Ocean 201 week 5 Lecture 1: Mantle Plumes and Hawaiian Volcanoes (M.J. Mottl)

Text from slides

Seamounts and Guyots

- Seamounts: volcanoes formed at or near MOR, or at "hot spots
- Guyots: Submerged seamounts with flat tops
- Seamounts that form at MOR become inactive and subside with seafloor as they move away from the ridge axis.
- Guyots formed from volcanic islands that are planed off at sea level by erosion, then subside as seafloor travels away from the ridge axis.

Atolls

- Ring shaped islands or coral reefs centered over submerged, inactive volcanic seamounts
- Corals can only live within the photic zone, in tropical regions.
- Coral reefs build upward ~1cm/yr.
- If volcanic islands sink sufficiently slowly, coral growth can keep up, producing an atoll.

Darwin's Theory of Atoll Formation

- Fringing reef grows upward around a young island.
- Barrier reef develops as corals grow upward, but the subsiding island is eroded and a lagoon forms.
- Atoll develops fully as island subsides further; "motu" form from accretion/consolidation of storm debris at barrier.

Motu on Barrier Reef of Atolls

The Darwin Point

- Darwin Point: where atolls "drown" because coral growth can no longer keep up with subsidence.
- When temp. becomes too low for coral to grow efficiently…
- Rate of subsidence of the volcanic edifice becomes greater than (upward) coral growth rate…
- In Hawaii this occurs ~ 29oN (i.e., just N. of Kure Atoll).

Mantle Plumes or "Hot Spots"

- First hypothesized by J. Tuzo Wilson (1963) to explain linear island chains in the Pacific.

Mantle Plume or "Hot Spot" Theory

- Proposes that "hot spots" are point sources of magma that have apparently remained fixed in one spot of the Earth's mantle for long periods of time.

The Hawaiian hot spot presently lies beneath the Big Island of Hawaii.

Age of the Hawaiian Islands increases with distance from Kilauea.

Linear Island Chains

- Bend in Hawaiian-Emperor chain reflects change in direction of motion of Pacific Plate…
- End of chain is ~90 Ma, bend is ~ 45 Ma.
- Change is believed by many to have resulted from collision of India with Asia, shutting down 1200 km of subduction zone.
- Hot spots represent major zones of upwelling in overall pattern of mantle convection.
- Downwelling, however, is not so localized as upwelling that occurs at hot spots…

Mantle Plumes: II

- Mantle plumes may be derived from near the core-mantle boundary, as demonstrated in this simulation from the Minnesota supercomputing lab.
- They may be the major mechanism that cools the core.
- Note the bulbous *plume heads*, and the narrow *plume tails.*
- Plume heads flatten as they impinge on the outer sphere (the base of the lithosphere).
- Hot spots commonly occur on or near the MOR (Easter Island, Iceland, St. Helena, Tristan da Cunha).
- This led Morgan (1972) to suggest hot spots play an important role in driving plate motion…
- Hot spots near MOR create aseismic ridges that extend outward from spreading axis (e.g., Tristan da Cunha, which produced the Walvis Ridge and Rio Grande Rise in the S. Atlantic).
- Hot spots also occur in middle of oceanic plates (e.g., Hawaii, Reunion) and under continental crust (e.g., Yellowstone).

The Yellowstone hot spot: beautiful . . . But ***dangerous***!

- Because they remain more or less fixed in mantle, hot spots lead to linear track of volcanism that can be used to trace absolute plate motion.

Large Igneous Provinces

- Initiation of of new mantle plume is thought to cause formation of a LIP, because head of the plume is large.
- Similar features are found on the Moon, Venus, and Mars.
- On land, LIPs are called “flood basalts” (e.g., Columbia River, Deccan Traps in India).
- On the seafloor, LIPs are called “oceanic plateaus”.

Flood Basalts: I
Deccan Traps in India (67Ma)

- Several 100 km across
- Several km thick

- Erupted in <1My ➔2- 8km3/yr
- Produced Chagos-Laccadive Ridge and Mascarene Plateau.
- Present position of hot spot is Reunion Island.

Flood Basalts: II
Siberian Flood Basalts (248Ma)
- Largest on land
- Accompanied by the ***most severe biotic extinction ever*** for multicellular life, at end of Paleozoic.
- 95% of marine life vanished!

Flood Basalts: III
Columbia River Plateau (17 Ma)
- Original area larger than NY State
- Erupted within 1.5 My

Oceanic Plateaus: I
Ontong-Java (122 Ma)
- Largest in the world (36 Mkm3)
- Formed in <3 My ➔ 12 km3/yr
- 25x larger than Deccan
- 2/3 size of Australia
- Plume head (at 5-30% melt): 600-1400 km (up to ½ thickness of mantle)
- Eruption would have raised sea level by ~10 m and mean atmospheric T by ~7-13oC.

Oceanic Plateaus: II
Kerguelen Plateau (122Ma)
- Southern Indian Ocean
- 2nd largest in ocean
- Formed within 4.5 My

Global Effects of LIPs
- Raise sea level when erupted on sea floor.
- Raise seawater temperature.
- Raise atmospheric temperature.
- Potentially cause mass biotic extinctions.

Hot Spots: Mantle Plumes?
- Important because they represent:
  - Third type of volcanism on Earth (MOR: basalt, Volcanic Arc: andesite, Hot spot: basalt)
  - A major mode of mantle upwelling (focused point sources) that may cool the core
  - A measure of absolute plate motion (motion with respect to fixed point in mantle rather than relative to other plates).