THE LIFE AND TIMES OF A HAWAIIAN VOLCANO

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Compilation of volcano-order estimates

TABLE 1.3.—*Early estimates of the order of extinction of the principal Hawaiian volcanoes*

[Criteria used are given beneath each source; volcanoes listed in proposed order of extinction, oldest at top]

Dana (1849) Erosion	Brigham (1868) Erosion	Dana (1888) Erosion	Hillebrand (1888) Floral diversity	Wentworth (1927) Erosion	Hinds (1931) Erosion	Stearns (1946) Erosion and stratigraphy
Kauai	West Kauai, Niihau	Kauai	West Oahu, Kauai	Koolau	Waianae	Kauai
Waianae	Waianae	Waianae	Molokai, East Oahu	Kauai	Koolau	Waianae
West Maui	East Kauai	West Maui	Kohala, West Maui	East Molokai	Niihau	Koolau
Koolau	West Molokai	Kohala	Mauna Kea	West Maui	Kauai	West Molokai
Mauna Kea	West Maui	Koolau	East Maui	Mauna Kea	West Molokai	East Molokai
East Maui	Kohala	East Maui	Hualalai	Waianae	East Molokai	West Maui, Lanai
Mauna Loa	Koolau	Mauna Kea	Mauna Loa, Kilauea	East Maui	Lanai	Kahoolawe
	East Molokai	Hualalai		Lanai	West Maui, Kohala	East Maui
	Mauna Kea	Mauna Loa, Kilauea		Niihau, West Molokai	Kahoolawe	Kohala
	Lanai, Kahoolawe			Kahoolawe	East Maui	Mauna Kea
	East Maui			Kohala	Mauna Kea	Haulalai, Mauna Loa, Kilauea
	Hualalai			Hualalai, Mauna Loa, Kilauea	Hualalai	
	Mauna Loa, Kilauea				Mauna Loa, Kilauea	

Clague & Dalrymple (1987)

East Moloka‘i, viewed from the north.

Wai‘anae Volcano, north side of Nānākuli Valley

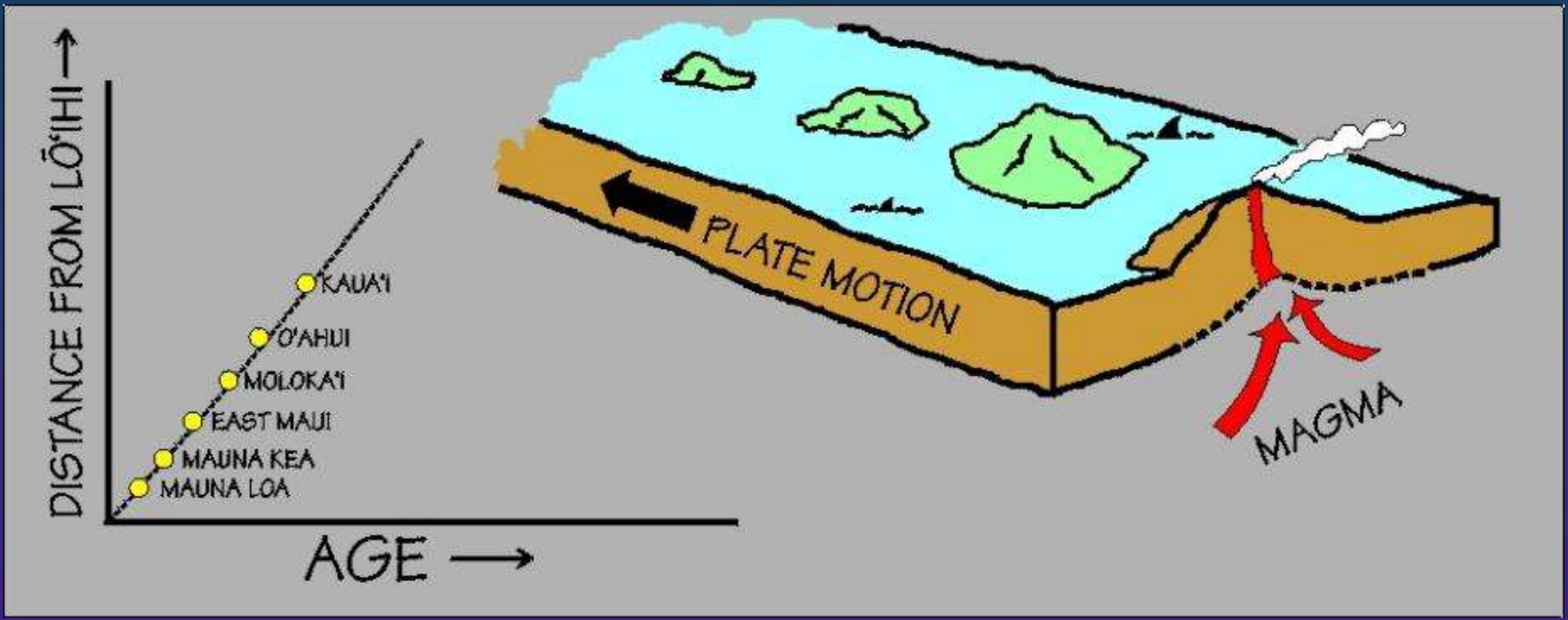
Upper flows
(thicker, weather to light grey)

Lower flows
(thinner, weather to red-brown)

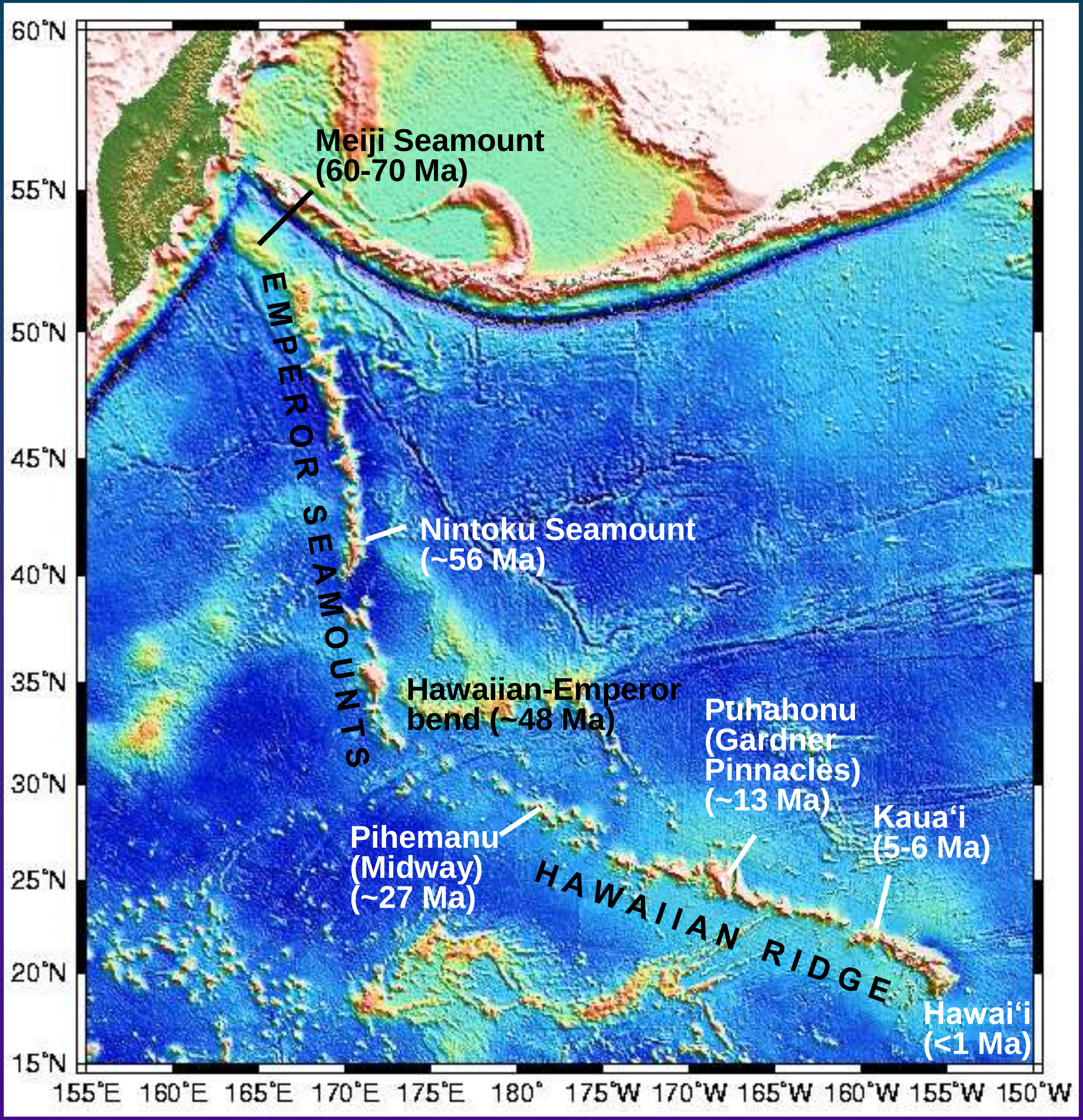
Slide by John Sinton

Photo by John Sinton

The “production line” model of Hawaiian volcano evolution...

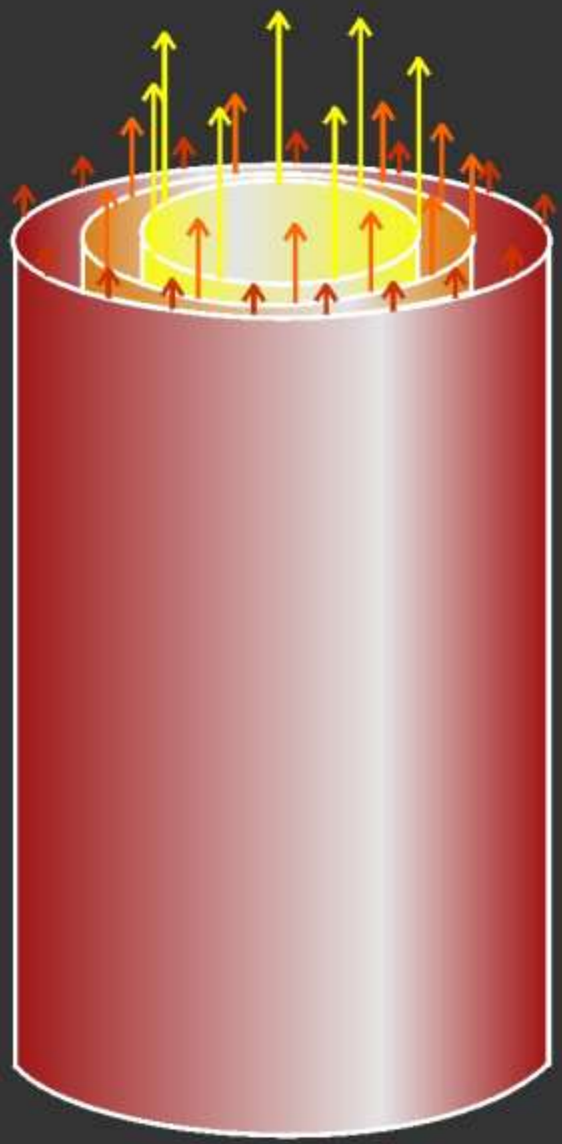


Hotspots on Earth (continents seem to avoid them)



Meiji Seamount
(60-70 Ma)
EMPEROR SEAMOUNTS
Nintoku Seamount
(~56 Ma)
Hawaiian-Emperor
bend (~48 Ma)
Pūhāhonu
(Gardner
Pinnacles)
(~13 Ma)
Pihemanu
(Midway)
(~27 Ma)
Kaua‘i
(5-6 Ma)
HAWAIIAN RIDGE
Hawai‘i
(<1 Ma)
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
15°N
155°E 160°E 165°E 170°E 175°E 180° 175°W 170°W 165°W 160°W 155°W 150°W

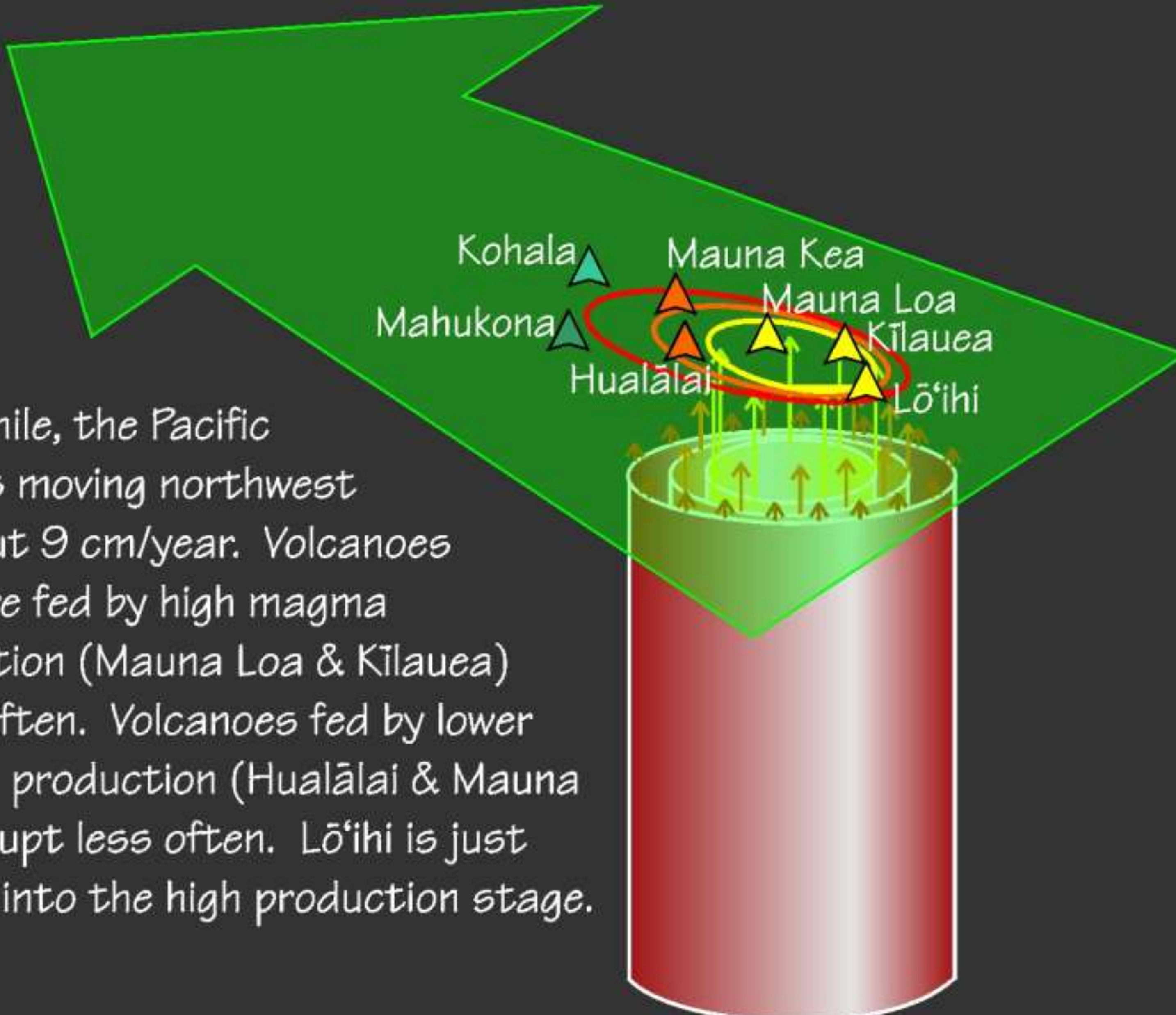
--diagram by Chuck Blay & Robert Siemers



A "hotspot", as we know it, is an upward-moving cylinder of solid mantle material.

