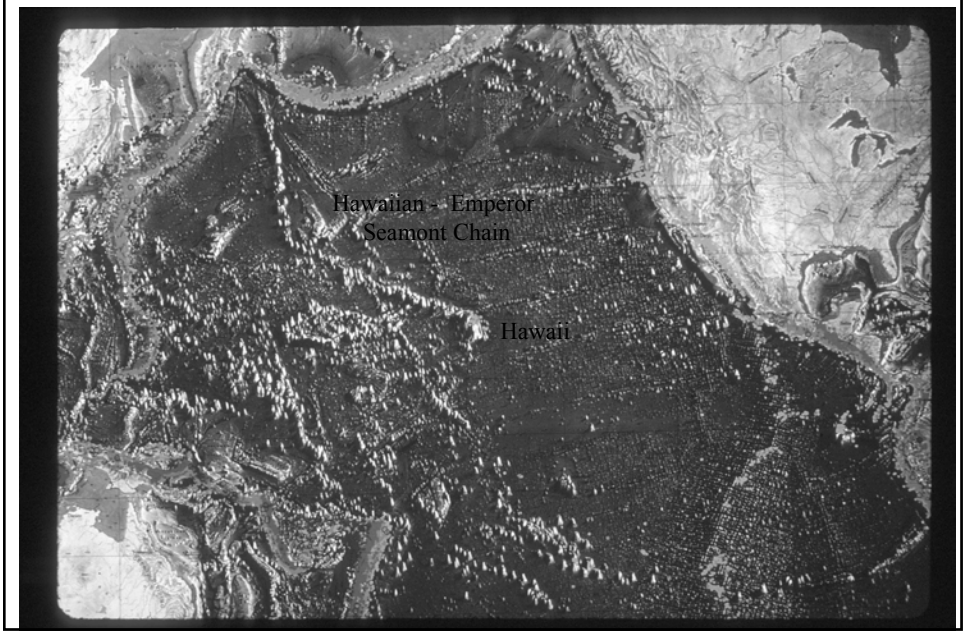
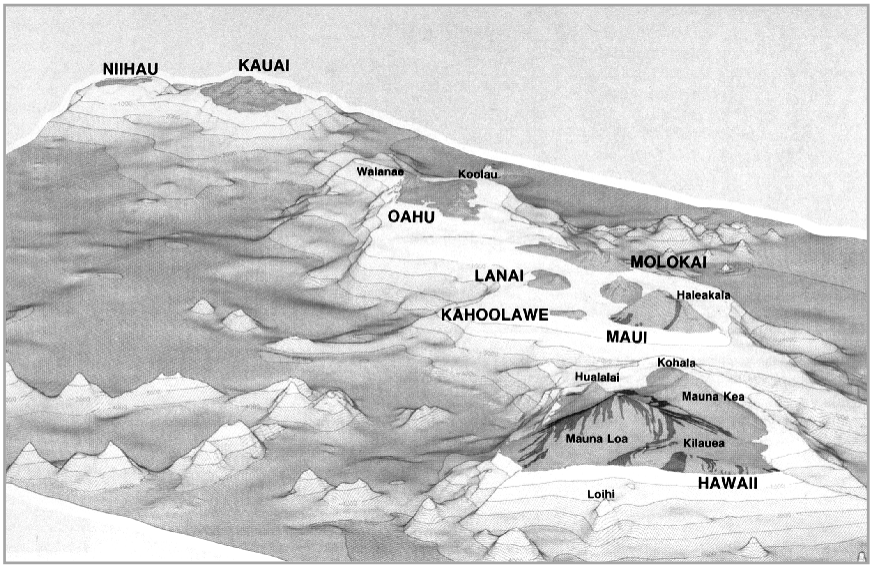
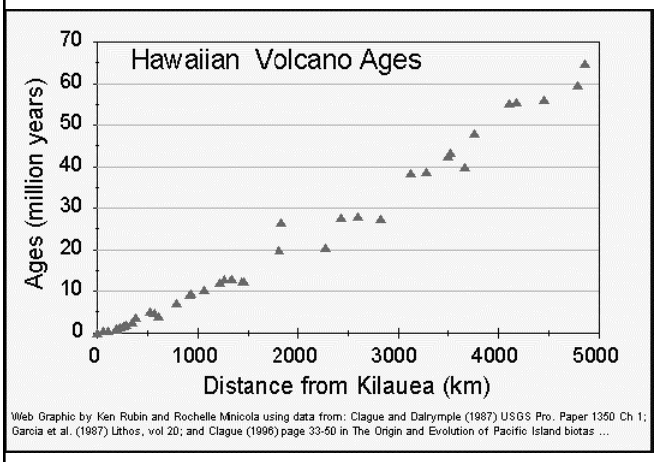
Hawaiian Volcanism





The Hawaiian Islands

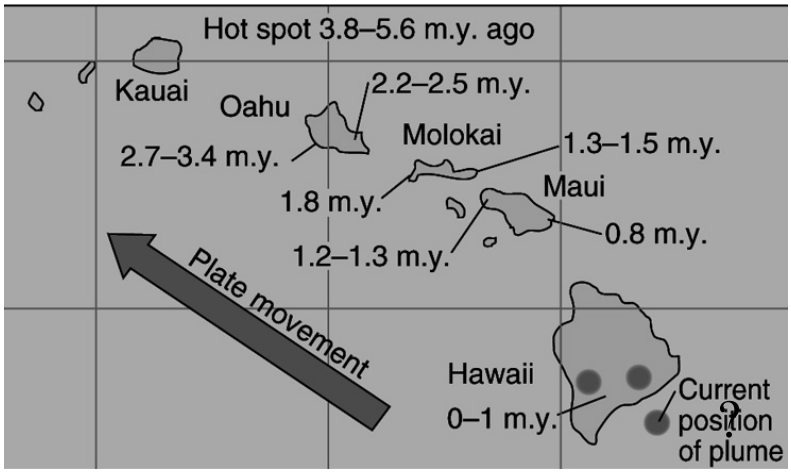
Age Progression of Hawaiian Volcanoes



The age progression of the volcanoes along the Hawaiian – Emperor seamont chain corresponds to a 9-10 cm/year north-west movement of the Pacific plate over a stationary mantle plume.

