Plate Tectonics Basics – Tutorial Script

To understand plate tectonics, we need to look closely at the convecting asthenosphere. The convecting asthenosphere will cause heat to pile up under certain portions of the lithosphere and cold material to sink under other parts. What does that do to the lithosphere? It causes it to break into pieces we call plates. Where heat rises, material must be pushed away in opposite directions to make room for the continual rising of new hot material (much like boiling water). That drags on the lithosphere above and causes it to stretch and thin and break apart. On the surface we call the zone where two plates are moving apart a **divergent plate boundary**. The build-up of heat and material below pushes the plate upward at this point and creates a linear mountain ridge (when these form along the ocean floor, we call them ocean ridges and rises). As the plates separate, a rift valley forms atop the ridge. The drop in pressure on the underlying mantle rock causes it to melt, and now that it's lower density, the melted rock, or magma, rises to the surface and erupts along the center of the rift valley. When new convection cells form under a continent, divergence tears the continent apart. The most recent supercontinent that tore apart to create the current geometry of Earth's plates was called Pangaea, and based on fossil evidence, it existed 250 million years ago when all the continents we know today were fused together – one continent and one surrounding ocean. After this supercontinent began to break apart, and the plates thinned enough, dense basaltic magmas erupted, and the new plate that formed was oceanic, producing oceanic plate, fused to broken halves of continental plate now moving away from each other. Through this process, new oceans form and spread. We call this **seafloor spreading**. The new ocean crust that forms at these ocean ridges consists of four main layers – the magma that erupts on the seafloor cools quickly under high-pressure, cold water, and forms structures that look similar to hardened toothpaste squirted out of a tube. They are called **pillow basalts**. The cracks in the crust that fed the magmas to the surface cool to form vertical walls of basalt called **sheeted basalt dikes**. The chambers that hold the magmsa under these ridges will also spread; as their outer edges cool, they crystallize slowly to form a larger-crystal rock with the same composition as basalt, but now called **gabbro**. As this crust spreads apart to allow new crust to form between it, the ocean will deposit fine grains of dust, ash, shells, and other debris – otherwise known as **sediment**. These are the four layers of ocean crust. Under the ocean crust is the mantle rock that melted to produce the magmas in the first place. It is sometimes referred to as depleted mantle, because it has had magmas produced from it. And it is attached to and underplates the crust above it, making up the base of the ocean lithosphere. So ocean lithosphere, everywhere in the world, is basically made of this same sequence of rock – sediment of varying thicknesses above pillow basalt above basalt dikes above gabbro above mantle rock. And what happens to this ocean lithosphere as it spreads? Not much. It grows gradually colder and older and denser and collects a thicker sequence of sediment atop and a thicker section of mantle plating underneath it (thus thicker lithosphere), until eventually it's so dense that it becomes denser than the rock underneath it. It detaches and sinks back into the mantle, possibly sinking or **subducting** as deep as the core-mantle boundary before finally melting and becoming reabsorbed back into the mantle. Dense, cold lithosphere sinks down, pulling the distant seafloor spreading center further apart, driving, together, a recycling engine for mantle material.

Pause now.

Where the old ocean lithosphere sinks, we get a deep trench on the seafloor above. When next to a continent, this trench can fill with lots of sediment. When next to ocean islands, it tends to be deeper, like the Marianas Trench.

Let's look more closely at these **subduction zones**. Remember that at divergent plate boundaries, the plates move apart. The old continental portions of these plates that were torn apart are also now spreading further and further apart. What happens at the outside of this spreading where continents are shoved towards other plates? They will collide at boundaries referred to as **convergent plate boundaries**. If continents collide with ocean plates, the ocean plate, being denser, will be forced under the continents. If the ocean crust is cold and dense, it will sink to the core mantle boundary to be recycled as already discussed. If the ocean crust is young and it not yet dense enough to sink, it will push under the continental plate and cause the continental crust above to be deformed. Convergent plate boundaries can also exist between two ocean plates, if one plate is much older than the other and convergence brings the two together. The older one subducts under the younger one. Convergent plate boundaries can also exist between two continents, when the ocean that existed between them entirely subducts, and the two collide and accrete together to form a larger continent. Just as divergence is the method for breaking up continents, convergence is the method for conjoining them. In fact, even as ocean floor still exists and subducts alongside a continent, accretion and continental growth is happening. Islands, continental fragments, sediment, and the crust that carries them can get scraped off and accreted to the edge of the continent. We call these accreted fragments **terranes**, and they are the basic building blocks of all continents. The other source of new continental material are the volcanic eruptions that happen alongside the subduction. Why? When ocean crust subducts, it carries with it a large amount of water that had soaked into the sediment over millions of years. That water is squeezed out by the high pressures at depth in a subduction zone. Because water is less dense than anything else, it rises upwards into the overlying asthenosphere. Water reduces the melting point of the asthenosphere causing it to melt. That molten magma is now less dense and so it, too rises, with the water, to the surface, where it erupts in a chain of active volcanoes known as a volcanic arc or island arc. Subduction zone volcanoes always happen above the subduction zone on the plate that does NOT subduct and produces some of the most hazardous volcanoes in the world. Why? Among other things, all that water can produce high amounts of pressure underground.