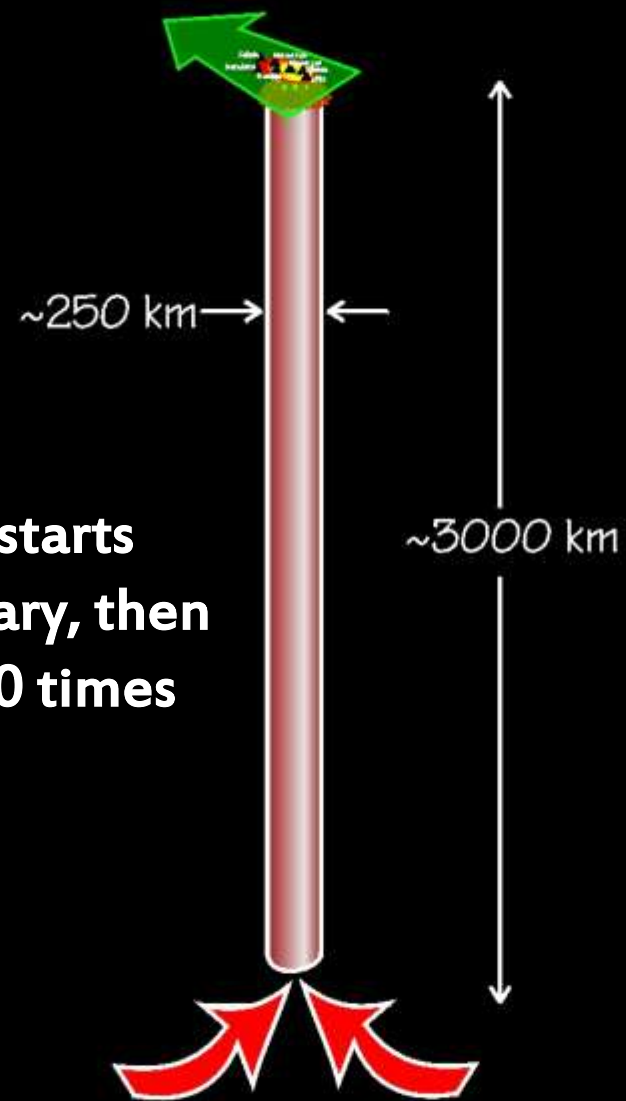
The material in the center moves the fastest and therefore finds itself out of equilibrium the most. In turn, it melts to the greatest degree. Volcanoes fed by this part erupt tholeiite basalt and erupt often.

The outer part moves the slowest and only melts a little bit. Volcanoes fed by this region erupt alkalic basalt and erupt infrequently.



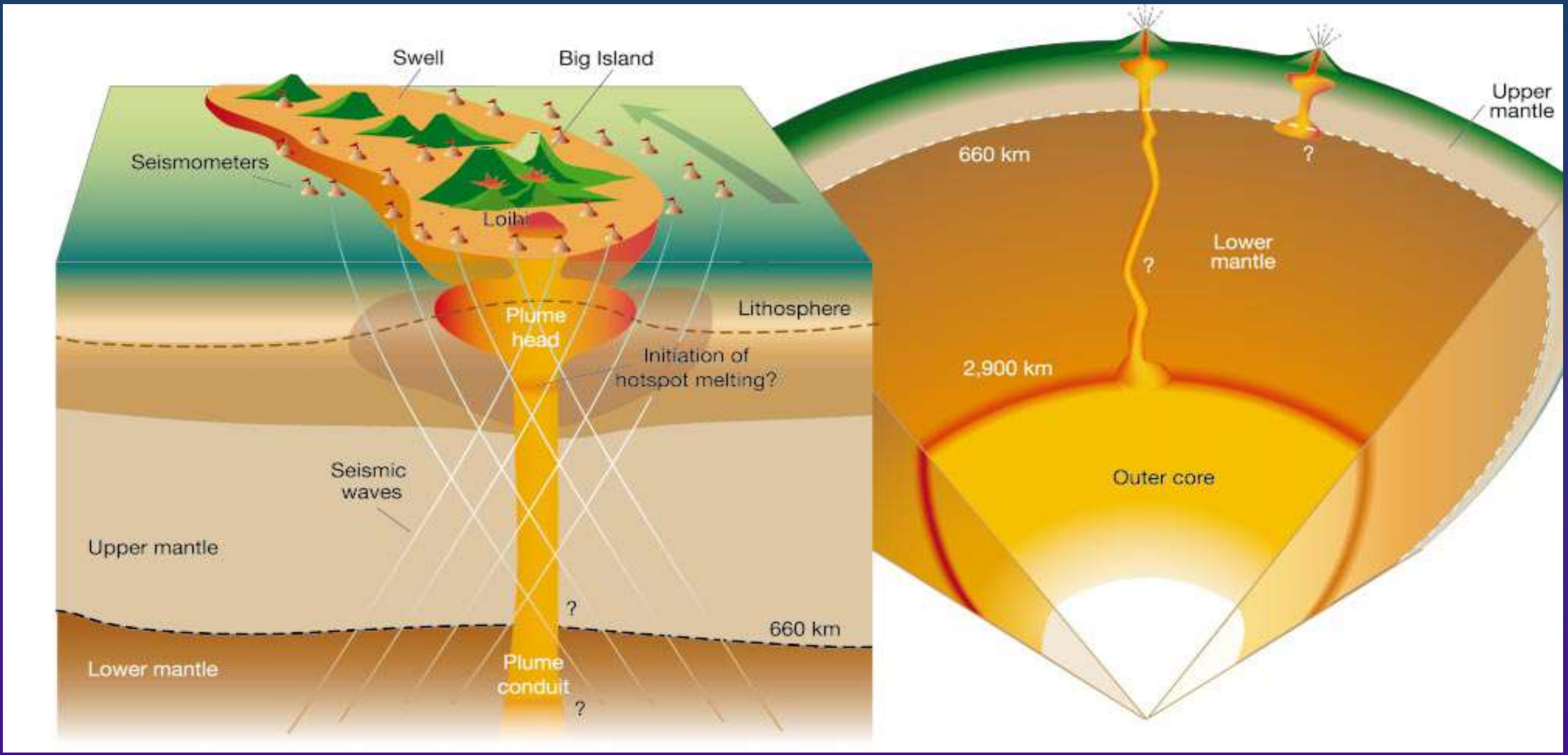
Meanwhile, the Pacific Plate is moving northwest at about 9 cm/year. Volcanoes that are fed by high magma production (Mauna Loa & Kīlauea) erupt often. Volcanoes fed by lower magma production (Hualālai & Mauna Kea) erupt less often. Lōʻihi is just moving into the high production stage.

A “HOTSPOT” IS PROBABLY MORE LIKE A “HOT COLUMN”



In reality, if the upwelling starts at the core-mantle boundary, then a "hotspot" is more than 10 times as tall as it is wide.

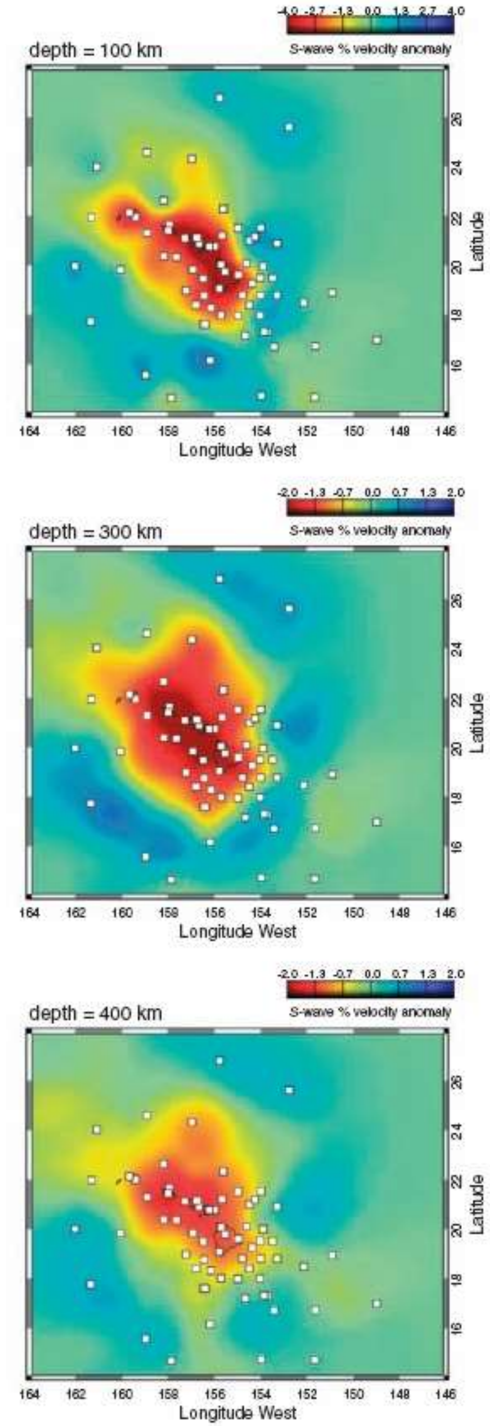
DIAGRAM SHOWING HOW SEISMIC WAVES FROM DISTANT EARTHQUAKES PASS UPWARDS TO HAWAI‘I SEISMOMETERS. IF THEY DON’T PASS THROUGH HOT ROCK, THEY ARRIVE WHEN EXPECTED. IF THEY DO PASS THROUGH HOT ROCK (I.E., THE HOTSPOT) THEY ARE SLOWED AND ARRIVE LATE.



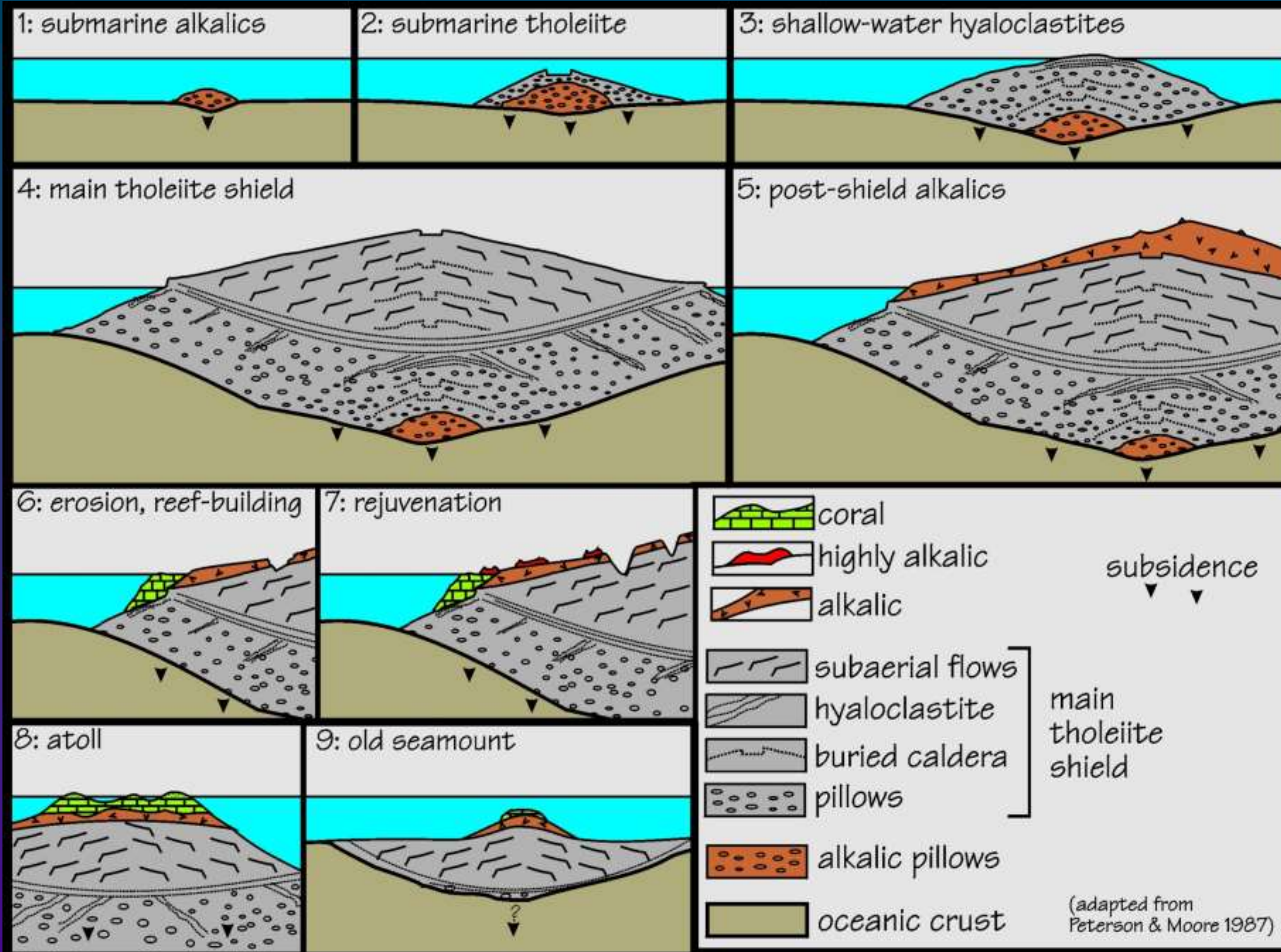
http://www.higp.hawaii.edu/~cecily/plume.nature.pdf

NATURE|VOL 421 | 2 JANUARY 2003 |www.nature.com/nature

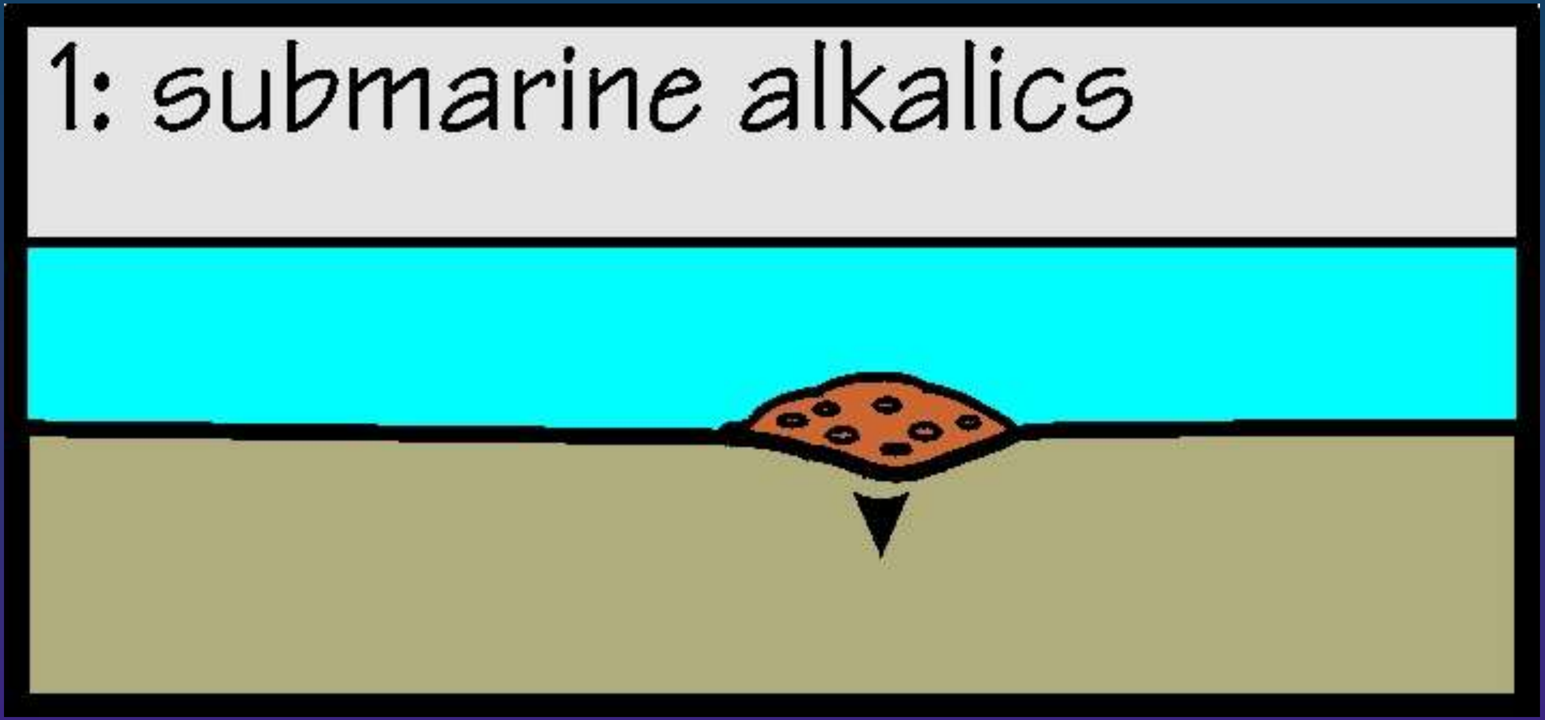
SEISMIC TOMOGRAPHY DATA SHOWING ANOMOLOUS SLOWING OF S-WAVES UNDER HAWAI‘I. THE INTER-PRETATION IS THAT THESE WAVES ARE SLOWED BY THE PRESENCE OF ANOMALOUSLY HOT ROCK (THE HOTSPOT)



