active**.

Where continental margins have no active subduction, because the nearby ocean crust is fused to the continent – all part of the same plate moving together – we call them **passive**. At passive margins, the sediment that collects along the shelf can extend quite a distance offshore. Sometimes these shelves can extend up to 700 km! The deep flat seafloor that sits offshore of the shelves is called the **abyssal plain**. The **continental slope** extends from the shelf break down to the abyssal plains. The base of the shelf is covered in an apron of sediment that has fallen off the shelf above. That apron of sediment is called the **continental rise**. Why? If we journey from the deep abyssal plains (which are, on average, 5,000 m or 5 km deep) towards the margins, returning to the shore, the first thing we see is a gentle “rise” of sediment, then a much steeper slope that rises up to the flat continental shelf above. Because passive continental margins have no trenches or subduction, the sediment can collect in large amounts. Like any large pile of material that sits high above its surroundings (think snow piled atop a mountain in winter), there will be a natural instability at the edge or break, and regular slides will happen down the slope to settle debris in the continental rise apron of sediment. When large avalanches of sediment occur, which we call **turbidity currents**, they carve out deep channels or valleys called **submarine canyons**. These canyons can get quite deep and extensive, as successive turbidity currents continue to occur in the same location and carve the valleys out deeper and deeper.

So where do we find passive versus active margins? Hopefully you remember from last week’s lecture where to go to find subduction zones in the world. Let’s review. Starting with the Atlantic Ocean – where are the subduction zones? Aside from the ones in the Caribbean Sea, there are none, so what does that mean? The entire Atlantic Ocean is surrounded by passive margins. Ocean plate is fused to continental plate – typical for a relatively young ocean that is still growing and spreading. What does that mean? No major earthquakes. No volcanism. No coastal terrane accretion and mountain building. And really wide continental shelves! In fact, what else do you remember will happen on these passive margins as sediment collects each day? Isostatic subsidence or sinking under the weight. Minor earthquakes associated with this isostatic sinking might occur. And not much else.

Let’s stay in the Atlantic and move outward across the abyssal plains. What will we encounter in the middle? The seafloor should become more rugged as it approaches the mid-ocean ridge that marks the divergent plate boundary and seafloor spreading center. What will that look like? Rough topography and rising mountains that have a down-dropped square-shaped **rift valley** at the very top – sort of like rising bread that splits at the top. Instead of butter drizzling down along this split, we instead get eruptions of basalt (pillow basalts), hydrothermal vents, and shallow earthquakes. Each half of the Atlantic Ocean is a mirror image of the other, due to the nature of seafloor spreading and lack of subduction zones. Thus when travelling from New York to London, we’ll experience wide continental shelves on both margins – deep abyssal plains – and a mid-ocean ridge in the center.

Let’s look more closely at the **abyssal plains**. Why are these the flattest plains on the planet? As new seafloor forms at the ridges and is pushed away on either side, the crust on both sides gets slowly colder and older. As the lithosphere leaves the upward push of the ridge, and attaches more mantle to its base, it becomes denser and sinks down lower into the asthenosphere. Sediment collects atop – the smallest amount at the ridge where new seafloor is exposed. But as this sediment collects at rates of about 1 cm every 1,000 years, eventually, over millions of years, the sediment will completely cover any rough topography and leave a flat surface that hides

underlying irregularities. Imagine sifting flour over a countertop covered in pots and pans. If you keep at it long enough, the flour will cover everything, and the surface will be smooth.

As this Google Oceans flyby confirms for us, the Atlantic Ocean is surrounded by continental shelves, slopes, and rises, riddled with numerous submarine canyons. The ocean also has extensive flat, deep abyssal plains with an ocean ridge along the center with a well-developed rift valley.

Now let's review the Indian Ocean – what kind of margins dominate this ocean? As you can see, there is only one subduction zone, over here by Indonesia. Let's look more closely at this trench with a Google Ocean flyby. Not only will this subduction cause large earthquakes like the one that caused the Dec. 26, 2004 tsunami, but the islands above are all volcanic and thus volcanic eruptions are a continual hazard for Indonesia. The rest of the Indian Ocean margins are all passive and carved on their edges by submarine canyons. And again, hopefully you remember the triple junction discussed in last week's lecture, where three mid-ocean ridges come together. Let's look more closely at that and the rift valleys that sit atop, caused by divergence.

Now let's head to the Pacific Ocean, where you'll remember the Ring of Fire means subduction zones, large deep earthquakes, and volcanic arcs all around its margins. Let's do a Google Ocean flyby up the Peru-Chile trench, and then out to the spreading centers of the East Pacific Rise, before continuing north up through the Gulf of California or Sea of Cortez spreading centers where we hit the large transform known as the San Andreas Fault system. Continuing northward, we are now on what kind of margin? No subduction. Therefore, by our definition, passive! Sediment collects. No deep earthquakes. No volcanoes. Wide continental shelf. And deep submarine canyons, like this one here in Monterey Bay – one of the largest and most well-studied submarine canyons in the world.

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**Boat with sonar – USGS*

**Seismic profiles – The Open University*

**Sidescan sonar from boat – USGS*

Sidescan sonar of Golden Gate Bridge entry – USGS

**Continental Shelf of San Francisco – © Google Earth – data from: SIO, NOAA, US Navy, NGA, GEBCO, MBARI, LEDO-Columbia, NSF; Image Landsat*

**USF and USGS scientists launch a new sidescan sonar towfish off R/VBellows in the Gulf of Mexico. – USGS*

**Sidescan sonar mapping from RRSS James Clark Ross – British Antarctic Survey*

**Turbidity Current – NOAA*

**Google Earth Flybys of world oceans: © Google Earth – data from: SIO, NOAA, US Navy, NGA, GEBCO, IBCAO; Image Landsat, USGS, PGC/NASA*

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