Does continental crust ever subduct? No. Why not? It's the least dense material on the planet.

How old does ocean lithosphere need to be before it detaches and subducts all on its own? All we can find to answer that question is the age of the oldest ocean rock currently residing in the oceans, and that's 200-million-year-old rock subducting under the Marianas Trench in the Pacific. Why is the Marianas Trench the deepest part of the planet? Because it's a convergent plate boundary where two ocean plates are colliding. That means that both plates are already riding low isostatically. Now combine that with one subducting under the other, and no nearby continents to fill the trench with sediment, and there you have an answer!

Do ocean-ocean subduction zones produce the same types of features as continental-ocean subduction zones? Trenches? Volcanoes? Accreted terrane material that forms coastal mountain ranges? Yes. The only difference is that the volcanoes erupt through thinner oceanic lithosphere, and that makes them slightly less dangerous than the magmas that rise through thicker continental lithosphere. Why? The thicker the lithosphere, them more likely the gas content will increase in the magmas, and this gas leads to higher pressures and more explosive volcanoes.

Let's look again at what happens when two continental plates collide. Subduction brings the two together, but then after they collide, the subducting plate completely detaches and sinks into the mantle. Volcanism stops. The trench disappears. And the largest mountains found on the planet form as terrane accretion mashes the two continents up into a folded faulted mountain system that rises high above the surface and has a deep isostatic root beneath.

Pause now.

That leaves one remaining plate boundary to discuss – transform – where plates slide past each other. There's no way to have plate motion moving apart and together without having some edges slide past each other. It's really easy to see how transform plates form when we look again at divergent plate boundaries and remember that the tearing apart of the lithosphere has to accommodate a spherical surface. Like seams on a baseball, it's hard to sew together or pull apart two pieces of fabric on a spherical surface without buckling or tearing. To accommodate divergent motion along ridges that run along a spherical surface, the ridges break into sections, and each section is offset from the next one by a **transform boundary**. As this image shows, there are two plates, but in these zones the boundaries are divergent. In these zones the boundaries are transform. Let's test our understanding with a few questions. Where is the youngest rock in this image? Let's put a Y there. Where is the oldest rock? Let's put an O there. How do points A and B compare?

Pause now.

Rocks at points A and B formed at different locations but are now found alongside each other, so they will look very different. They will have different thicknesses of sediment. The younger one will be higher in elevation. There will be a cliff between them. And that cliff marks a line that runs outward from the active transform faults and creates a spectacular scar. We call this old scar **a fracture zone**. Occasionally there are small amounts of residual transform motion along these zones, but mostly they are now part of the ragged edges of a single plate.

Pause now.

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

[end credits]

Plate Tectonics Video Series:

Part I: Earth's Layers and Isostasy
Part II: Plate Tectonics Basics
Part III: Plate Tectonics Global Impacts
Part IV: Plate Tectonics and Calif. Geology
Part V: Hotspots
Part VI: Paleomagnetism
Part VII: Hydrothermal Vents

Plate Tectonics Basics
Produced by Katryn Wiese
City College of San Francisco

All media produced by Katryn Wiese unless indicated below:
**Intro and exit music: used with permission © Alexis Harte*
**Review music: used with permission © Proceed With Caution*
**Pangaea – GNU Free license*
**Pangaea Fossil Evidence -- USGS*
**Pillow Basalt photo – USGS*Line drawings of Accreting Terranes and Earth's Convection: used with permission © The Cambridge Guide to the Solar System, 2nd Edition 2011, Kenneth R. Lang*
**Subduction Zone 3D cross section drawing: USGS*
**Bobbing Cork – source unknown.*
**Age isochrons – world's oceans – NOAA*
**Animated squares puzzle – source unknown*
**Sphere with spreading and transforms – source unknown*