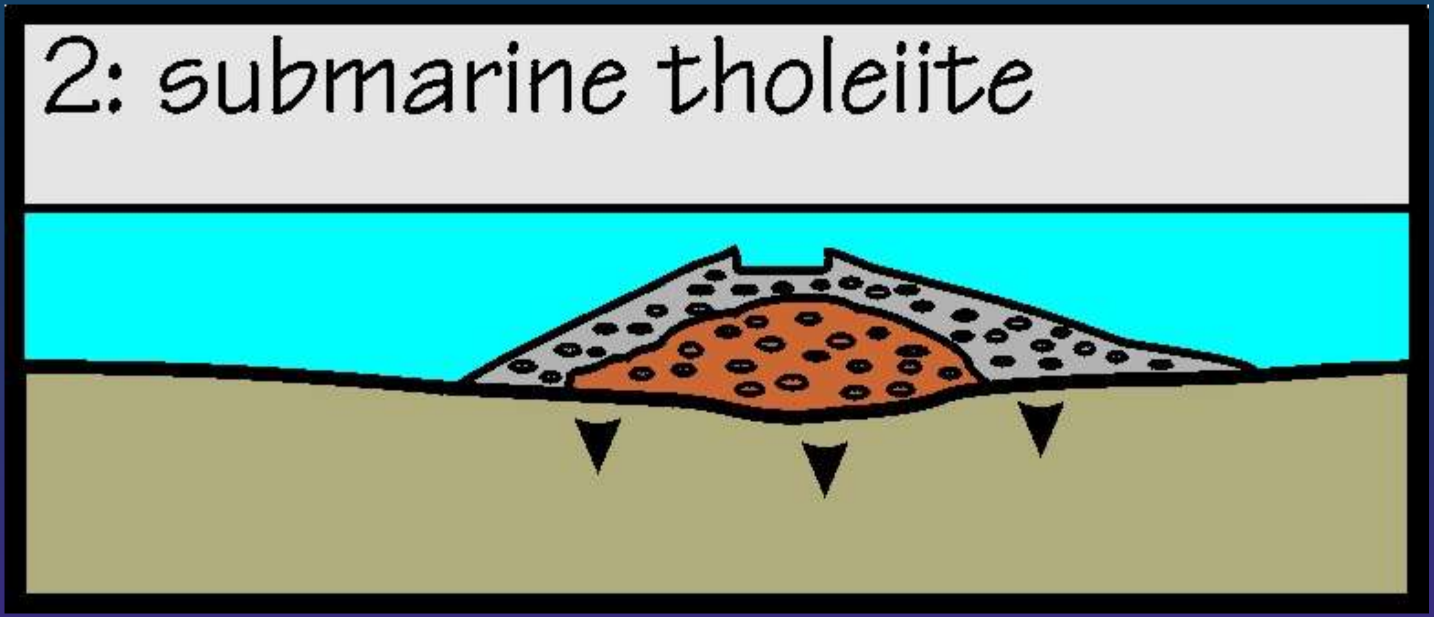
Wolfe *et al*. (2009), Science vol. 326, pp. 1388-1390



adapted from Peterson & Moore (1987)

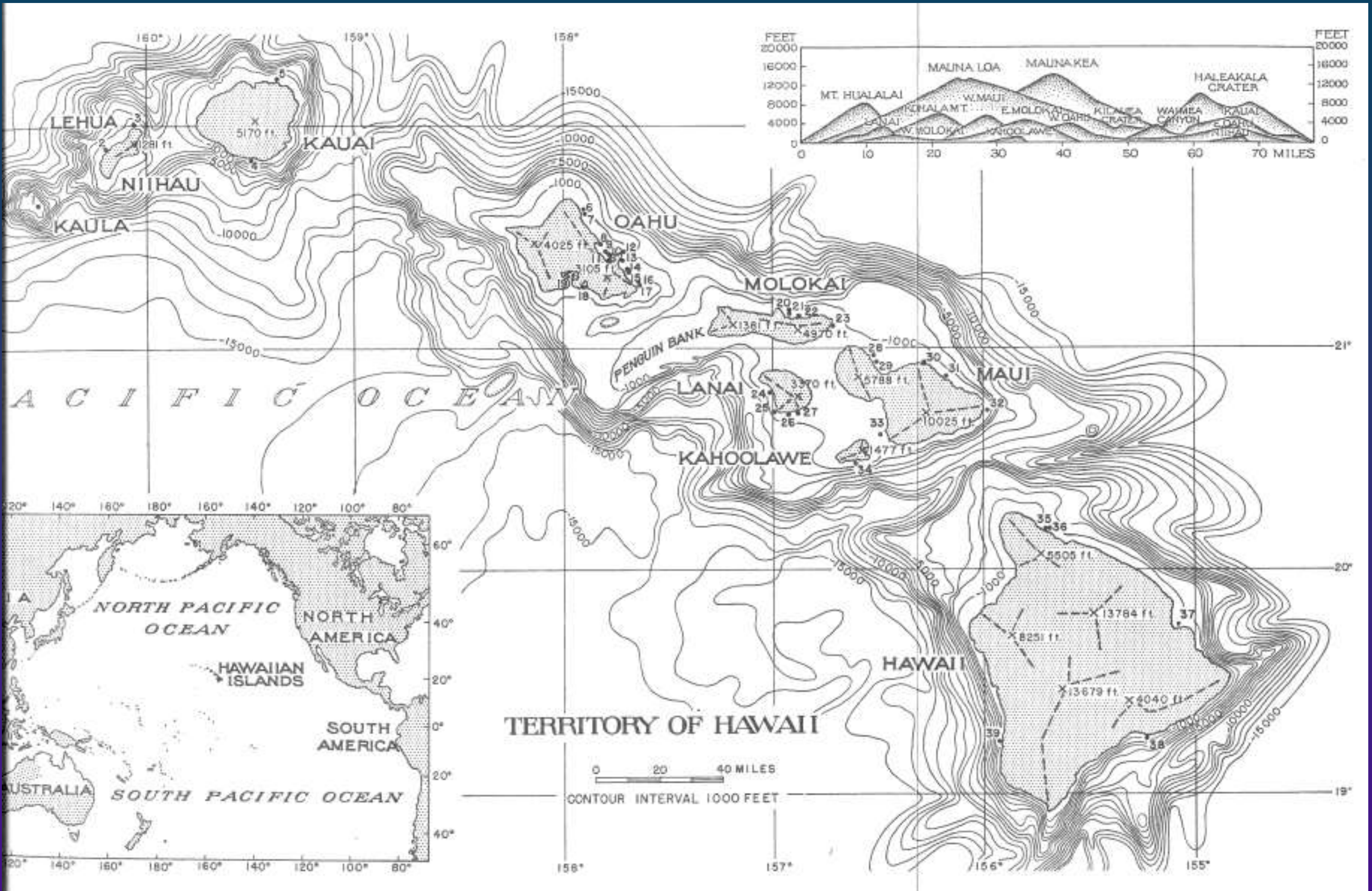


-melting is just getting going
-alkalic basalt composition
-water pressure prevents explosive activity
-no current Hawaiian examples



-magma production becoming more efficient
-tholeiite composition
-water pressure prevents explosions
-caldera and rift zones developing
-Lōʻihi

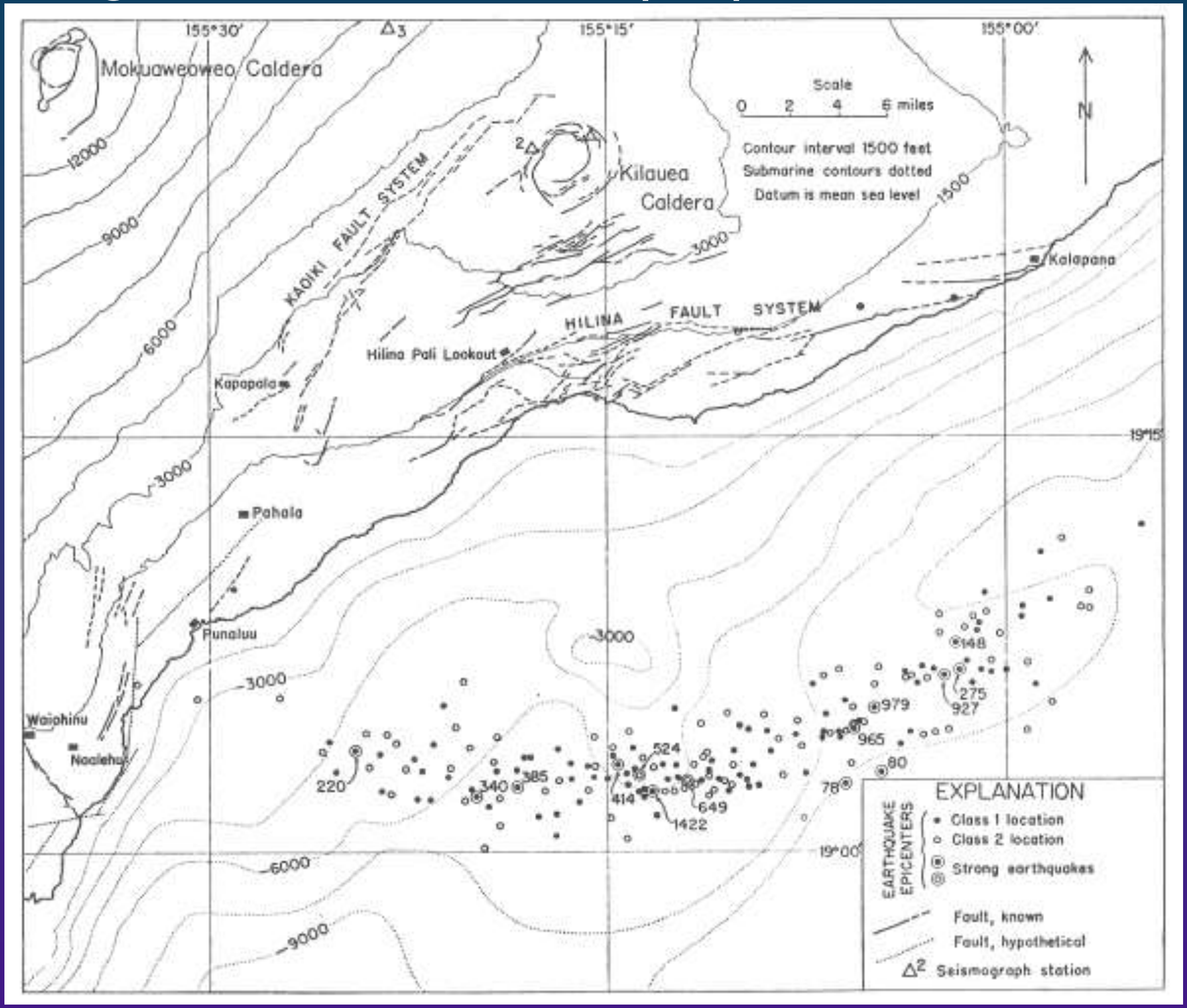
The first bathymetric map to show (but not identify) Lōʻihi



MAP OF THE LARGER ISLANDS OF HAWAII, THEIR KNOWN RIFT ZONES, SUBMARINE CONTOURS IN FEET, AND PRINCIPAL ISLETS. (Explanation of numbers on facing page.)

Stearns HT (1946) Geology of the Hawaiian Islands. Hawaii Div Hydrography Bulletin 8

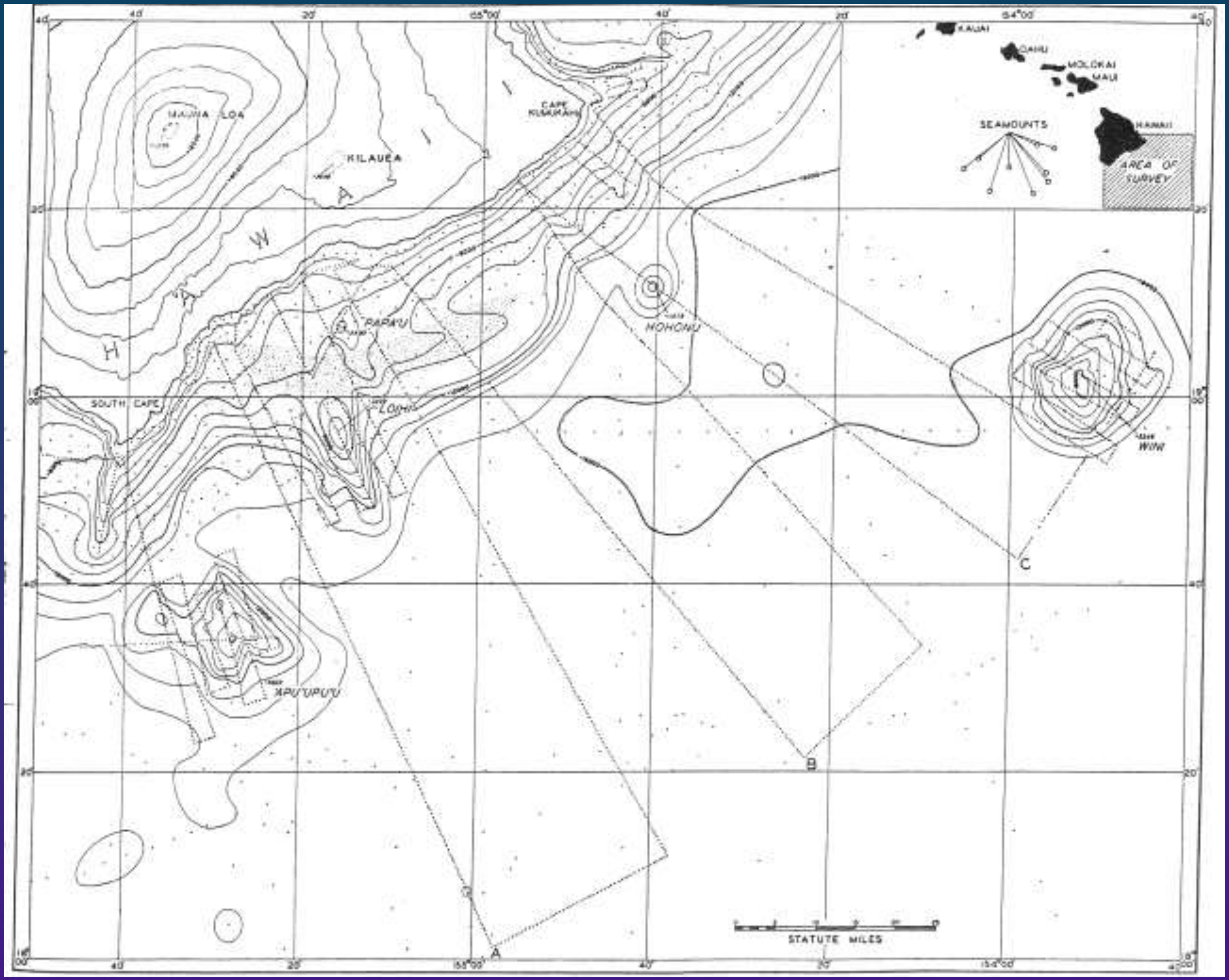
Earthquake data from March and April, 1952, young volcano idea first proposed



“Submarine contours…show a broad dome with its apex 21 miles nearly due south of the summit of Kilauea volcano…This dome is probably a shield volcano, lying against the side of the Kilauea shield just as Kilauea does against the side of Mauna Loa.”