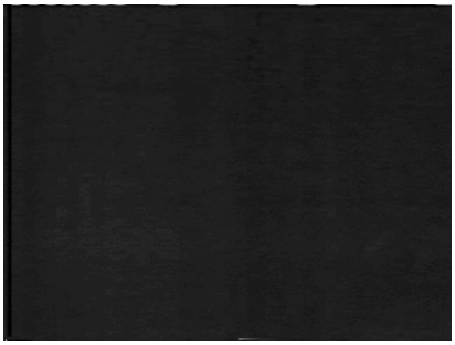
Kilauea is currently active, so is close to the present location of the plume

Hawaii

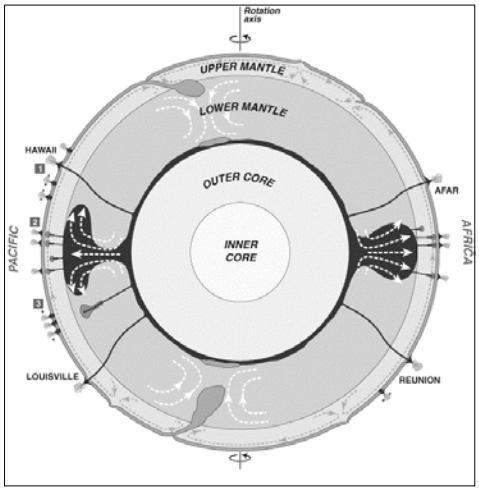


The age progression even applies to the Hawaiian Islands themselves.

Video showing origin of Hotspots



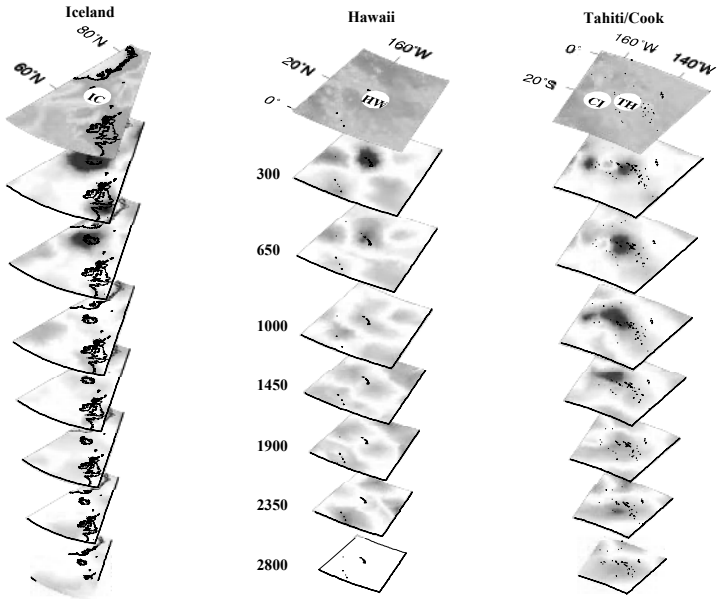
THE GREAT PLUME DEBATE
What Plume Debate?

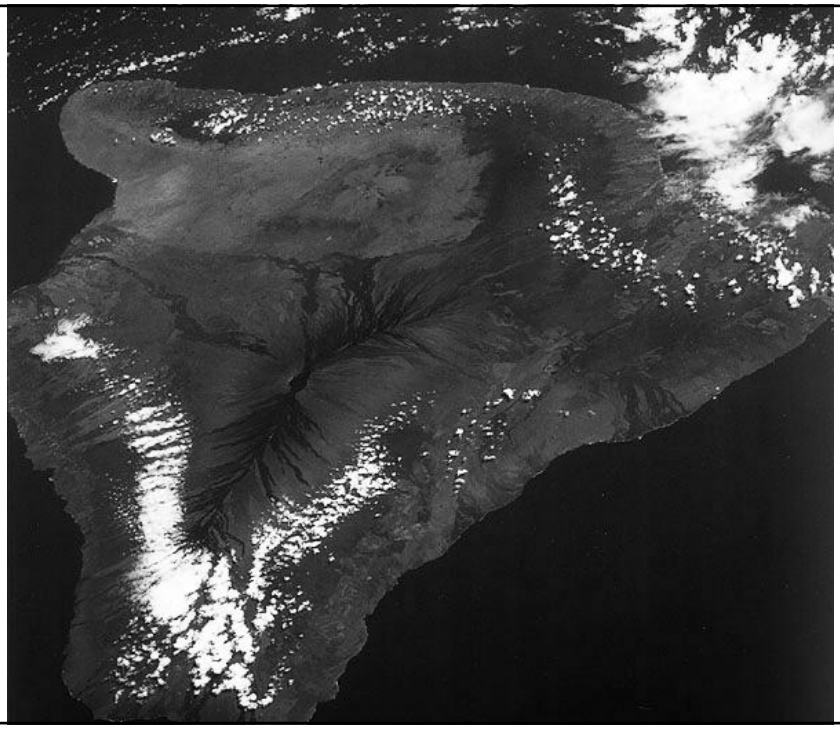


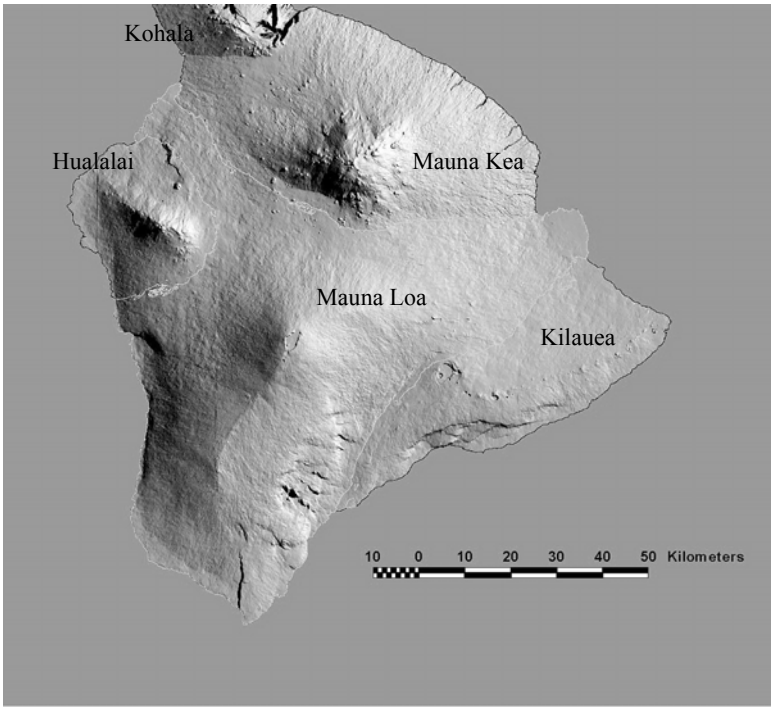
Courtillot et al (2003) recognize about 49 hotspots:-

1. Primary plumes from the Core/Mantle boundary (7 – 10).
2. Plumes associated with Superswells (about 20).
3. Non-plumes from the upper mantle (about 20).

