Plate Tectonics and Global Impacts – Tutorial Script

Where can we find plate boundaries on the planet? Well the best way to see plate boundaries is to look for the major earthquakes. Earthquakes form when building stresses within the Earth's solid crust are released in single instants of motion. These stresses build where plates are being stretched apart, pushed together, or slid beside each other. Think of the friction that must exist in these zones. The plates will stick together until the stresses build high enough to overcome the friction. The stress is released all at once as the plates jump. We call this catastrophic stress release and ground motion an **earthquake**! This image of a decade's worth of major earthquakes on the planet shows that most of these earthquakes happen at plate boundaries and, in fact, mark the edges of these plates. You'll also notice earthquakes happening in areas where old plate boundaries have fused together, such as in fracture zones or old suture zones in the center of continents conjoined in the past. Minor earthquakes happen as magmas move through the crust above hotspots, and where isostatic adjustment is happening especially along coastlines.

Let's look more closely at these earthquakes and color code them by depth. The shallowest earthquakes dominate at divergent plate boundaries and transform plate boundaries. At some plate boundaries, such as this one off of South America, we get three different depth earthquakes in parallel stripes. Why? As the ocean plate subducts under South America, it descends to deeper and deeper depths. The shallowest frictional sticking and consequent release will happen at the top of the subduction zone. Further down in the subduction zone, you'd expect deeper sticking and deeper quakes. So these color-coded earthquake maps act like an x-ray, giving us an image of the depth of the subducting plate at various distances from the subduction zone itself. We can SEE the plate subducting under South America.

Pause now.

Now that we know where the plate boundaries are, how can we determine what types of boundaries they are? We can measure their movement, and we can study the surrounding topography, bathymetry, and geology. For example, what do we see in South America that shows us subduction is going on? The dark-blue arc-shaped deep trench on the seafloor forms as the plate subducts. What else? The volcanic arc – the chain of active volcanoes known as the Andes Mountains. And the coastal mountains here? The uplift? That's associated with the terrane accretion. In fact, this satellite image shows that there is a chain of underwater seamounts colliding with the South American coast, and over millions of years, they pile up, are scraped off, and become part of the coastal mountain system. South America is growing through volcanism and terrane accretion along its western margin. What about its eastern margin? That side is part of the same plate as the nearby ocean – the entire unit is being pushed away from the seafloor spreading center that marks the center of the Atlantic Ocean. In fact, that's why the subduction zone on the western margin even exists – the seafloor spreading in the Atlantic is causing the collision along on the western margin.

Now let's look at a few more world examples and review the evidence of spreading in the Atlantic Ocean.

First, let's review the entire Atlantic Ocean. The dark blue-black arc-shaped features are trenches. Do you see any in the Atlantic? No. There's one in the Caribbean Sea, but otherwise the edges of the Atlantic Ocean are free of trenches. What does that mean? We are looking here at two plates – both spreading away from the center of the Atlantic Ocean. These two plates each have ocean crust fused to continental crust. At the center of the plate boundary, we see an ocean ridge with a central rift valley. We also see the ridge is broken into segments, each offset from the one next to it by a transform boundary. Scars, which we referred to earlier as fracture zones extend outward from these transform boundaries. What would happen if we moved the plates backward and undid the spreading? The coasts of North and South America would come back together and merge with those of Europe and Africa. The perfect puzzle-piece fit and the snail-trail marks of the fracture zones confirm the story of seafloor spreading. Other evidence that connects these two halves together include rocks and mountain ranges that exist on one side of the Atlantic and then continue and are found identically on the other side. The Atlantic Ocean has been spreading for the past 200 million years and is spreading today at a rate of about 1-2 cm per year a little slower than your fingernails grow. In fact, as this image shows, it is the slowest spreading center in the world. If we look only at the apricot color age range – we see that during that time period, the Atlantic spread only this far, but the southeastern Pacific spread much further. In fact, the East Pacific Spreading Center spreads at a rate of about 18 cm/year. Why the difference? Let's look more closely at what happens to new seafloor forming in the Southeast Pacific Rift – on the west it moves toward the Marianas Trench and other trenches that line the western edge of the Pacific Ocean – a long distance away – almost 1/3 the circumference of the planet. On the east, it enters a nearby subduction zone under South America. In fact, the entire Pacific Ocean, except for a short stretch along the California Coast consists of trenches, subduction, and related volcanoes, hence the name the **ring of fire**. Does it seem likely that seafloor spreading accompanied by subduction would move faster than seafloor spreading that has to push away continents and has no subduction to help it? Also, notice that spreading is faster on the east of the ridge. Why? We can see that the subduction zone is much closer on this side. Does that make a difference? These are all good questions to consider as we study global plate tectonics.