Macdonald GA (1952) The South Hawaii earthquakes of March and April, 1952. *The Volcano Letter* 515:3-5

Lōʻihi gets a name

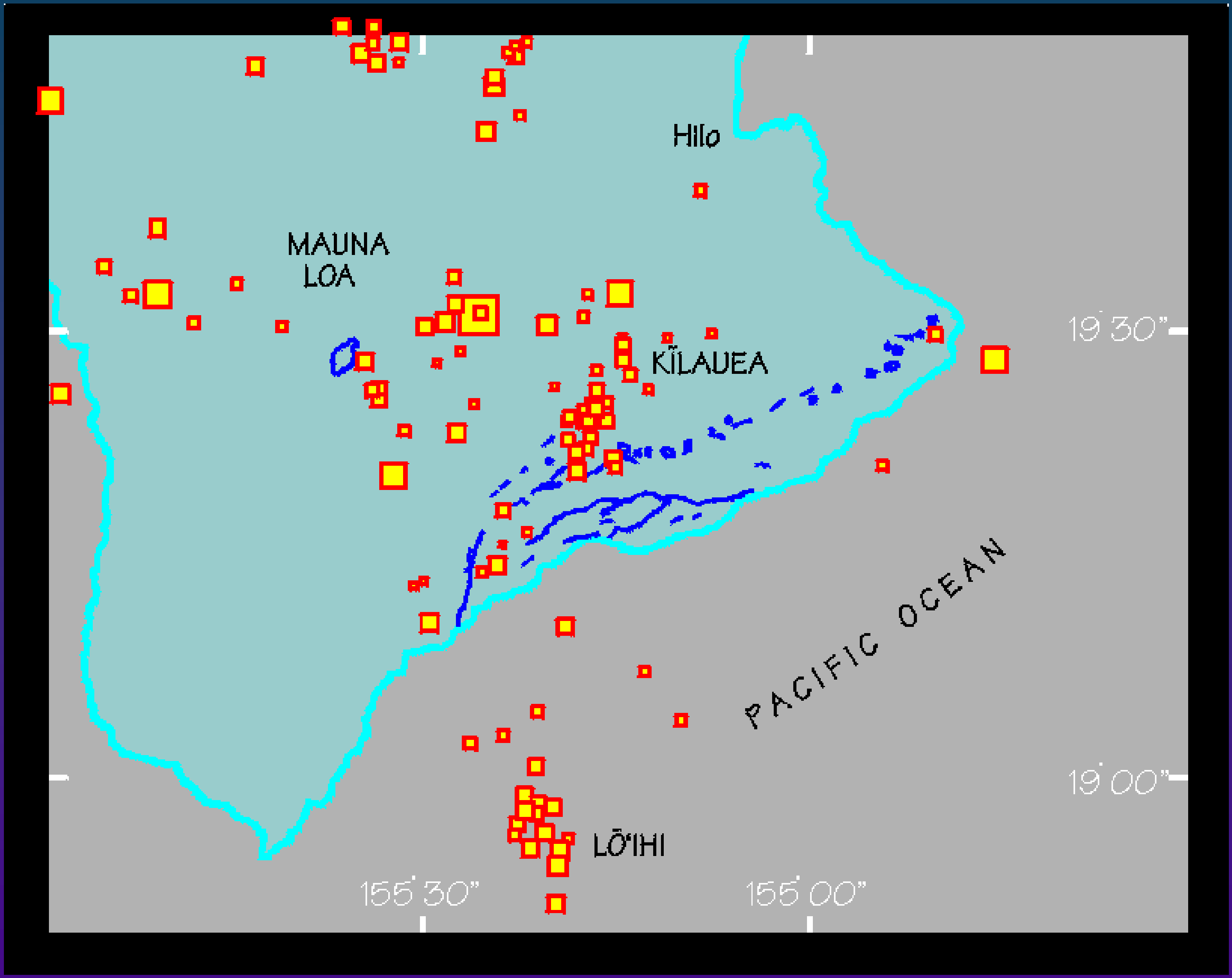


"One of the seamounts (Wini – "coming to a point, sharp pointed") is conical in shape, one (Loihi – "to extend, to be long") is elongate, one (ʻApuʻupuʻu – "a rough, uneven surface, such as a hillock" is irregular with several peaks, and the other two smaller ones (Hohonu and Papaʻu – "to be shallow, as water") are of uncertain shape, possibly conical"

Emory KO (1955) Submarine topography south of Hawaiʻi. Pacific Science 9:286-291

‘Keiki ‘ehu kama ‘ehu a Kanaloa,’” she explains. “‘The reddish child, the reddish child of Kanaloa,’ who is the deity of the ocean.” *Hānau Ka Moku*, a chant by Hālau O Kekuhi

Earthquakes between 20 and 24 km depth from 1970 to 1983

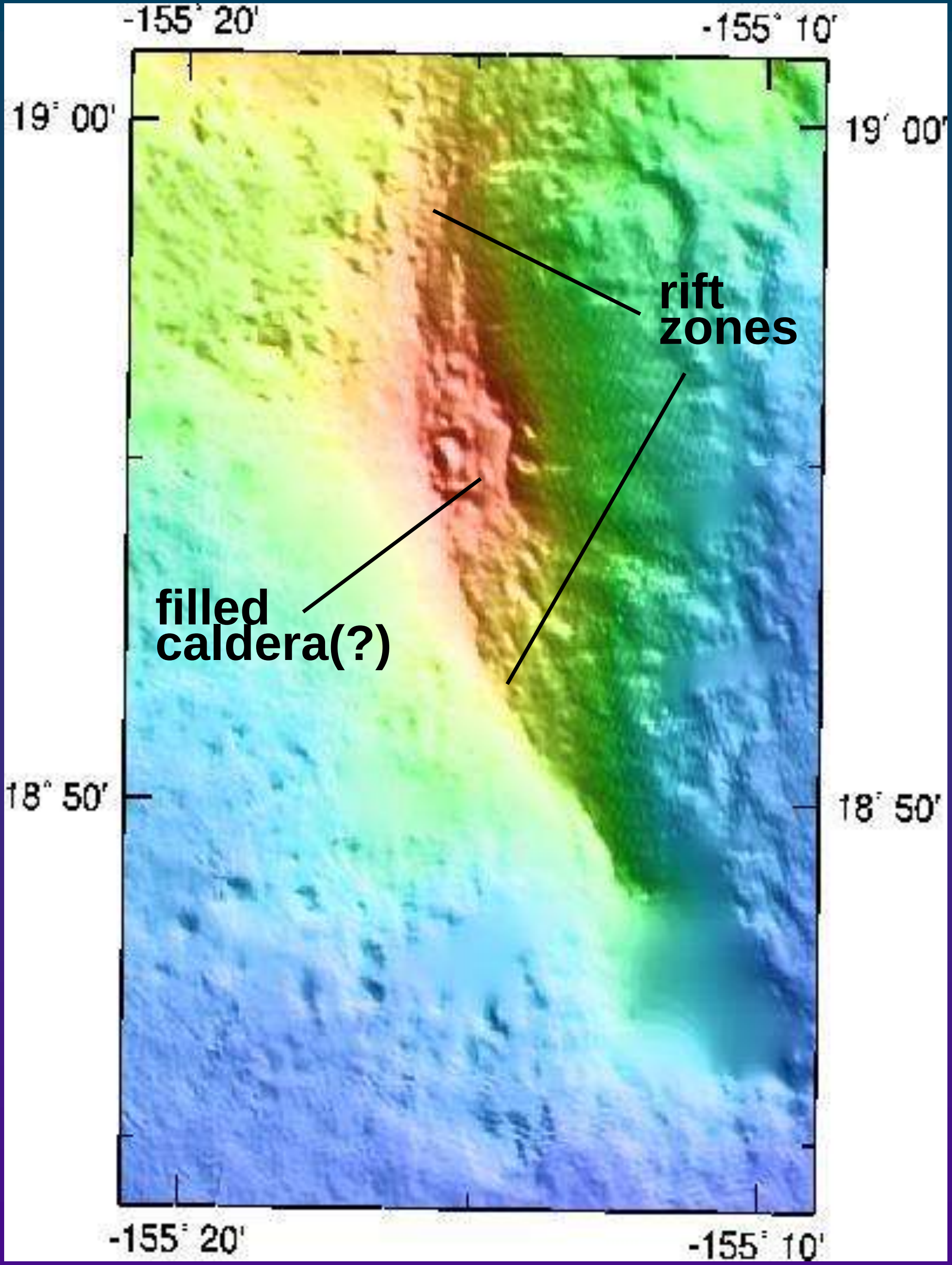


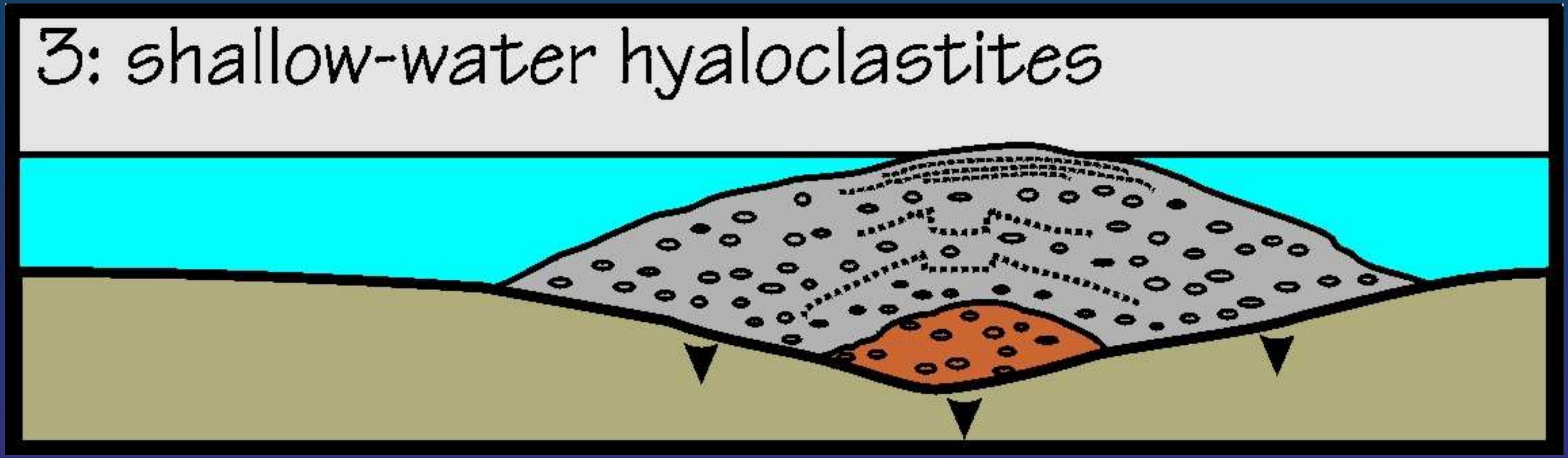
(Klein *et al*. 1987)

pillow lavas on Lōʻihi, viewed from the ALVIN submersible

talus on the upper flanks of Lōʻihi, viewed from ALVIN

Bathymetry of Lōʻihi, compiled by the Hawaiʻi Mapping Research Group



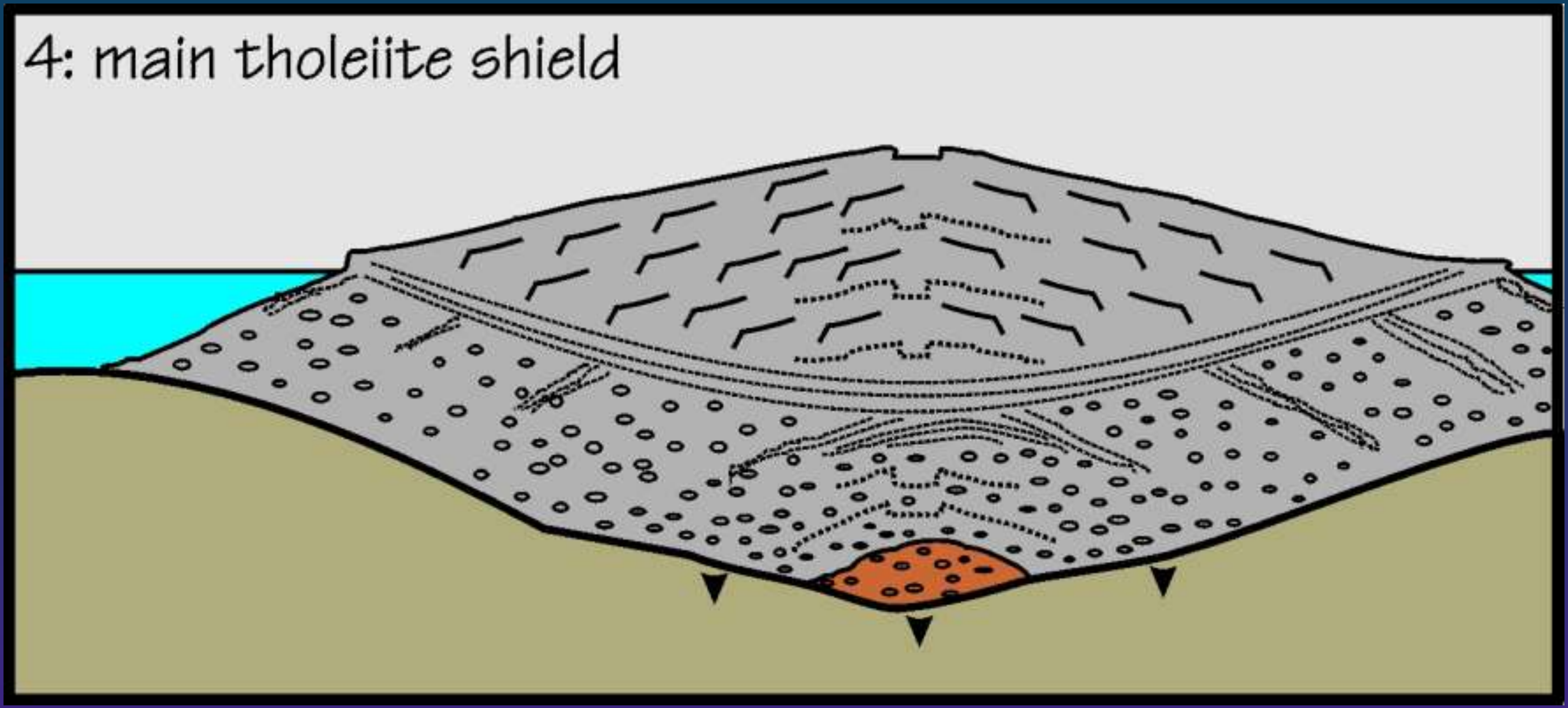


-high magma production rate continues
-shallow water depth no longer prevents explosive activity
-no current Hawaiian examples