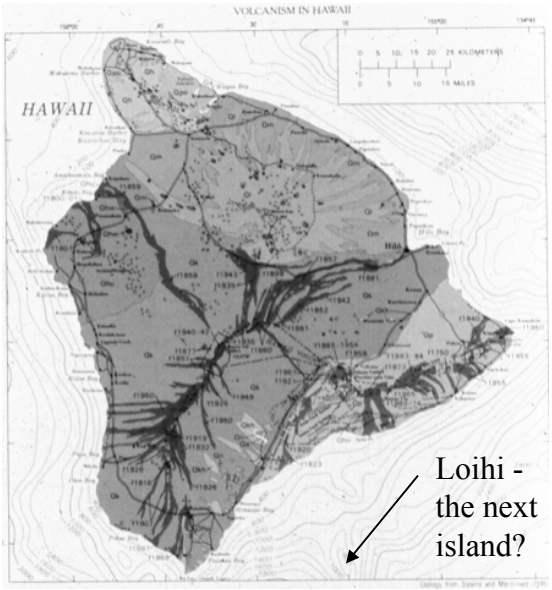
Seismic tomography (Montelli et al. 2004)







The Island of Hawaii



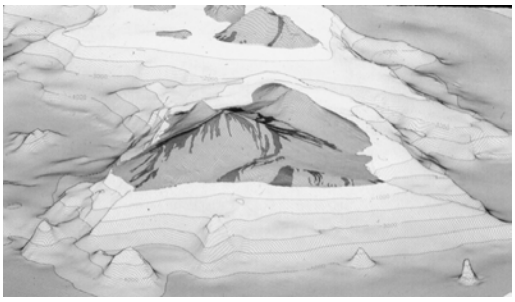
The Volcanoes

- Kohala
- Mauna Kea
- Hualalai
- Mauna Loa
- Kilauea
- Loihi

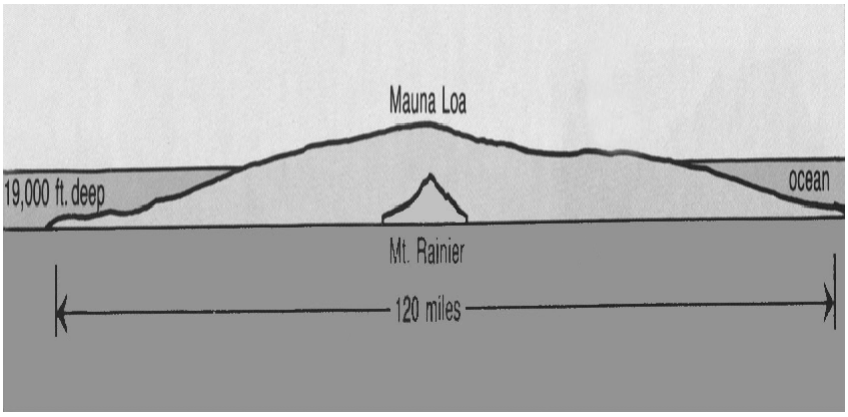
Loihi is currently about 1,000 m below sea level. It last erupted in 1999.

Mauna Loa Volcano
13,679 feet

Mauna Loa rises
33,000 feet from
the ocean floor!



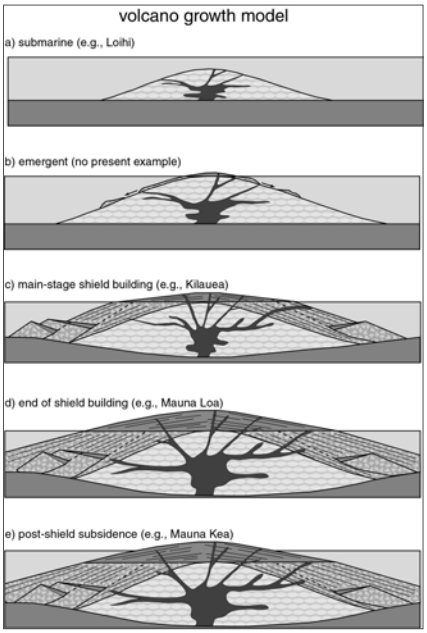
Comparison of Mauna Loa and Mt. Rainier!



Stages of Volcanism

There are 6 stages of HawaiianVolcanism: (modified from 4 stages initially proposed by Stearns (1938)

1. Submarine
2. Emergent
3. Shield
4. Post-Shield
5. Erosional
6. Post Erosional

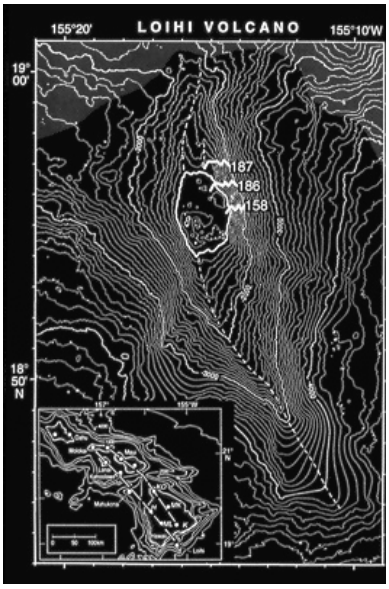


Submarine Stage
(Loihi)

Emergent Stage
(No example)

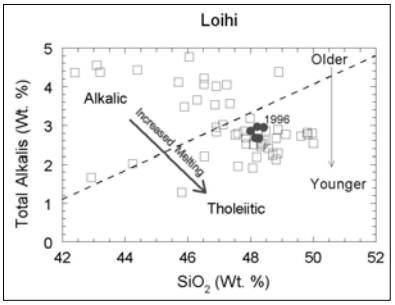
Shield Building Stage
(Mauna Loa, Kilauea)

Post-Shield Stage
(Mauna Kea, Hualalai)

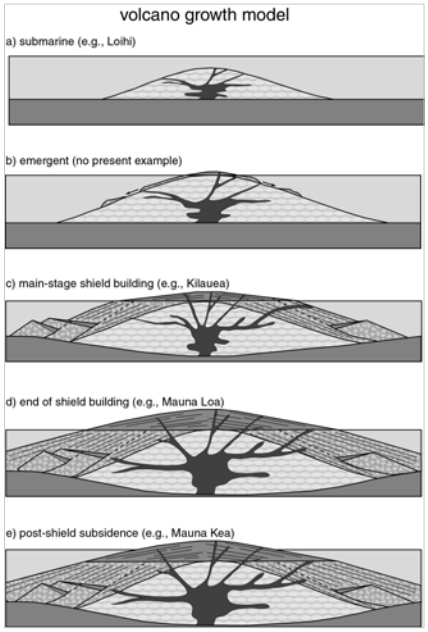


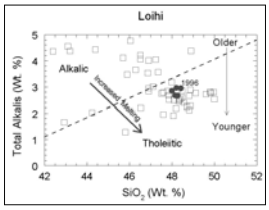
Submarine Stage

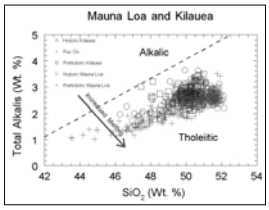
Bathymetric map of submarine Loihi volcano, showing summit caldera and two rift zones. Loihi last erupted in 1999.

