

Hotspots - Tutorial Script

Hotspots are deep-seated sources of heat and magma that extend from depths as deep as the core-mantle boundary and generally stay fixed relative to plate motion – the plate move across the hotspots, but the hotspot doesn't move. Volcanoes are left behind in tracks that show us the direction and speed of plate motion. As this image shows, some hotspots form through large amounts of heat that are injected into the lower mantle and cause melts to form. As these melts are less dense, they rise. More mantle melts and the plume grows a large mushroom-shaped head. When it finally hits the surface, the magma collects under the rigid lithosphere, and pressure builds. Cracks open up in the lithosphere and allow the magmas to erupt on the surface in a massive eruption of basalt that floods the surface. These basalts from the head of the plume can take over a million years to completely spill out – covering areas as large as Texas with kilometers thick piles of dense basalt. We call these massive initial hotspot eruptions **flood basalts**, and they have been associated with major mass extinction events, including the extinction of trilobites, ammonites, and later, the dinosaurs. When the head of the plume has finished erupting, the main stalk of the plume continues to erupt for hundreds of millions of years. Though these eruptions are much less massive than the initial flood basalt eruption, they still produce more volcanic material and activity than subduction zone volcanoes or divergent plate boundary volcanism. As they erupt, large volcanic mountains form on the surface, continually fed by the large amounts of magma. Eventually, however, these volcanoes are moved away from the hotspot, as the plate moves, and when they get far enough away, a new set of cracks and conduits will form, and a new volcano will take the place of the old one. So we can study these hotspot tracks and from them learn both the direction and speed of plate motion. A good somewhat local example is the Yellowstone Hotspot. The Columbia River Basalts are the flood basalts that mark the initial eruption of that hotspot. Here is the location of the hotspot and the active volcanism in North America today. Here are the older volcanoes the hotspot produced before the plate moved them away. Where was this older volcano when it formed? Right up here where the active volcanism is today. So what direction did it move? This way. And thus this arrow represents the general direction of movement of the North American plate over the past 9 million years. And how fast has it been moving? If we know that that the volcano is 9 million years old, and we can measure the distance it has travelled since it formed – 270 km, we can calculate a speed – 270 km in 9 million years is roughly 30 kilometers per million years. To convert to a more useful unit – centimeters per year – we have to convert kilometers to centimeters and millions of years to years. That ends up cancelling out a lot of zeros and being the same as dividing by 10 – so 3 cm per year. Similar to what we mentioned earlier for the spreading rate of the center of the Atlantic Ocean!

Pause now.

This map shows other major hotspots across the planet and the identified flood basalts that connect to them. Notice two other important examples: Iceland and Hawaii. Iceland is unique because it sits atop the mid-ocean ridge, which means there are two sources of magma there – seafloor spreading AND hotspots. It also means that the island formed never really moves away from the hotspot, but only grows wider.

In the Hawaiian Islands, we see here, the active island and as we move northwest, the islands get older and more eroded, smaller, eventually becoming submerged seamounts that make up the Emperor-Midway chain. Can you tell the direction of motion of the Pacific Ocean from this track? Pause and think about it.

Pause now.

Two interesting things we see when we study this track closely: one: notice the bend that happens about 45 million years ago? What would cause that? The Pacific Plate has been moving in one steady direction for the past 45 million years and prior to that it moved also in a steady direction, but a different one. What happened 45 million years ago to cause the entire plate to change direction? The other thing that we see with this track is that the islands seem to be entering the subduction zones of the Aleutian Arc. What's happening there that we discussed earlier in this lecture? Terrane Accretion! A train wreck, so to speak.

Pause now.

And now... the answer to the direction change of the Pacific Plate! The only thing that can cause such a major shift in direction of a plate is if an obstacle blocked its path and it had to be diverted. What would have caused that? What major obstacle? India collided with Asia! And when it did, every plate on the planet had to shift to accommodate the major obstacle that formed in the middle of the road.

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

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

Hotspots

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**Fissure eruption. USGS.*

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**India Satellite Map -- NOAA*