Distribution of Epicenters and Foci

The Nature of Plate Margins, Ocean Basins, and Continental Margins
GEOGRAPHY OF THE OCEANS

Ridges, trenches, transform faults and their relation to earthquakes
Most epicenters are located at or near a margin of an active lithospheric plate – one of the thin slabs that moves slowly across the Earth’s surface. This plate motion necessarily moves any continent(s) that are part of the plate. It also creates and destroys oceans. This will be covered in detail in the second geology course.

This slideshow is intended to give you a basic idea about how the plate boundaries behave and produce earthquakes, and how that influences the structure of the ocean basins and adjacent continental edges.

We’ll begin with the ridges and transform faults (divergent and transform plate margins).
In the Atlantic is the **Mid-Atlantic Ridge** (MAR). In the far north it is called the **Reykjanes Ridge** (RR) but we’ll just refer to the entire thing as the Mid-Atlantic. To the south the MAR connects with the ridges in the Indian Ocean. To the north the RR connects to a ridge in the Arctic Ocean which is off this map.

In the Pacific lies the **East Pacific Rise** (EPR). It continues to the west as the **Antarctic Ridge** (AR) and into the Indian Ridge System. The Ridge “runs aground” at the Gulf of California, but connects in a roundabout way to the Arctic Ridge.

The ridges of the Indian Ocean are continuous with each other, but are given different names in different places. The **Southeast Indian Ridge** (SEIR) is a continuation of the Antarctic Ridge. The **Southwest Indian Ridge** (SWIR) is a continuation of the Mid-Atlantic. These two merge to form the **Mid-Indian Ridge** (MIR) which continues into the Red Sea between Africa and Asia.
Note two things: 1) The Ridges are crisscrossed by numerous offsets – transform faults, and 2) All the epicenters on the ridges and transforms are shallow-focus earthquakes (red).

The transforms exist because the spreading plates aren’t flat. They’re curved across the surface. As they move, different parts have to move at different rates and the transform faults allow this to happen. All transforms are associated with ridges. The famous San Andreas Fault in California is a very long transform connecting the EPR with a small ridge off the Coast of the Pacific northwest, Canada, and Alaska.

The ridges are **Divergent Plate Margins** and the transforms are **Transform Plate Margins**.
Earthquakes are distributed differently near the trenches (red arrows) and underneath large mountain chains (black arrows) like the Himalaya (Asia) or Caucasus (Turkey).

In these places the foci can be much deeper. We recognize three classes: shallow (<70km), intermediate (70-300km) and deep (>300km). Notice that at each place these classes lie beside each other on the map – the depth increases in one particular direction. At the trenches that depth is away from the trench. All foci are shallow in and just beside the trench and get deeper toward the volcanic arc beside the trench. In the continental mountains the foci deepen away from the nearest ocean.

The next slide explains this in more detail.
All the earthquake foci around a trench occur in a narrow zone, roughly the thickness of the lithosphere, sloping beneath the volcanic arc from the trench. Some foci occur in the lower part of the continental crust outside that narrow zone, but below that the brittle material that can fault is surrounded by asthenosphere, which cannot.

This suggests that a “slab” of lithosphere descends beneath the arc from the trench. This is called subduction.
In the Himalaya we see something similar – the foci deepen northward from a certain zone even though there is no trench.

The Himalaya, like other mountain chains, was built primarily in two ways. Buckling and bending of the deeper rocks as they were squeezed south-to-north raised the area. Shallower rocks broke and faulted, with the southern piece usually shoved over the northern piece on every fault. This process continues to this day, accounting for the shallow-focus earthquakes.

If you back up all that faulting (and folding) in your mind – unsqueeze the mountains, if you will – then you move India a little farther southward at each step. You reach a point where India is so far south of its present position that it isn’t even touching. And then you can back it up even more, until it is far off the coast of Asia and separated by an ocean – an ocean with a trench beside Asia. Trenches have Benioff zones. The focal depths in the Himalaya are simply residual from the subducting plate that used to be between India and the mainland.

That very same subduction zone was originally continuous with the one still operating beneath Indonesia to the southeast!