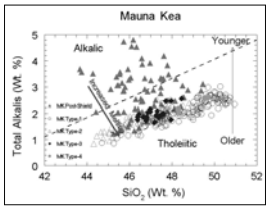


Volcanic Growth Stages, (Stearns, 1938??)

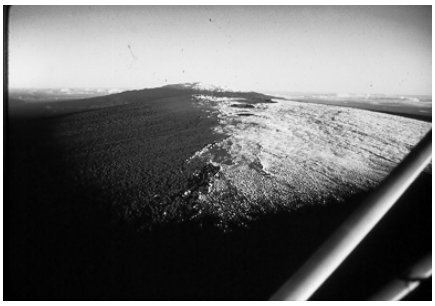




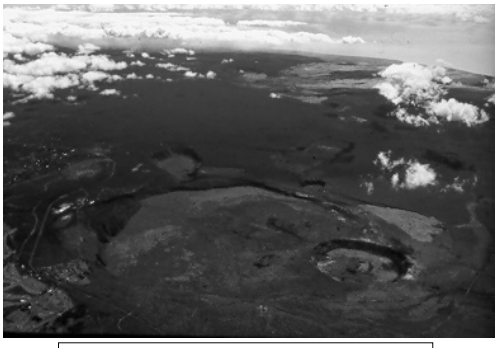


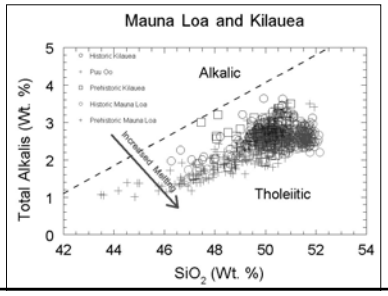


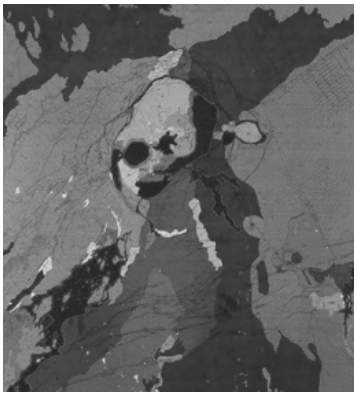
Shield Stage (Mauna Loa)



Shield Stage (Kilauea)







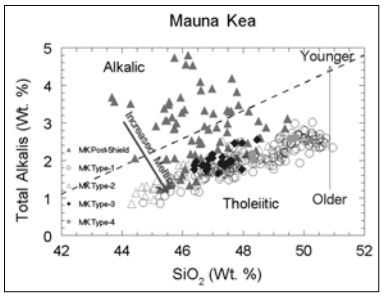
Kilauea Caldera

Post-Shield Stage

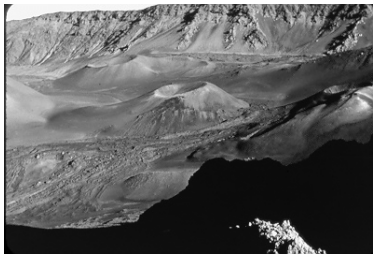
Mauna Kea
Last erupted about 3 ka

Note presence of cones on the basic shield form.

Hualalai
Last erupted 1801



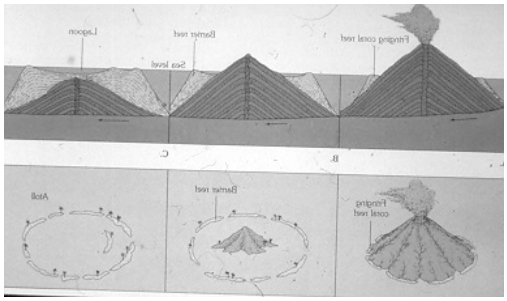
Post-Erosional (Rejuvenated) Stage



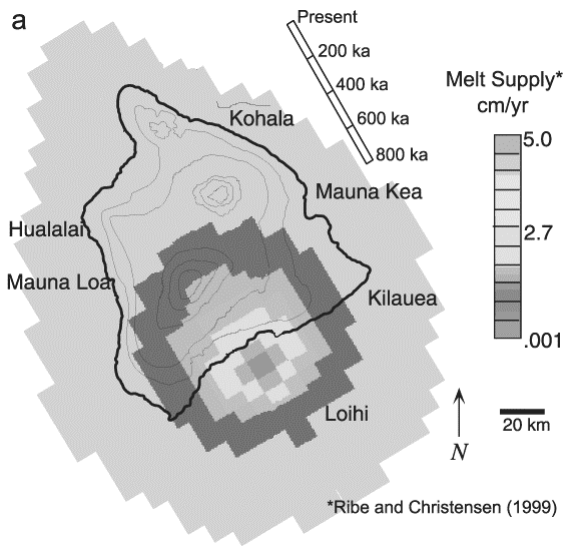
Views of Haleakala (Maui) showing post-erosional cinder cones (alkalic basalts) in an eroded valley (erroneously called a caldera).

More on Post – Erosional Volcanism

Diamond Head on Ohahu – an example of a phreatomagmatic tuff ring (alkalic and contains mantle xenoliths).

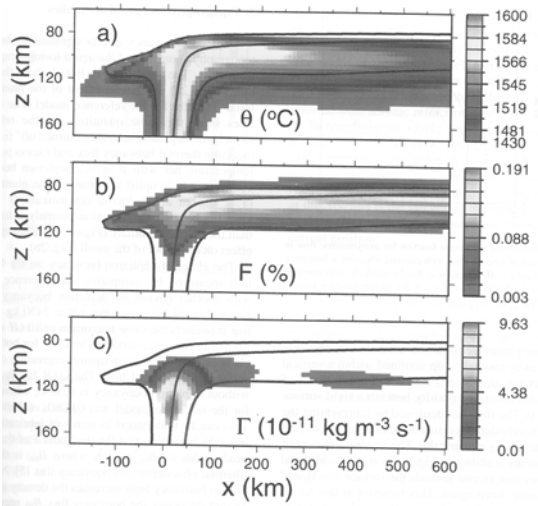


As volcanism wanes, coral reefs develop around the islands which eventually sink producing atolls (Darwin)



The plume is thought to be thermally zoned, with the hotter interior providing a greater magma supply. This notion is consistent with the evolutionary stages of Hawaiian volcanoes first proposed by Stearns.

