Seamounts and Guyots

- **Seamounts**: volcanoes formed at or near MOR or at “hot spots”
- **Guyots**: Submerged seamounts with flat tops
Seamounts and Guyots…

- 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 the 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 young island
- Barrier reef develops as corals grow upward but subsiding island is eroded and 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

Rose atoll
The Darwin Point

- Darwin Point is 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 volcanic edifice subsidence becomes greater than (upward) coral growth rate...
- In Hawaii this occurs ~ 29°N (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 (relatively) fixed in one spot of the Earth’s mantle for long periods of time.
The Hawaiian hot spot currently lies beneath the Big Island of Hawaii.
Age of the Hawaiian Islands increases with distance from Kilauea
• Bend in Hawaiian-Emperor chain reflects change in direction of motion of Pacific Plate.
• End of chain is ~90 Ma, bend is ~ 40 Ma.
• Change may 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 may be derived from near the core-mantle boundary, as demonstrated in this computer simulation from the Minnesota supercomputing lab.

- 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).
Trace of the Yellowstone hot spot: the Snake River Plain, Oregon to Wyoming

Southern Idaho

The Snake River Plain from space
The Yellowstone hot spot: a beautiful interaction between a deep reservoir and a surface reservoir...
But massive eruptions are dangerous!

(Mt. Pinatubo, Philippines, 1991: 3-5 km³)
• 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 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.
Growing Mantle Plume
Large Igneous Provinces

- On land, LIPs are called “flood basalts” (e.g., Columbia River, Deccan Traps in India)
Large Igneous Provinces

- On the seafloor, LIPs are called “oceanic plateaus”
RISING PLUMES of hot material migrate through the earth's mantle; where the head of the plume reaches the surface, a large igneous province forms (left). Plumes probably originate at the boundary layers between the core and mantle (the D'') and between the upper and lower mantle. The parent plumes of the most voluminous igneous provinces were so huge that they must have originated at least in part in the lower mantle, most likely at the D''. The spheres on the right depict the minimum (white) and maximum (dark orange) inferred diameters of the plumes associated with five major igneous provinces.
Flood Basalts: I

Deccan Traps in India (67Ma)

- Several 100 km across
- A few km thick
- Erupted in <1My ➔ 2- 8 km³/yr
- Produced Chagos-Laccadive Ridge and Mascarene Plateau
Deccan Traps

- India migrated to current position over past 67 Ma from East of Madagascar
- Present position of hot spot is Reunion Island
Flood Basalts: II

Siberian Flood Basalts (248Ma) ➔ largest on land
• Accompanied by *most severe biotic extinction* ever for multicellular life, at the 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
CRB Volcanism in Foothills of (current) Rocky Mountains

- Eruptions during Miocene
- Not all gentle lava flows…
- Large ash eruptions also occurred and buried local area, e.g., Clarkia Lake bed…
Oceanic Plateaus: I

Ontong-Java (122 Ma)

- Largest in the world (36 Mkm$^3$)
- Formed in <3 My $\rightarrow$ 12 km$^3$/yr
- 25 X 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 $\sim$10 m and raised mean atmospheric T $\sim$7-13$^\circ$C
Oceanic Plateaus: II

Kerguelen Plateau (122Ma)
• Southern Indian Ocean
• 2\textsuperscript{nd} largest in ocean
• Formed within 4.5 My
Global Effects of LIP

• Raise sea level when erupt on sea floor
• Raise seawater temperature
• Raise atmospheric temperature
• Potentially caused 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)
  – The major mode of mantle upwelling (focused point sources)
  – A measure of absolute plate motion (motion with respect to fixed point in mantle rather than relative to other plates)
Hot Spots of the World
HURL, PISCES V

Eric H. De Carlo, OCN201Sp2010
Lo`ihi Hydrothermal Vents (2004) from PISCES V
Lo`ihi Volcano

Aloha, see you next time

Eric H. De Carlo, OCN201 F2011