(You might be able to visualize where India was just before it made contact with mainland Asia.)
PLATE MARGIN TYPES
The ridges stand higher than the surrounding seafloor because the mantle beneath them is particularly hot, buoying them upward isostatically. In addition, a force is forcing the opposite sides of the ridge into different directions. The multiple stresses that arise from these interactions create faults of a particular type ("normal faults") in the thin region immediately above the hottest mantle.

These faults allow a narrow central region of the ridge, called the rift to subside, creating a canyon running the length of the ridge. You can see this on the wall map in the lab.

It is the slippage on the normal faults within the rift that generates earthquakes. The lithosphere is very thin, so all the movements are shallow (red on the cross-section and original map) and no intermediate or deep foci are possible.

(The spreading in the deeper lithosphere is accommodated by igneous activity as we’ll see.)
At transform margins the plates and faults move only horizontally. On the San Andreas Fault, for example, the west side slips northward with respect to the east side. The example above is the Clipperton Fracture Zone across the EPR.

This kind of fault is called a “strike-slip fault”, and this one is a “right-lateral” fault. No matter which piece you stood on the other would appear to have moved to your right, and so no matter which side of the cross-section you view from the right side appears to move toward you.

Transform margins are all associated with ridges and so, in general, the lithosphere is thin beneath them. Thus all foci are shallow here too (red dot on the cross section and original map).
When two plates move toward each other the Margin between is a **convergent margin**. Each plate can have oceanic or continental crust on it.

If both plates are oceanic then one is forced beneath the other, creating a **trench**. The plate diving under is said to be subducting. The overriding plate develops a volcanic island arc as the subducting plate melts beneath it.
If one plate is continental then the oceanic one is always forced beneath it, again creating a trench. The continental plate develops a volcanic arc as the subducting plate melts beneath it.

Foci of all depths are possible.
If both plates are continental then neither can be subducted. The edges press against each other, raising the mountains higher with every fault movement (and earthquake). The mountains are typically not volcanic.

We say the continents have “collided” though nothing that violent actually occurs.

This is the result of a historical process beginning when the continents were not in contact, but approaching each other, usually at an ocean/continent margin. Eventually the continent on the subducting plate arrives at the trench, cannot be subducted (its too thick and its density is too low) and so it just grinds into the other side.

Often there may be movement on the original oceanic slab for a long time after the trench is gone, creating intermediate and maybe deep-focus earthquakes on one side of the chain.
BATHYMETRY OF THE OCEANS
and FORMS OF CONTINENTAL MARGINS

The relationship of physical geography to plate tectonics and earthquakes.
In the Atlantic Ocean (also the southern Indian Ocean, Arctic and Ocean and Antarctic Seas) the ocean basins (and adjacent continental margins) have the forms shown below. In these oceans the ridge is halfway between the adjacent continents and the continents do not have volcanically or seismically active margins.

Such continental margins are called **Atlantic-type** continental margins. They are also known as Stable or Passive or Trailing margins because of the lack of tectonic activity and the fact that they are on the trailing edges of continents moving away from the ridge. Be able to label the parts.

The ocean basin is very symmetric across the Atlantic Ocean, and the continental edges on both sides are called "Atlantic-type continental margins".
In the Pacific Ocean (also the northern Indian Ocean) the story is different. The Ocean has the structure shown and the adjacent continental margins can have one of the two forms shown below. In these oceans the ridge is generally not halfway between the adjacent continents and the continents do have volcanically and seismically active margins. As in Atlantic type oceans there is a ridge rift flanked by abyssal plains. Instead of a rise/slope/shelf the continental margins have a trench adjacent to the abyssal plain and a volcanic arc beside it (and toward the continent).

In some cases the arc is immediately on the edge of the continent (as in the Andes Mountains) and these are **Andean Margins**. In other cases there is a body of marine water between the arc and the mainland (as in Japan) and these are called **Japanese Margins**.

Such continental margins are called *active* continental margins. Be able to label the parts and identify as a Japanese or Andean margin.
Though it might be beating a dead horse this slide reminds you of the expected earthquake distribution in these two types of ocean basins.

The dots mean what they have in previous slides: red = shallow-focus; orange = intermediate-focus; and green = deep-focus earthquakes.

Remember that transforms are really just part of the ridge system and have similar earthquakes.