Note scale showing inferred location of volcanoes in the past with relationship to the plume

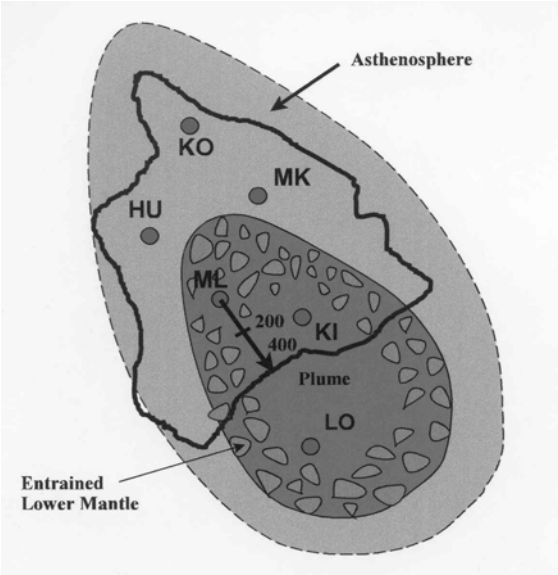


Temperature

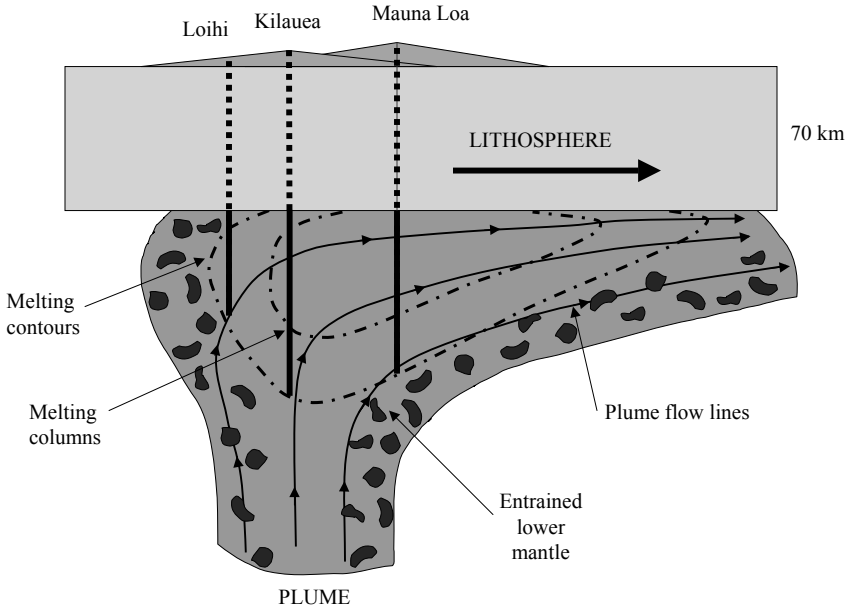
Extent of Melting

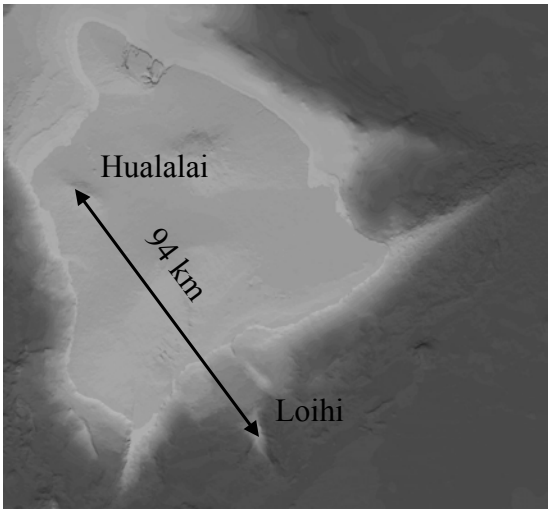
Melt Fraction

Theoretical model of the Hawaiian plume (Ribe and Christensen (1999). Note that this model identifies a secondary melt zone that explains post-erosional volcanism



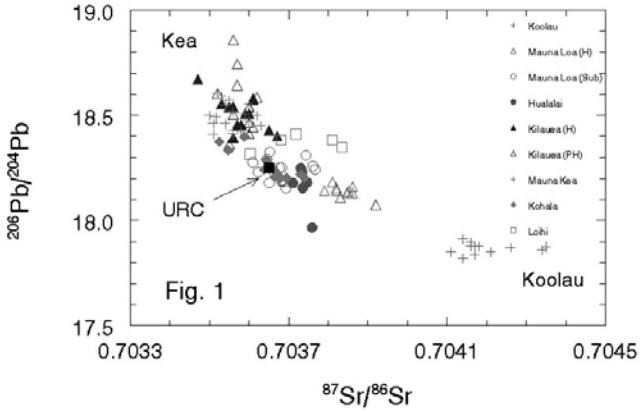
Fluid dynamic models of the Hawaiian plume, suggest that it is also concentrically zoned due to entrainment of lower mantle and asthenosphere as it ascends, possibly from the core-mantle boundary.



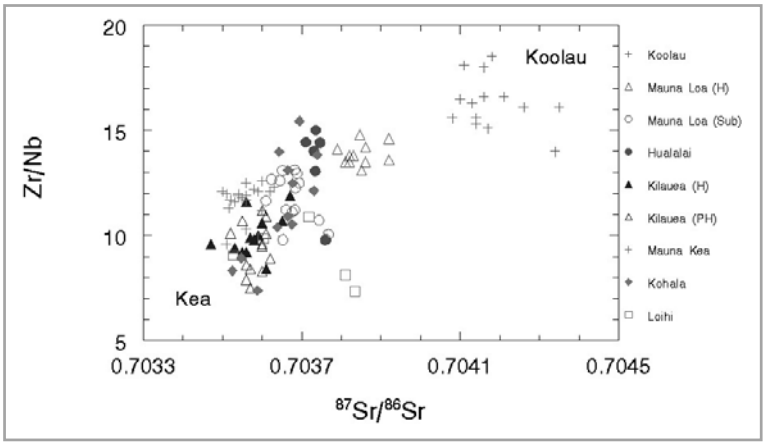


Evolution of Hawaiian volcanoes from an alkalic pre-shield stage, through a tholeiitic shield stage, to an alkalic post shield stage is consistent with movement of the Pacific plate over a thermally zoned melting anomaly.

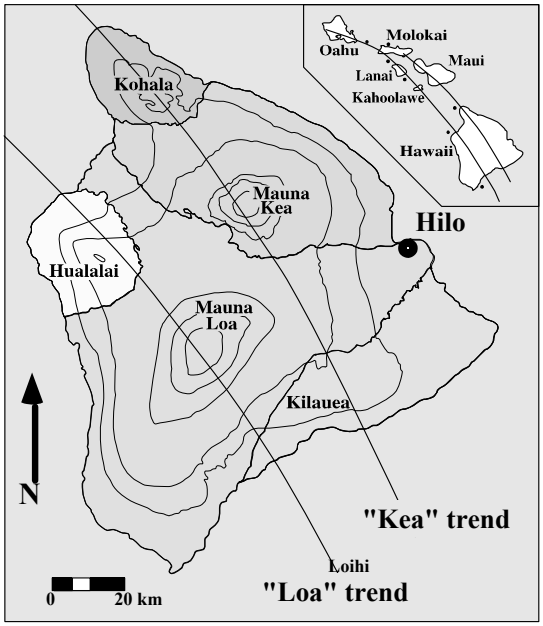
The distance from Loihi to Hualalai (94 km) provides a constraint on its dimensions.