Violent interaction of erupting magma and shallow ocean water

Nuku‘alofa eruption, Tonga, March 2009

http://deems.files.wordpress.com/2009/03/bigpicture_2009_03_volcano.jpg



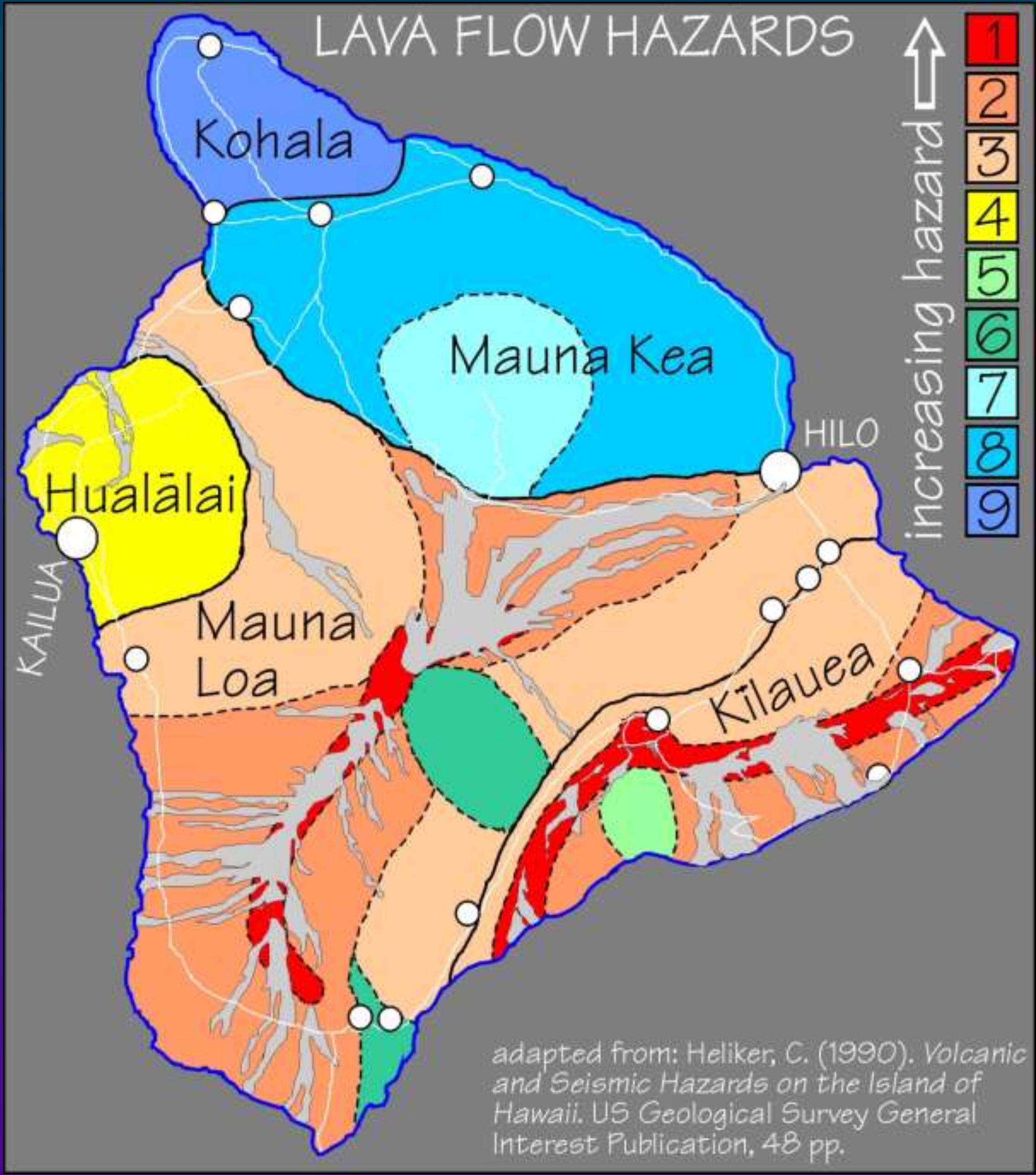
- magma production rate at highest level
- alternating infilling and re-forming of caldera
- ‘a‘ā and pāhoehoe flows
- Kīlauea and Mauna Loa

Mauna Loa, viewed from Kīlauea

~400 m-high fountain, Puʻu ʻŌʻō, Kīlauea, April 1985

Topography of Mauna Loa’s SW rift zone (dark flows post-date 1778)

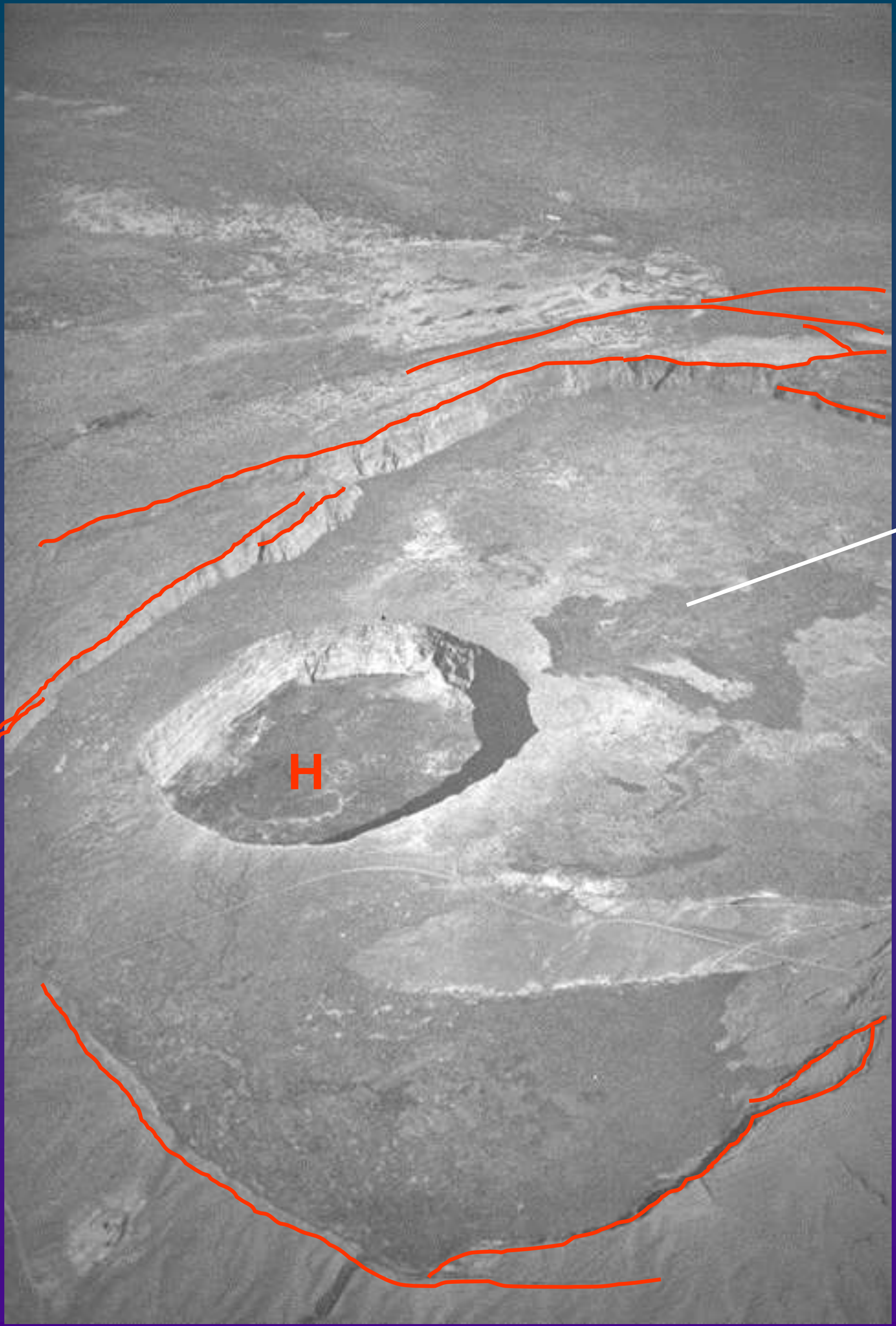
IS THERE A NON-GEOLOGY REASON TO CARE ABOUT THE FACT THAT FLANK ERUPTIONS ON HAWAIIAN VOLCANOES ALMOSTALWAYS OCCUR FROM RIFT ZONES?



Of course !!

Kīlauea caldera:

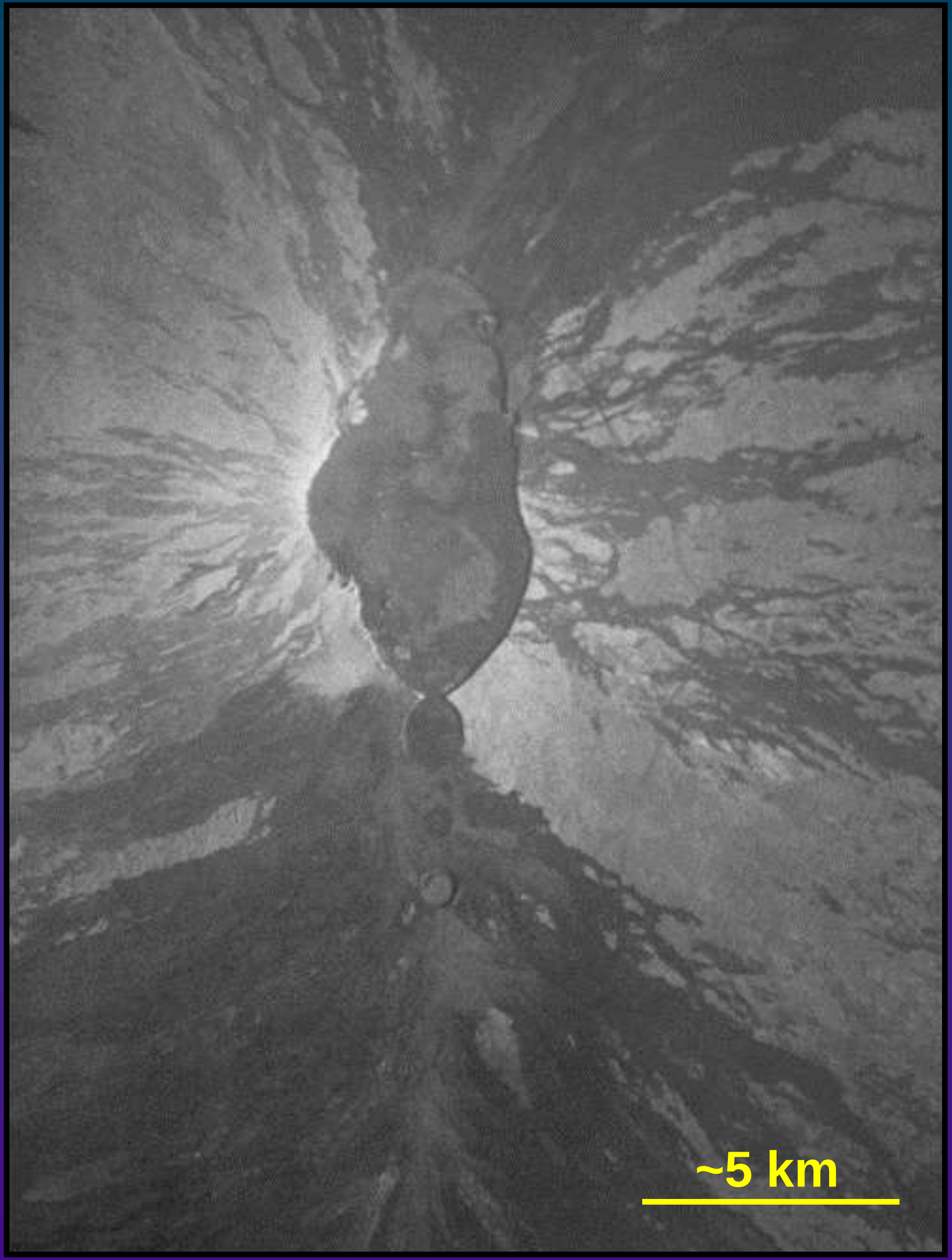
Complex caldera-boundary faults, and Halema‘uma‘u, (H) an intra-caldera pit crater



