**Narration text for “*What drives plate tectonics?”***

<https://www.iris.edu/hq/inclass/animation/557>

We once thought that mantle convection below the tectonic plates could drive plate motions.  Early textbooks showed mantle convection cells, like in a beaker of hot liquid on a Bunson burner, pushing plates along from below. Current dynamic models have plates moving as part of a gravity-driven convection *system* that pushes young hot plates away from spreading ridges and pulls old cold plates down into subduction zones.

Remember that lithospheric plates, also called tectonic plates, have a layer of crust on top of lithospheric mantle, the outermost rigid part of the mantle. These move as a single unit.~~.~~ The hotter asthenosphere beneath the plates is solid but less-rigid mantle rock that can slowly flow.

Now let’s look at the broader picture.

This map shows how the seafloor increases in age with distance away from spreading ridges, such as the East Pacific Rise or the Mid-Atlantic Ridge, where new ocean plate is forming Spreading ridges stand 2500 meters higher than deep ocean basins. At a spreading ridge, the ocean depth is only about 3000 meters . Ocean depth increases with age of the underlying plate, so that where the plate is more than 80 million years old, the overlying ocean increases to 5500 meters deep.

Let’s examine the formation of new ocean plate and how that plate cools with age.

As hot mantle rock rises to lower pressure, a small portion of this upwelling asthenosphere melts to form magma that builds the 7-km-thick oceanic crust at the edges of two diverging plates along the ridge axis. Beneath the crust at the spreading ridge, there is only a thin layer of lithospheric mantle because it is unusually hot in the upwelling zone. This hot, and therefore lower-density, mantle rock, supports the 2500-meter elevation of the spreading ridge As the plate slowly moves away from the ridge, it cools by conducting heat through the crust to the cold ocean water above. At the same time, the underlying asthenosphere cools and adds to the bottom of the lithospheric plate. Thus, although the *crust* maintains its thickness during migration away from the ridge, the *lithospheric plate* thickens and cools to create ocean basins that exceed five kilometers in depth.

A simple way to think about elevation is that the plate is “young, hot, and high” at the spreading ridge and becomes “old, cold, and low” during the aging and cooling process. Mathematical modeling of this cooling process illustrates the ocean plate becoming cooler and thicker with age. The temperature at the bottom of the plate is about 1300° centigrade. Notice that most of the cooling process occurs between age zero at the ridge and about 80 million years when the ocean plate has grown to about 100 km thick. The upper plate is less than 600°, thus is the only part of the plate cold and brittle enough to fracture and produce earthquakes. Though still rigid, the lower plate is warmer and can deform in a ductile or plastic fashion.

So what force pushes ocean plates away from spreading ridges? Any mass on a slope is affected by gravity, seen most dramatically with avalanches and landslides. Spreading ridges are broad undersea mountain ranges and, although the flanks of a spreading ridge are a relatively gentle slope, the mass on that slope is humongous. The force of ridge push is zero at the ridge but increases quickly with distance and age, pushing the cooling and thickening ocean plate away from the ridge.

Now, what about “slab pull”?. We’ll consider a 30-million-year-old ocean plate subducting at 5 centimeters per year into hotter asthenospheric mantle beneath a continental plate. As the ocean plate, subducts, the warming process takes many millions of years as the slab descends. The deeper part it is continuously replaced, in a conveyor-belt fashion, by cooler plate from above. Mathematical modeling again illustrates the temperatures within the subducting ocean plate.

In this example, lithospheric mantle rock in the subducting plate at 150 km depth is ***1000***° cooler than the asthenospheric mantle at the same depth. The cooler temperatures mean that the density of rocks in the subducting slab is greater than the density of the hotter asthenosphere. While gravity pulls down on all rocks, it pulls down harder on more-dense rocks. This enhanced gravitational force on the cooler and denser rocks in the subducting plate is the slab pull gravity force.

Earthquakes, including great megathrust earthquakes, occur on the shallow part of the boundary between the converging plates and within the shallow parts of both plates near that boundary. In addition, there is a zone of rock cooler than 600°C within the subducting plate that remains brittle and within which earthquakes can occur to depths of hundreds of kilometers.

Observations of intraplate earthquakes and other indications of stress with tectonic plates suggest that the slab pull force is usually larger than the ridge push force. It is noteworthy that fast-moving plates, like the Pacific Plate, generally have a fast spreading ridge pushing on one side while a subduction zone pulls on the other side.

In this big picture view, we see that lithospheric plates are part of a planetary scale thermal convection *system*. The energy source for plate tectonics is Earth’s internal heat while the forces moving the plates are the “ridge push” and “slab pull” gravity forces.

So far, we have illustrated these forces on a flat image. This may make it appear that mantle convection is turning like gears in a flat plane. As a result, it may look like these movements occur only along narrow regions. However, if we cut away part of our diagram, we can see that the motion of this convection system, occurs in three dimensions, and may extend over hundreds or even thousands of kilometers. Additionally, it is important to note that Earth’s convection system is more than just the simplified handful of convection cells we have shown. In reality, scientists find evidence of many upwelling and downwelling arms of mantle material all over Earth. Some of these are large but many, too numerous to show here, are smaller and indicate the complex nature of Earth’s convection system.

On screen:

Earth's plate tectonic-system is complex, with

mantle and plates interacting in many different ways.

Scientists continue to make new discoveries

and our understanding continues to grow.