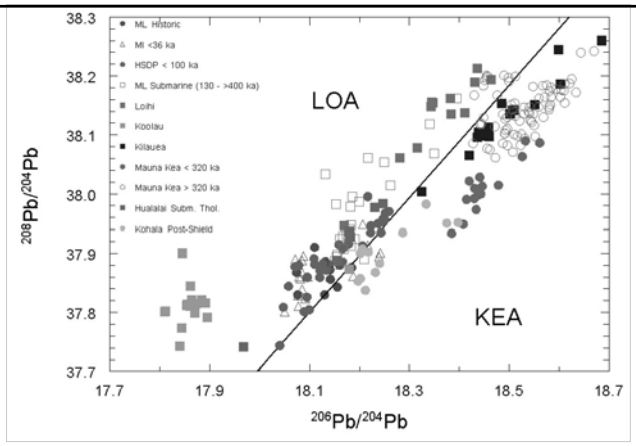
Isotopic data for Hawaiian volcanoes plot along trends that range between a “Kea” component and a “Koolau” component. Which of these components represents the plume, and which the entrained mantle is open to debate.



Zr/Nb variations correlate with isotopic variations and can be used as a proxy for variations in the plume source of the magmas. Caution, Zr/Nb is also increased by progressive melting!



Hawaiian volcanoes appear to lie on two sub-parallel trends, the "Loa" trend and the "Kea" trend. Note that Loihi, which is chemically and isotopically similar to "Kea" trend volcanoes falls on the "Loa" trend.

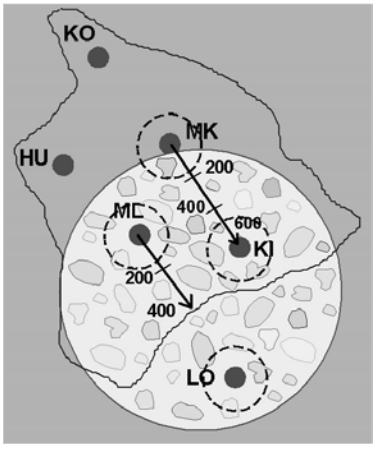


Pb – Pb Isotopes

High-precision Pb data from Abouchami et al. (2000, 2005) and unpublished data of Weis.

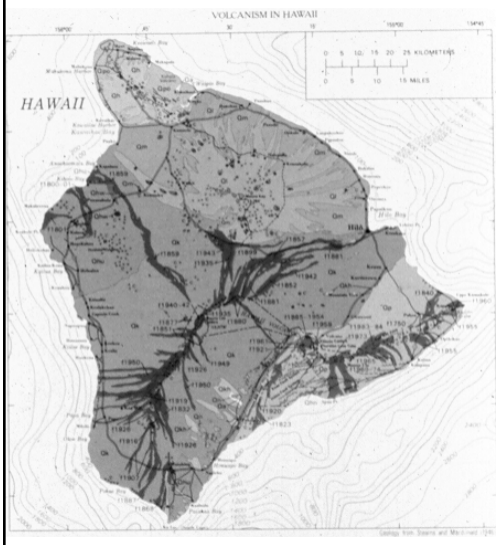
- Distinct bilateral asymmetry in the Pb data between Loa and Kea trends.
- Older Mauna Kea (> 320 ka) overlaps with Kilauea – long-lived (~ 400 ka) heterogeneities sampled by the two volcanoes.
- Mauna Loa lavas become progressively more like Loihi (not Kea!) lavas with increasing age (~ 100 to 400 ka).
- Hualalai submarine tholeiites overlap with <100 ka Mauna Loa lavas.

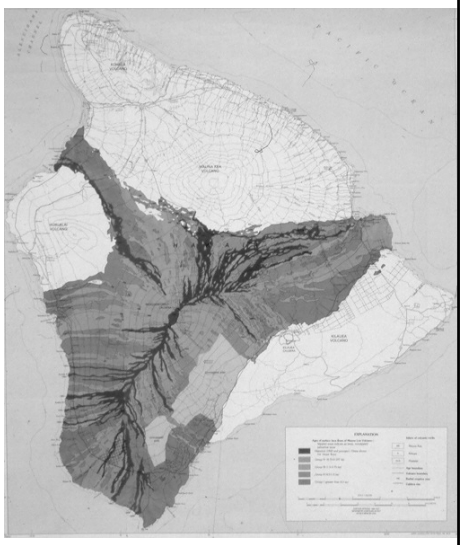
Implications for a Zoned Plume?



- Distinct bilateral asymmetry in the plume (not concentric).
- Mauna Kea would have been close to where Kilauea is today 500 – 600 ka ago. Implies long-lived, vertically stretched source components.
- Mauna Loa was closer to Loihi at 400 ka, consistent with greater proportion of Loihi components in Mauna Loa lavas at that time.

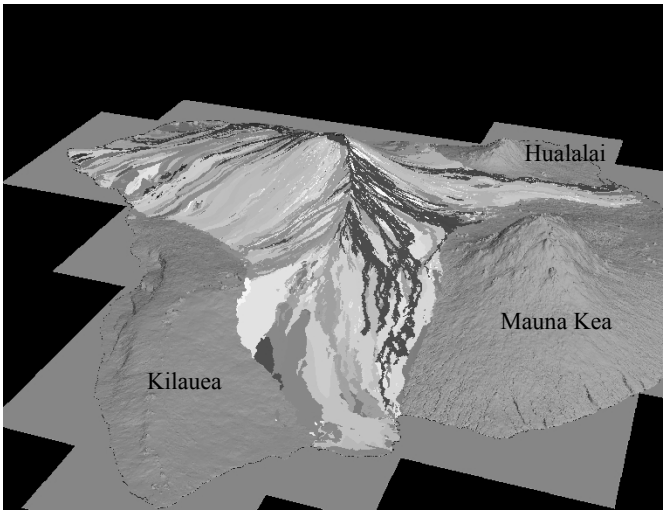
Rift Zones





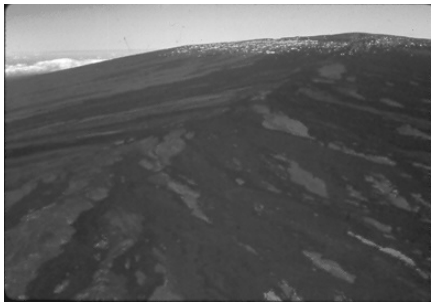
Eruptions on Hawaii's active volcanoes occur predominantly at a summit caldera and along distinct rift zones.

