Hot Spots

Building a Tropical Paradise - Hot Spots in the Pacific

Reading: 3.25

Graphic: Steam explosion off the coast of Hawaii caused by lava reaching the sea. Volcanic debris produced by the explosion washes ashore and forms black sand beaches. J.D. Griggs, photographer. Courtesy of USGS.

Hawaii – Living with a Hot Spot

Scientists routinely monitor Hawaiian volcanoes

Hazards:

- Lava flows

- Earthquakes

Graphics: (top left) Oct. 1987, (top right) June 1989, both J.D. Griggs photographer, courtesy of NOAA, (bottom) CNN.com 14 Sept 2004.

What is a Hot Spot?

Hot spot = surface expression of a magma plume that rises through the mantle

After erupting, this magma cools to form volcanic mountains

As lithospheric plates move above hot spots, volcanic island chains can form

Graphic: Eruption of Pu'u 'O'o. J.D. Griggs, photographer. Courtesy of USGS.

Hot Spots and heat flow-
A View from Earth's Interior

Graphic: See Garrison, Fig. 3.13.

Locations of Hot Spots

<u>Hot spots are associated with processes deep inside the Earth</u> - they are not "tied" to lithospheric plates

Hot spots <u>can occur anywhere on the planet</u> - at plate boundaries or plate interiors

Examples: Iceland, Hawaii, Yellowstone

Graphic: Map courtesy of USGS, See Garrison Fig. 3.15.

Two Hypotheses Regarding the Formation of Hot Spots

<u>Temperature variations in the outer core:</u>

Very hot areas of the outer core may melt material in the lower mantle

<u>Melting of previously subducted material:</u>

Material that has broken off of subducted slabs may melt in the lower mantle

Graphic: See Garrison Fig. 3.22.

Hot Spot Volcanoes – Inflation and Deflation Cycles

<u>Hot spot volcanoes form due to eruptions</u> over many years

- Magma swells up toward the surface

- The magma reservoir inflates, cracking the ground and triggering many small earthquakes

- An eruption releases magma and the magma chamber deflates

Graphic: Drawings courtesy of USGS. See **http://hvo.wr.usgs.gov/howwork/subsidence/inflate_deflate.html**

Explosive Eruptions

<u>Some hot spot volcanoes erupt explosively</u>

- Water in the crater contacts molten rock and flashes to steam

- Under stress, the walls of the crater collapse, blocking the crater

- Pressure builds up and the volcano erupts explosively

Graphics: (left) Courtesy of USGS, (right) 1924 eruption of Kilauea, courtesy of USGS.

Hot Spot Volcanoes and Earthquakes

Small, shallow earthquakes occur as magma moves through the upper part of the volcano's interior (these can provide advance warning of a major eruption)

Larger, deep earthquakes occur due to stresses exerted by magma rising deep in the chamber

Graphic: Earthquakes on and around the Big Island of Hawaii, 1929-1994. Courtesy of USGS.

Islands, Seamounts, and Guyots

- **As the plate moves away from the hotspot, it cools over millions of years, becomes denser and sinks into the asthenosphere.**
- **Volcanic Islands sink beneath the sea to become Seamounts or flat topped Guyots**
- **Guyots are flat-topped due to erosion from wave action**

Hotspot Islands and Isostacy

- **The Hawaiian Island volcanoes are so big they isostatically depress the Pacific Plate around them**
- **This depression creates a 500m deep "moat" in the seafloor around the Hawaiian Island Chain**

Formation of a Volcanic Island Chain

Heat weakens the plate above the hot spot and magma migrates upward to form a volcano

As the plate moves, the magma supply is cut off and the volcano cools and sinks isostatically

A new volcano begins to form above the hot spot

Graphic: Garrison, Fig. 3.32. (animation)

Measuring Plate Motion

Plate direction:

Determined from the orientation of volcanoes within the chain

Plate speed:

Determined from ages of volcanoes and distance between volcanoes

Graphic: Garrison, Fig. 3.32.

Changes in Plate Direction Over Time

One hot spot created both the Hawaiian Islands and Emperor Seamounts

The Hawaiian-Emperor "bend" in the chain is due to an abrupt change in plate direction 40 million years ago

Hot spot volcanoes help reconstruct plate motion over long periods of time

Graphic: Garrison, Fig. 3.33.

Hot Spot Volcanoes and Time

Volcanoes farther from the hot spot are older

(Ages shown in yellow are in millions of years)

Graphic: Ages of volcanoes in the Hawaiian-Emperor Chain, Garrison, Fig. 3.33.

Lo'ihi - Hawaii's Youngest Submarine Volcano

Lo'ihi rises 3000 m above the sea floor (summit = 969 m below sea level)

Generates frequent earthquake swarms

Expected to break the surface and become an island in 30,000-100,000 years

Graphics: (top) Map courtesy of USGS, (bottom) Earthquakes on and around the Big Island of Hawaii, 1929-1994. Courtesy of USGS.

How can heat flow alter a planet?

- A planet's heat loss depends on it's volume, sources and sinks of heat.
- **<u>What are the sources and sinks of heat on Earth?</u>**

Image source: NASA

Hotspots on Earth and Mars

Source: http://www.nasaimages.org/luna/servlet/detail/NSVS~3~3~10065~110065:Earth-Mars-Volcano-Comparisons--Tra

Venus: Surface

- Size and Volume of Venus indicates it should have internal heat.
- Crater density age estimates indicate the surface is uniformly ~500 million year old.
- Relatively flat surface with only a few major highlands
- **<u>How does this differ from Earth's surface?</u>**

Earth vs. Venus: Surface

- Surface in the south is heavily cratered, indicating an old surface and no recent geological activities
- Crustal dichotomy: Southern highlands (5 km higher) versus northern lowlands
- Surface in the north is smooth and free of craters, indicating relatively young

- Mars has no ongoing geological activity.
- However, Mars had ancient geological activity, e.g, huge volcanic mountains and deep rift valleys.

Volcanism on Earth, Venus and Mars

- Volcanoes

  Earth: Some active

  Venus: Some active

  Mars: no active volcanoes, all extinct

Earth, Venus & Mars: Heat loss mechanisms

- Earth
  - **<u>Plate + Plume Tectonics</u>** : the lithosphere is divided into several large pieces (~14); **young oceanic surface, old continents**

- Moderate internal heat

- Venus
  - **<u>Flake Tectonics</u>**: the crust breaks up into numerous flakes, producing small scale deformation and reshaping of the surface; **uniformly young surface, micro-continents?**
  - Relatively strong internal heat

- Mars
  - **<u>"Plume" Tectonics</u>**; thick & rigid crust; **old, dormant surface**
  - Relatively weak internal heat

Preview of Next Lecture

Plate Tectonics and Ancient Oceans

Graphic: CNN, Jan 23, 2003. Photo by the Associated Press.