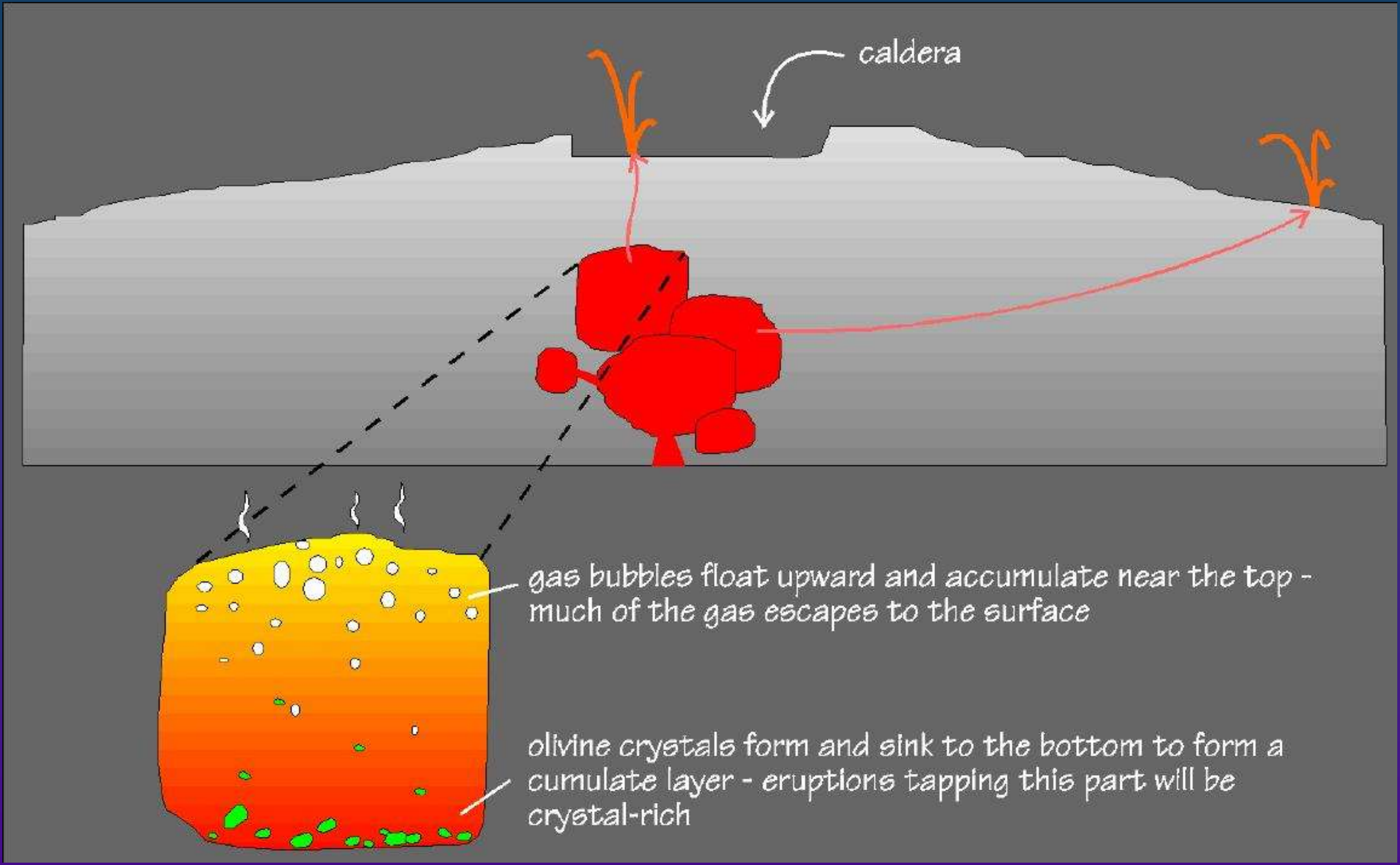
1954 lava flow

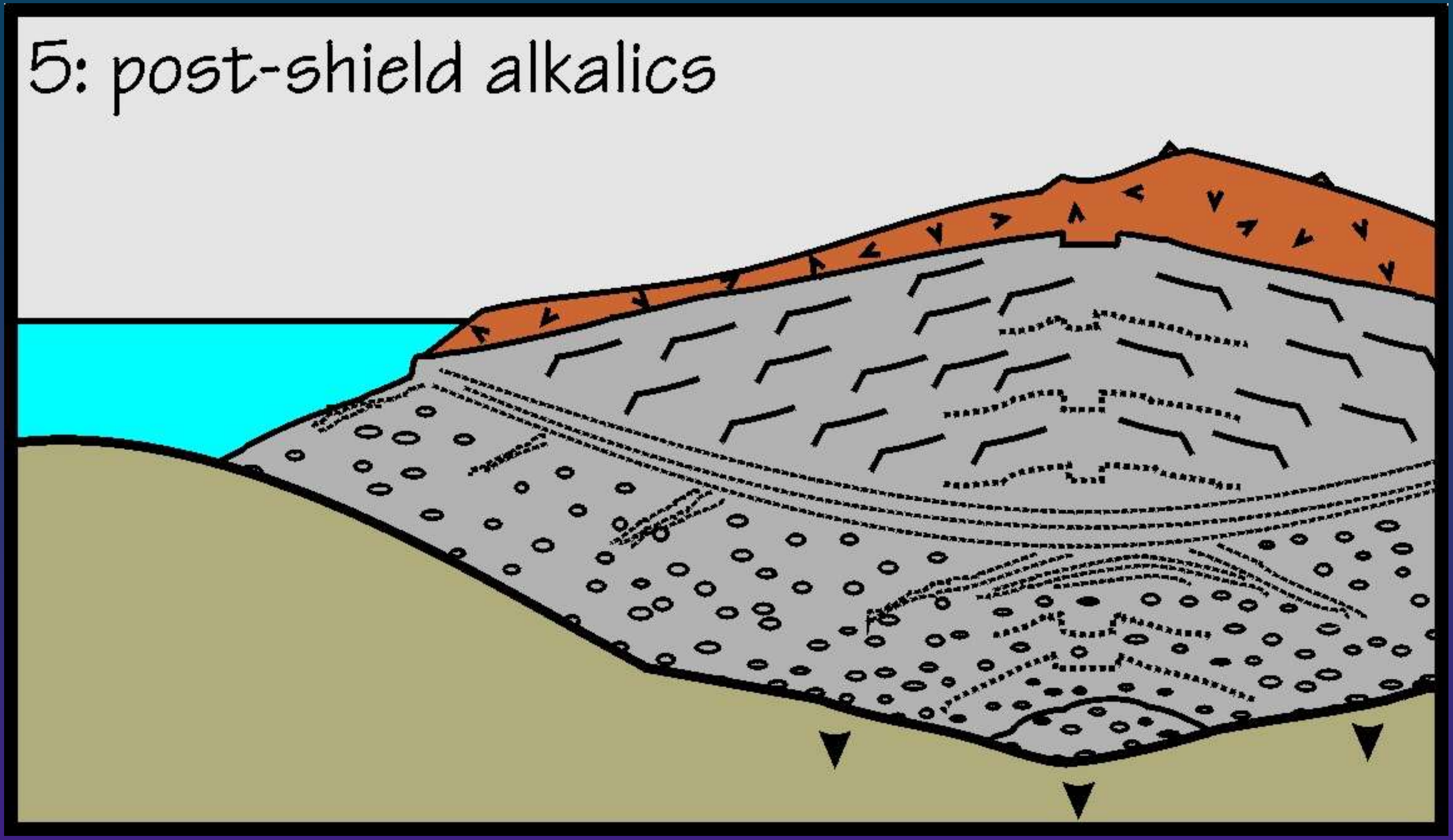
Vertical air photo of Moku‘āweoweo, the summit caldera of Mauna Loa.

Note flows truncated by caldera margin.



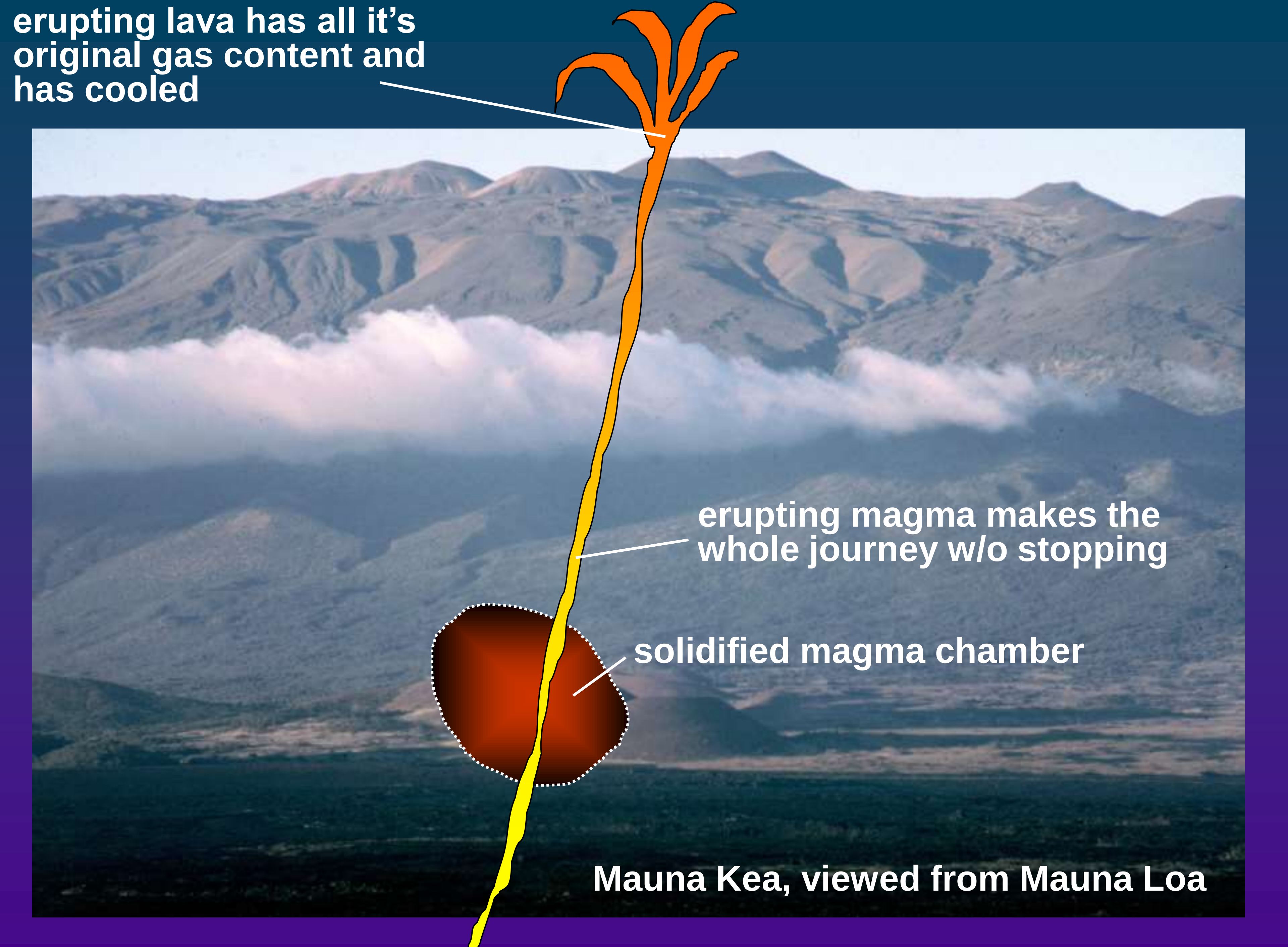
Magma chamber processes, as long as there is sufficient supply to keep the magma chamber from solidifying

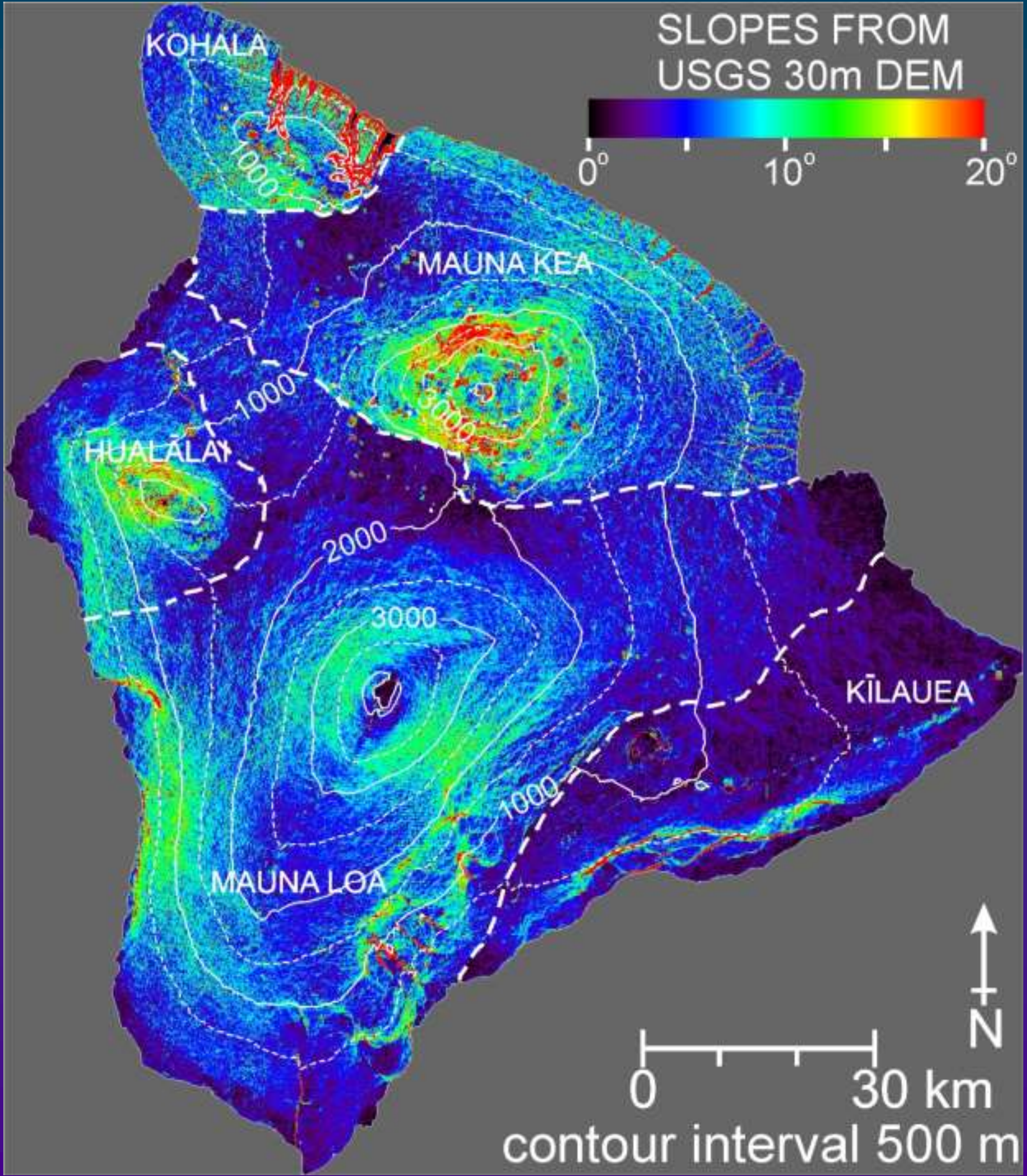




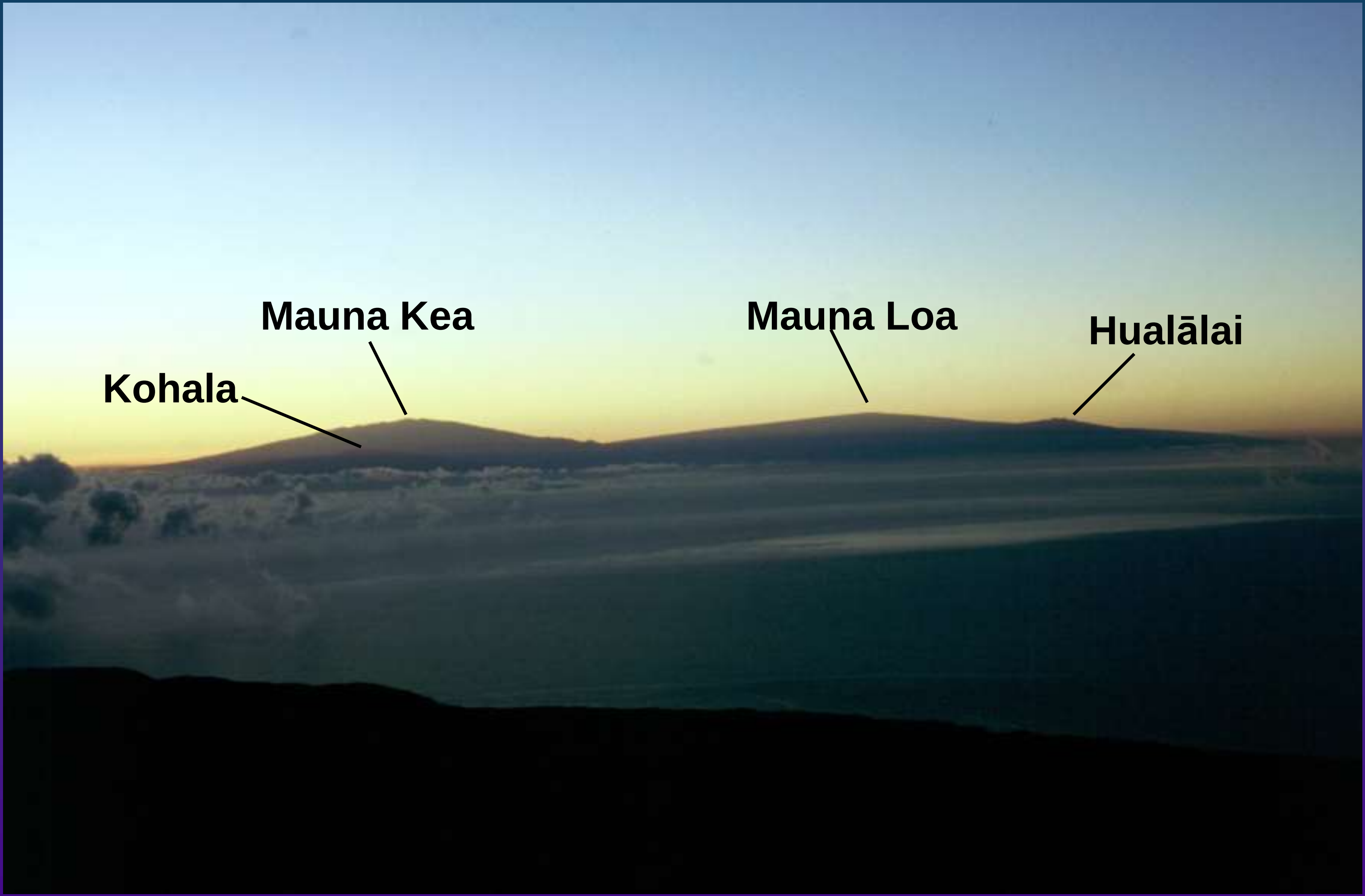
- volcano moves off hotspot
- magma production declines
- alkalic composition of magma
- magma chamber solidifies
- Hualālai, Mauna Kea

Mauna Kea, viewed from Hilo airport.