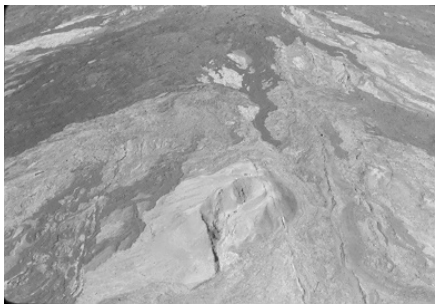
Mauna Loa's NE Rift Zone



Color-coding reflects increments of 1000 yrs in age

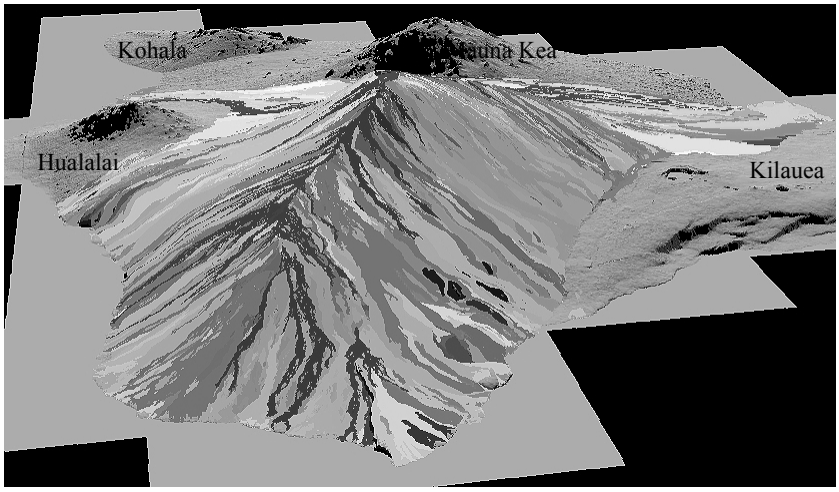
Mauna Loa's Northeast Rift Zone

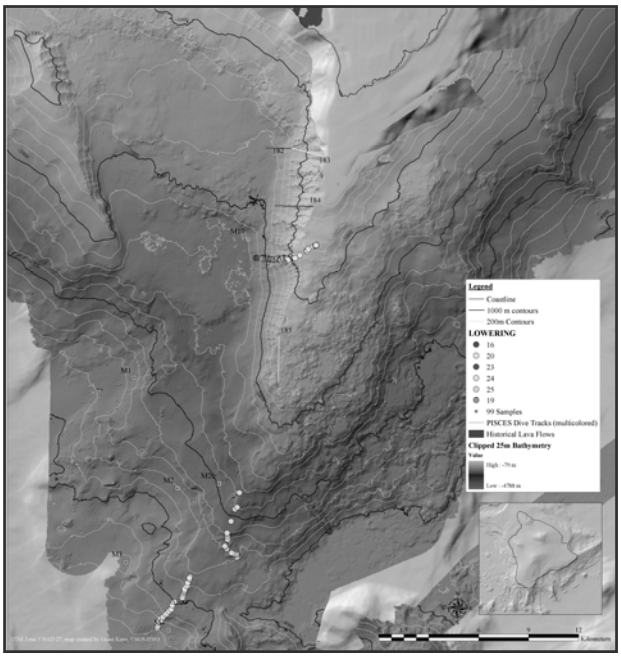




Note how the flows originate from vents and cones located along a very narrow zone (~2 km wide) that forms the rift zone

Mauna Loa's SW Rift Zone

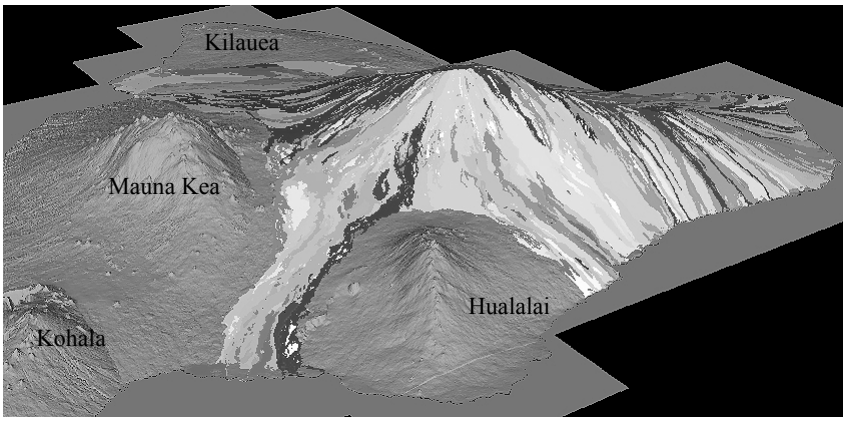




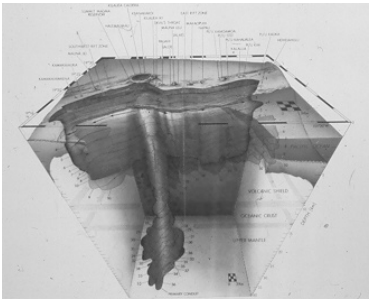
Mauna Loa's SW rift zone extends under water to a depth of around 4km

Map shows submersible sampling sites

Pisces V with Pete Lipman and Mike Rhodes



Radial vents along Mauna Loa's western and North-west flanks

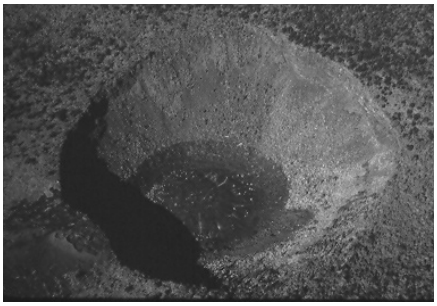


Kilauea's magmatic plumbing system

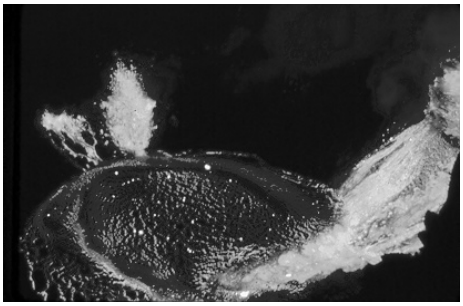
Kilauea caldera eruption (1971)

Rift zone eruption on Mauna Loa (1984)

Pit Craters



Pit craters are collapse features that form along rift zones. They are thought to reflect the location of pockets of magma stored in the rift zones.