Pause now.

Let's go to the Indian Ocean – what do we see here? Three ocean ridge spreading centers meeting at one point in the center of the ocean. Are there any trenches? Not along the east coast of Africa. Not along the southern coast of India or the west coast of Australia. There is one, however, along the islands of Indonesia. This was the subduction zone that caused the large tsunami in 2004 that killed ¼ of a million people in the Indian Ocean.

Let's go back to India. This satellite image shows quite clearly the borders of India are marked by large mountains -- the Himalayas – and a high plateau that extends into Tibet and Nepal. About 45 million years ago, India collided with Asia in a continent-continent convergent plate boundary. That collision is still going on today as the Himalayas continue to grow and India continues to accordion Asia as it pushes northward.

Now let's look at satellite images of Eastern Africa. Notice the rift valley atop a chain of active volcanoes that includes Mount Kilimanjaro? If we follow this chain north, it joins with a seafloor spreading ridge that runs across the center of the Red Sea and another that runs along the center of the Gulf of Aden. A triple junction where three seafloor spreading centers come together – just like we saw in the center of the Indian Ocean. This cartoon shows what a divergent plate boundary first looks like as it breaks through continental crust. Notice the square shape to the valley and the jagged down-dropped edges of the continent? Now compare that to this photograph. Notice the square shape to the valley and the down-dropped edges of the continent? Eastern Africa is part of a new rift zone and one of the only places to see this type of plate boundary at this stage on land.

Pause now.

Let's move back to California. What's happening here? There's a divergent seafloor spreading center off of Washington, Oregon, and Northern California, and one that runs up the Sea of Cortez (or Gulf of California). What happens to it between there? Notice that it's offset with transform boundaries north and south. Imagine that the North American continent is moving over the Pacific Ocean and causing the eastern edge of that ocean to subduct, including the subduction of a seafloor spreading center. The zone between the two active spreading centers is just one big transform boundary that connects the two – what used to be between them has long-since subducted under the continent. That transform boundary is known to us more commonly as the **San Andreas Fault System**. And north of us, in Oregon and Washington and Northern California, what's happening along the coast? New seafloor forms offshore and then spreads and collides with North America, where it subducts underneath and causes the Cascade Volcanoes to form, the southernmost extension of which include both Mt. Shasta and Mt. Lassen in northern California.

If we continue around the rim of fire, we also see a number of ocean-ocean convergent plate boundaries in the western Pacific, most notably in Japan, the Philippines, and New Zealand. These areas are rocked by large earthquakes and explosive volcanic eruptions, making them very dynamic places to live.

Pause now.

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

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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 Global Impacts
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**Global Earthquake Map color coded by Depth – USGS.*
**Globe Imagery of World Oceans – Google Earth – Image Landsat and IBCAO and USGS, Data SIO, NOAA, U.S. Navy, NGA, GEBCO*
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**Plate Boundary map of world (Ring of Fire) – USGS*
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**Time-lapse image of India hitting Asia – USGS*
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**Satellite Imagery of Red Sea Triple Junction – NOAA.*
**Photo of Rift Valley across body of water – source unknown.*
**3D cross section of Pacific Northwest Plate Boundaries – USGS*
**Plate Boundary map of western coast of North America – USGS*
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**Plate Boundary map of western coast of North America highlight Cascade Volcanoes – USGS*