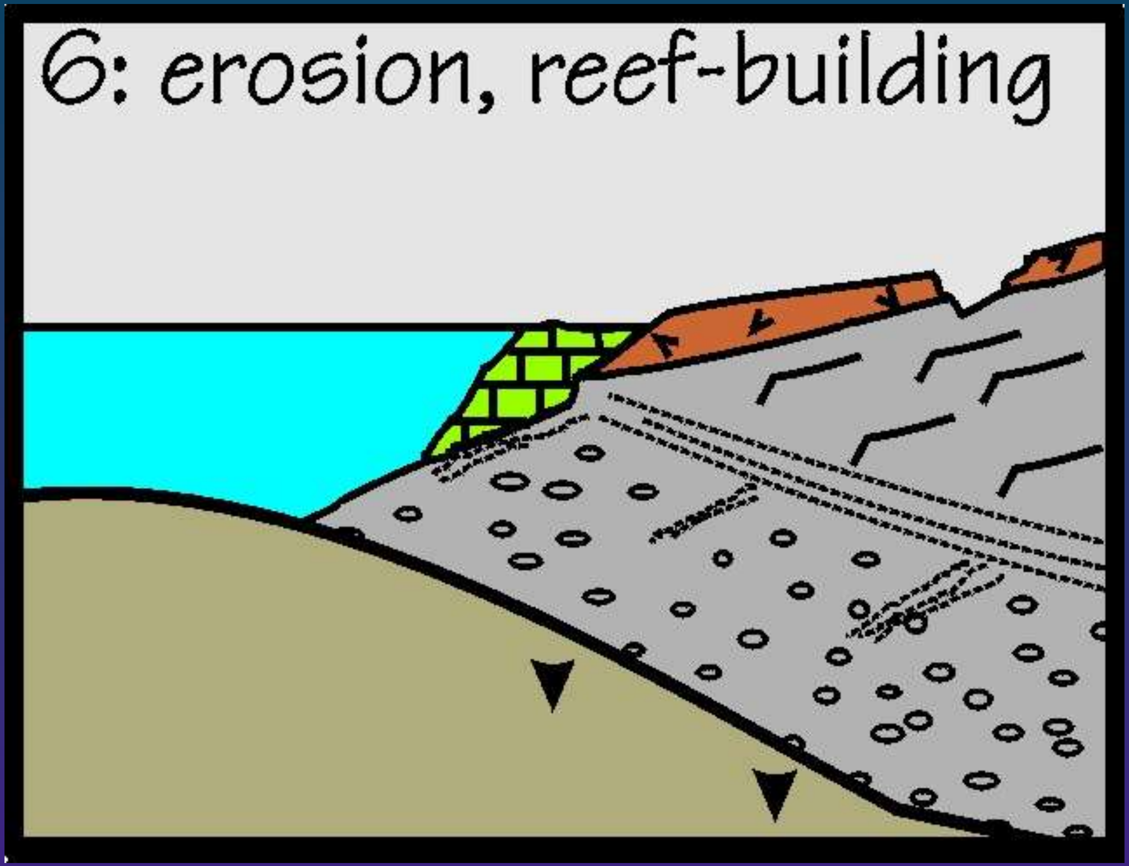

erupting lava has all it's original gas content and has cooled
erupting magma makes the whole journey w/o stopping
solidified magma chamber
Mauna Kea, viewed from Mauna Loa


SLOPES FROM
USGS 30m DEM
0°
10°
20°
KOHALA
1000
MAUNA KEA
1000
3000
HUALĀLAI
2000
3000
KĪLAUEA
1000
MAUNA LOA
N
0
30 km
contour interval 500 m

Hawai‘i, viewed from Maui



East Moloka‘i, viewed from the north.



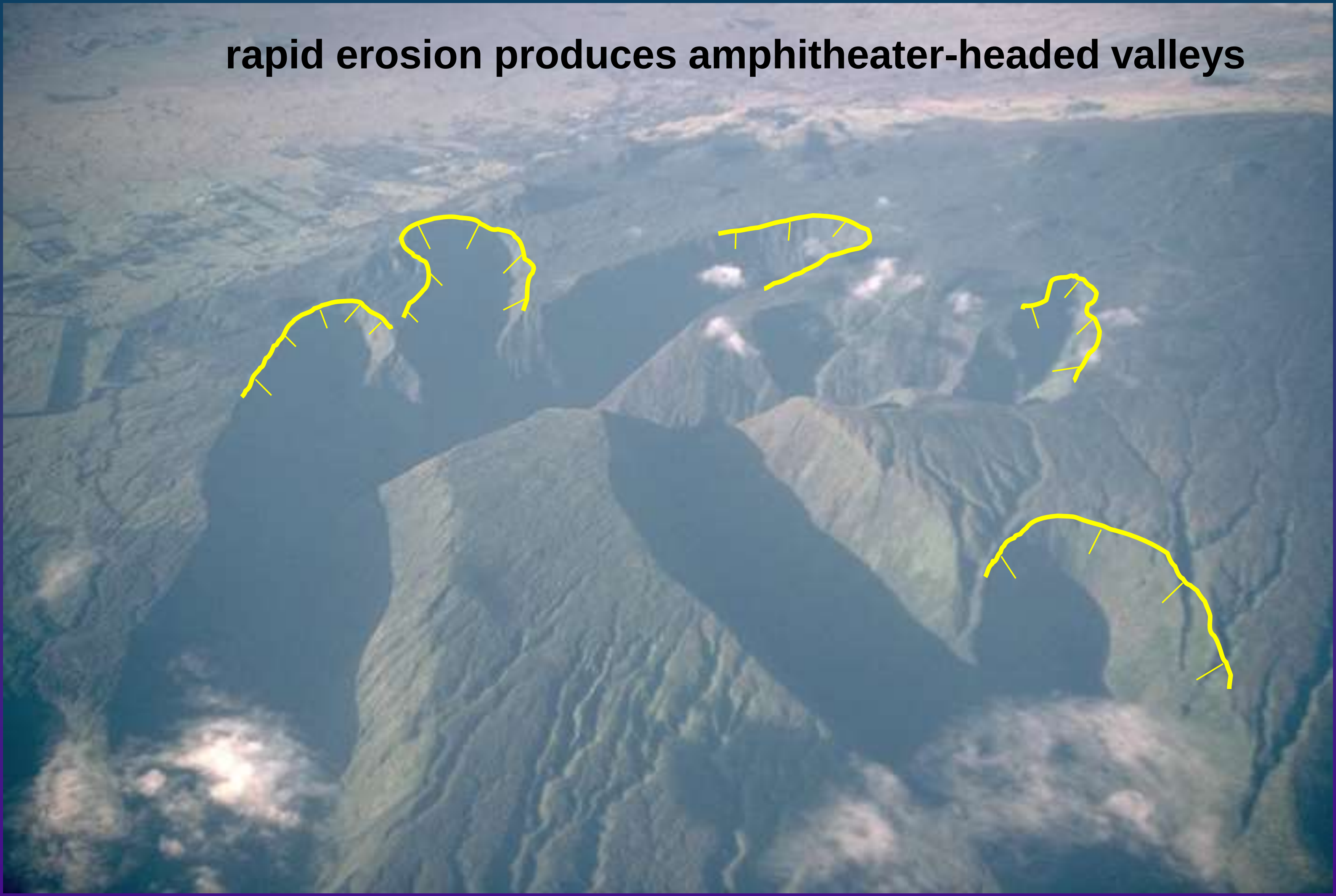
-volcano moves off hotspot
-erosion becomes dominant geological process
-extensive reefs develop
-Kohala

Mauna Kea's lower NE flank

Laupāhoehoe, Mauna Kea

peninsula formed from lava that flowed down a large stream valley

Waipi‘o and Waimanu valleys, Kohala volcano

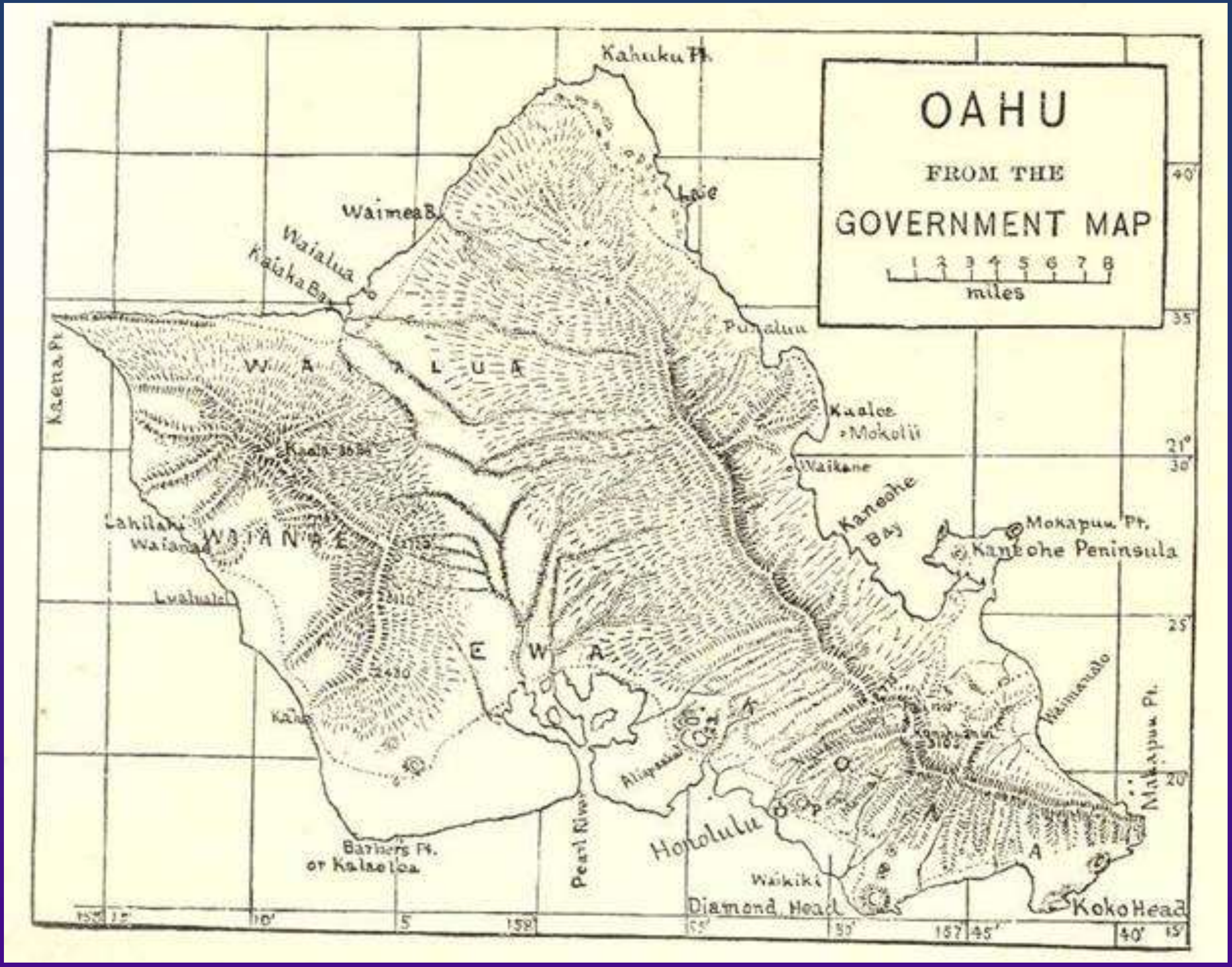


Extensive reef development on the S coast of East Moloka‘i

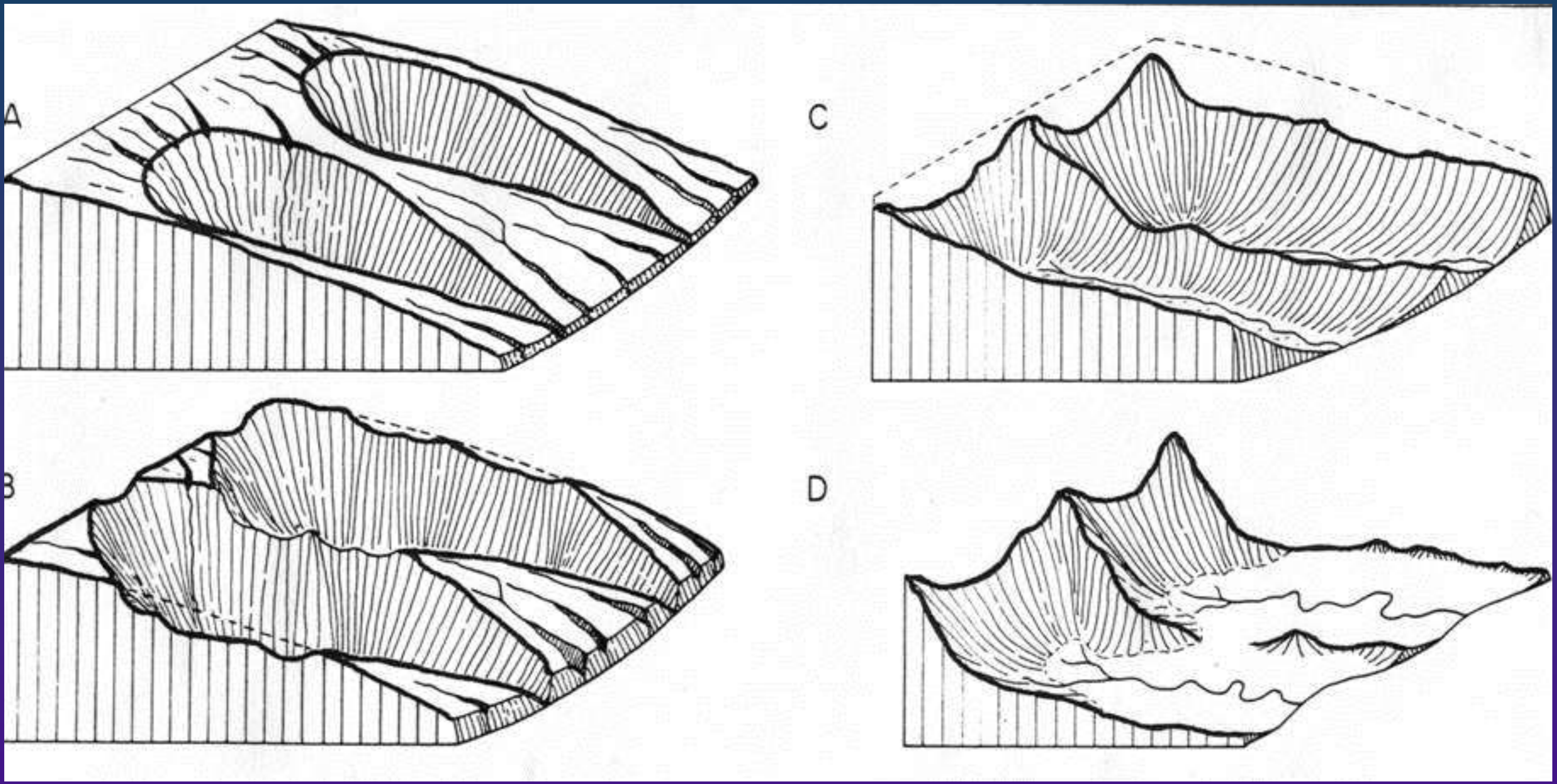
N coast of E. Moloka‘i

WHAT CAUSED THE HUGE PALI? FAULTING? MARINE EROSION? VALLEY EROSION? SOME COMBINATION OF THESE?