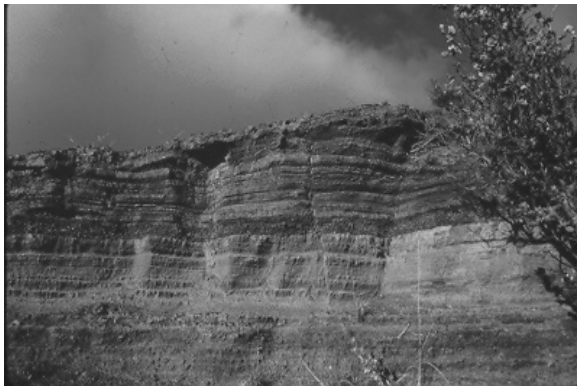


Because of Kilauea's frequent eruptions, lava often cascades into pit craters forming lava lakes. These lava lakes are excellent natural laboratories for studying the cooling, crystallization and evolution of basaltic magma

Tree Molds

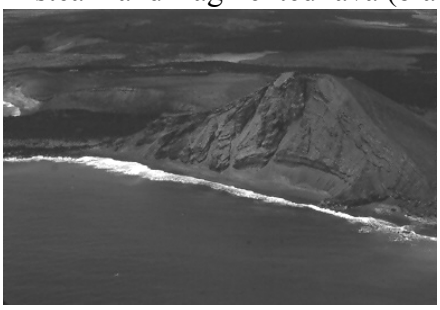
Kilauea eruptions frequently occur in forested areas. This leads to the formation of bizarre tree molds

Explosive Eruptions
Kilauea 1924



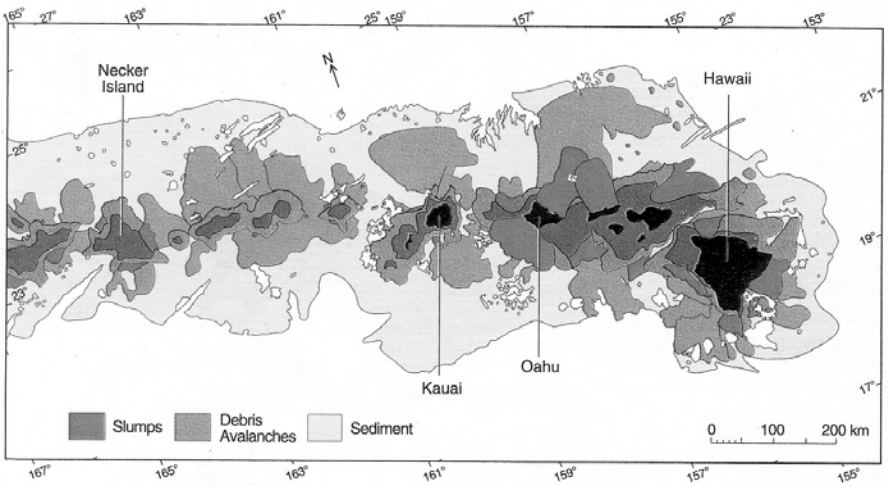
Explosive eruptions are not common during the shield-building stage of volcanism, but they do happen. This is the layered tephra produced by the explosive 1790 eruption.

When lava enters the ocean it may react explosively, producing steam and fragmented lava (black sand beaches).

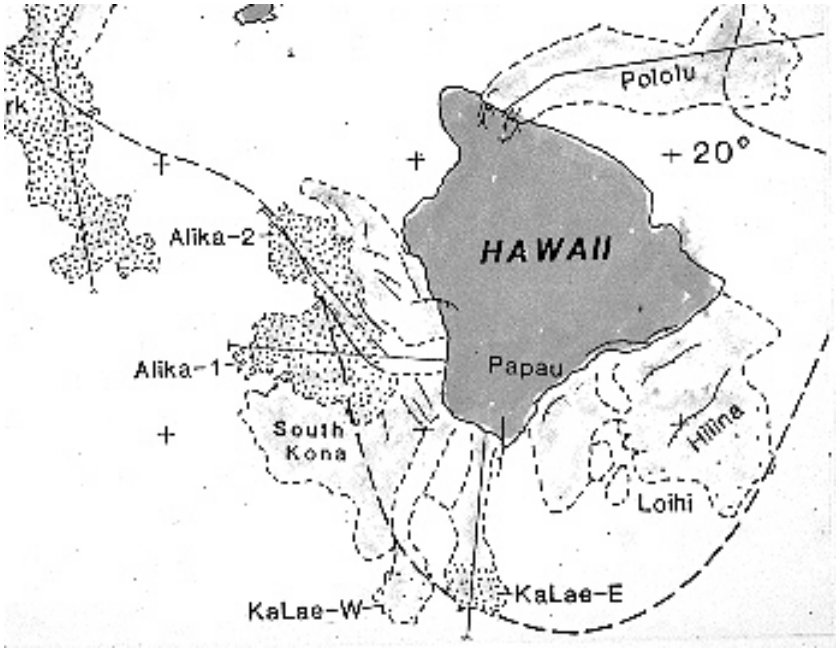


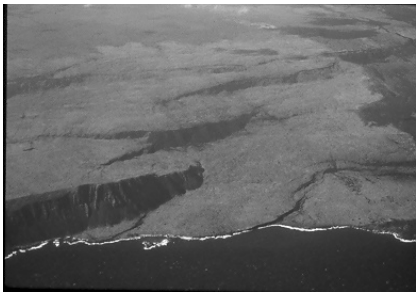
Continuing eruptions produce littoral cones where the lava enters the ocean (Puu Hou 1868)

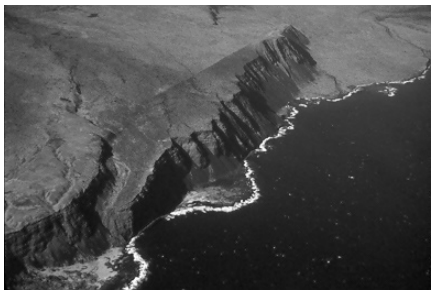
Submarine Landslides



Giant submarine landslides are ubiquitous to all of the Hawaiian islands.

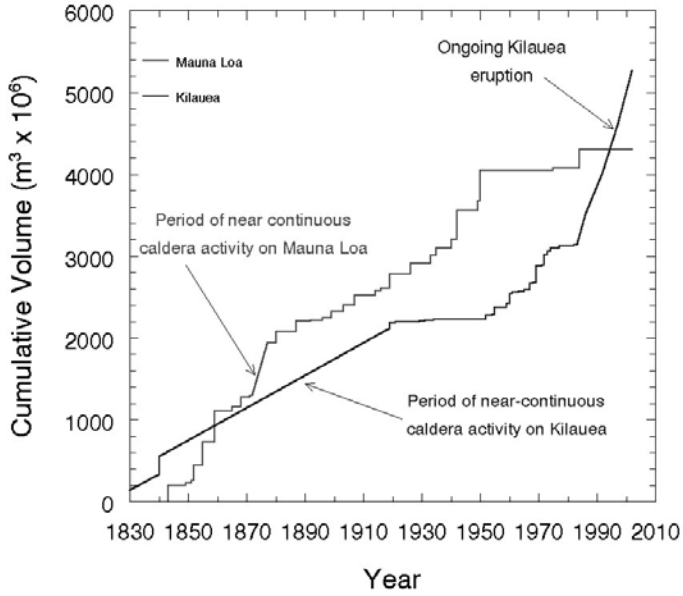






Hilina scarp system on Kilauea

Kealekakua landslide scarp on Mauna Loa



Consequences of a stratified magma column