Dana (1890) "Thus such precipices are rather the rule in the Hawaiian group; and if seashore erosion is not the origin, - as many facts from the islands of the Pacific appear to show, - fractures and subsidence must be.

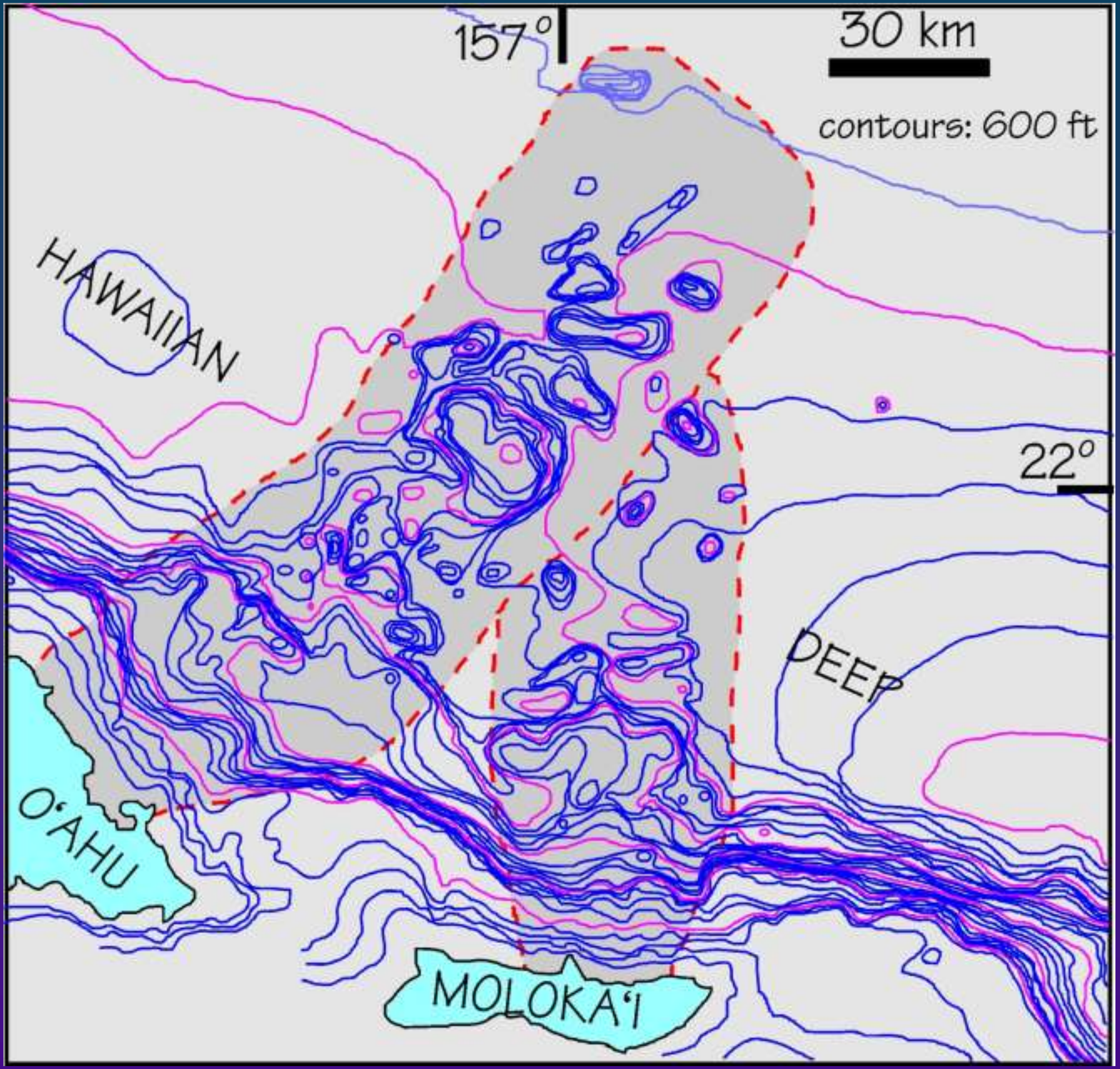


Formation of a cliff (that might be, or has been, mistaken for a fault or avalanche scarp) by coalescence of amphitheater-headed valleys

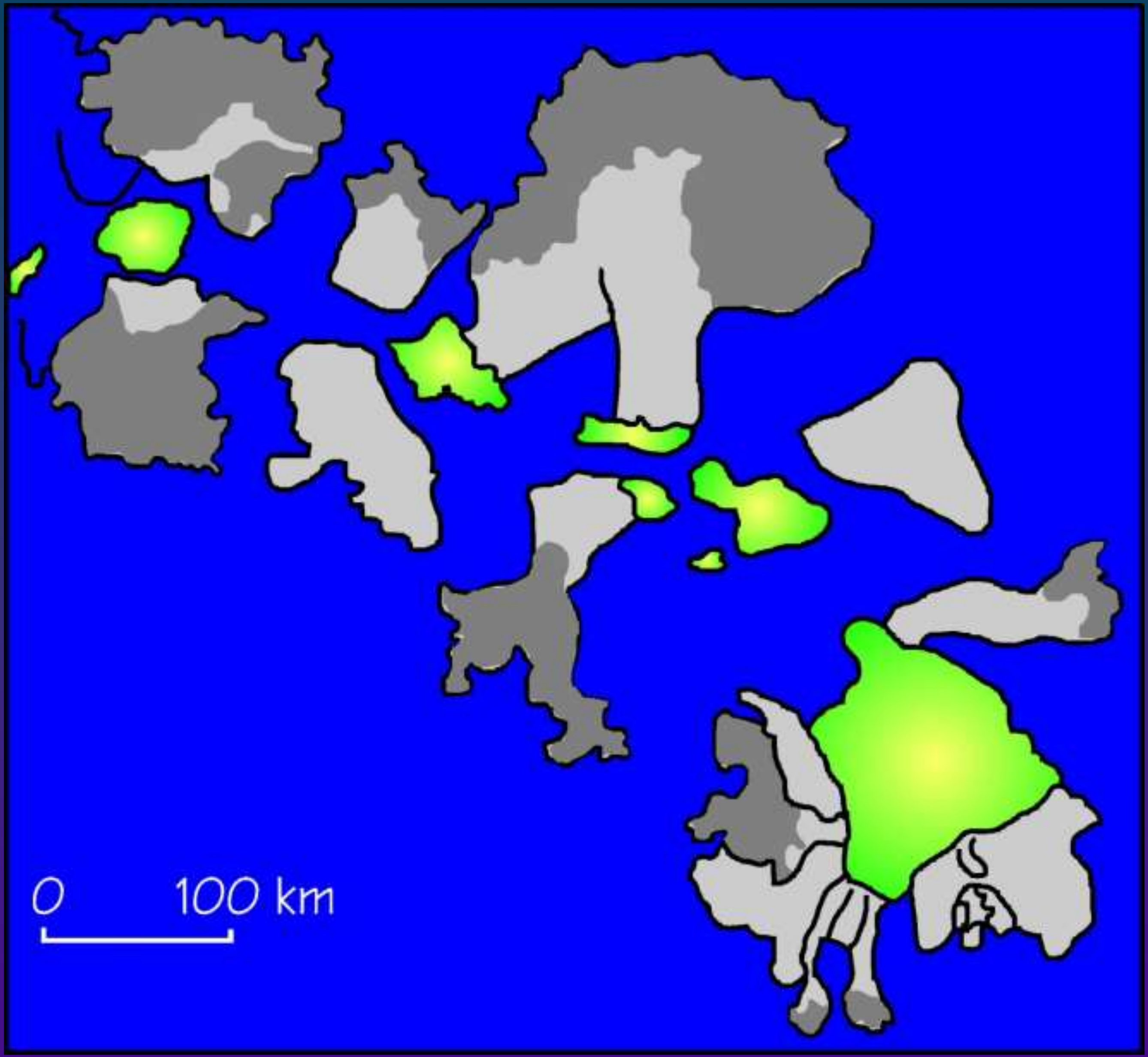


(Modified from Stearns & Vaksvik 1935)

Wai'anae volcano
Honolulu
Kalihi Valley
Lanihuli
Nu'uanu Valley
Kōnāhuanui
Wilson tunnel
Pali tunnel

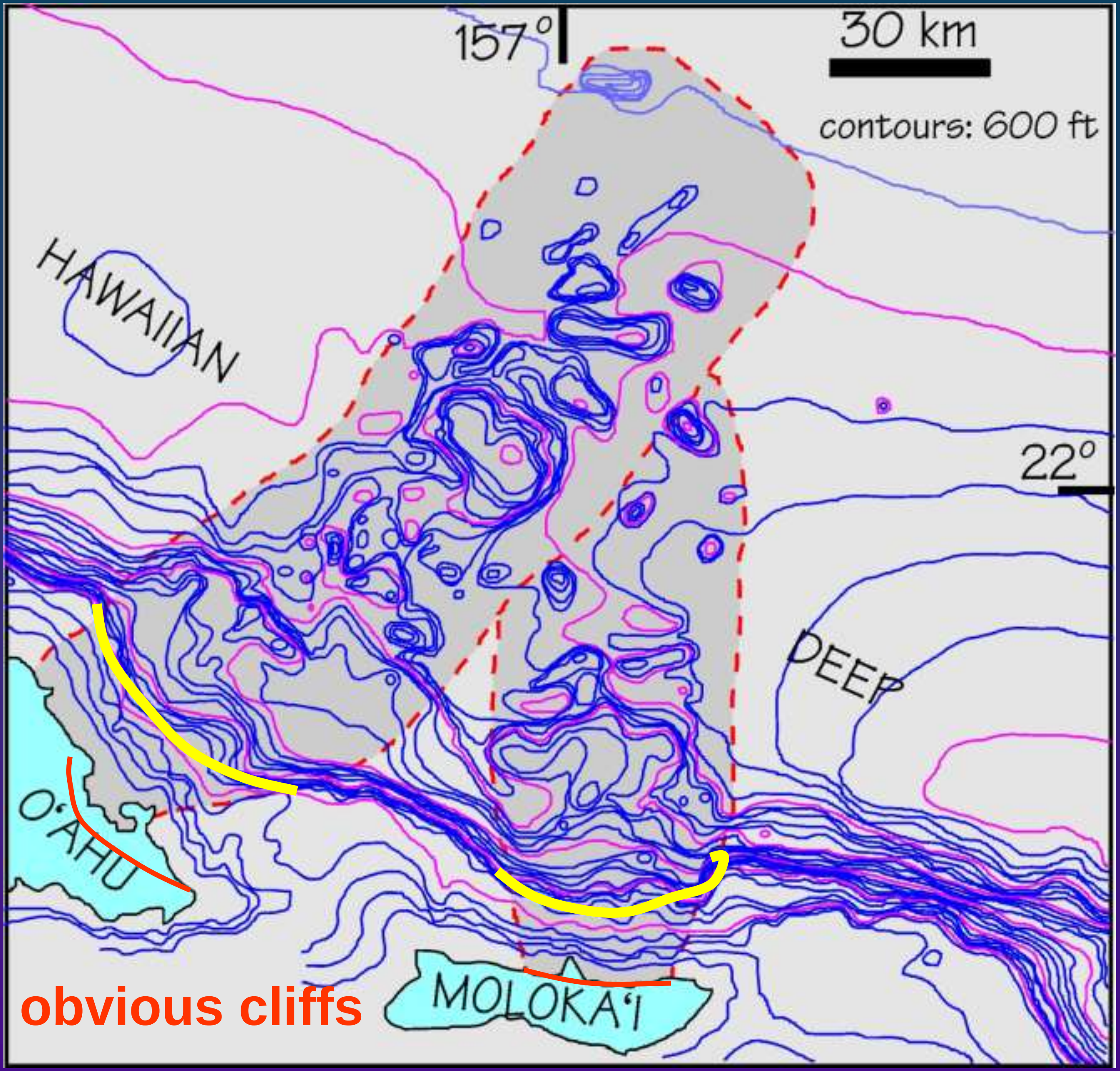


after Moore (1964)



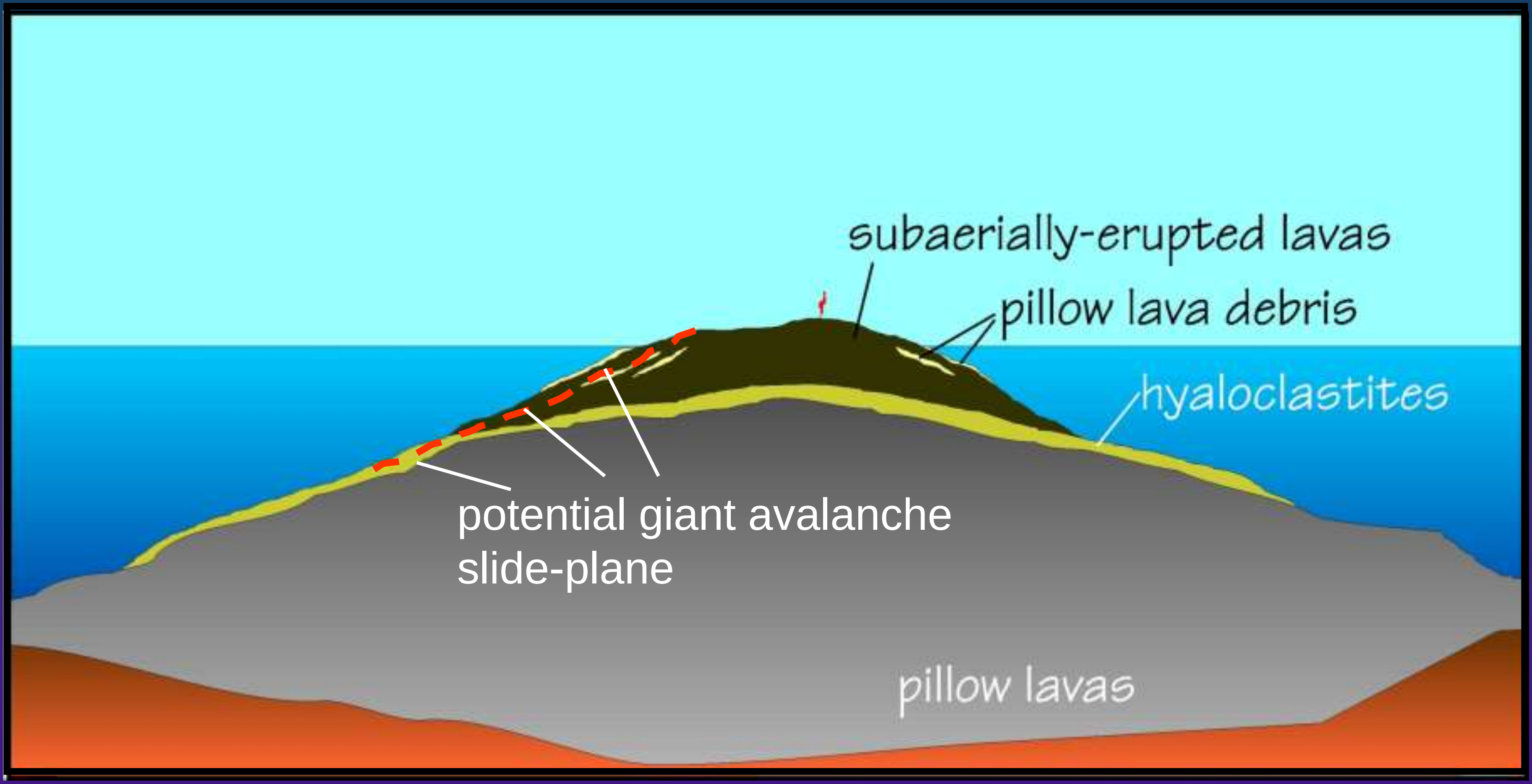
from Moore *et al*. (1989)

actual avalanche scarps

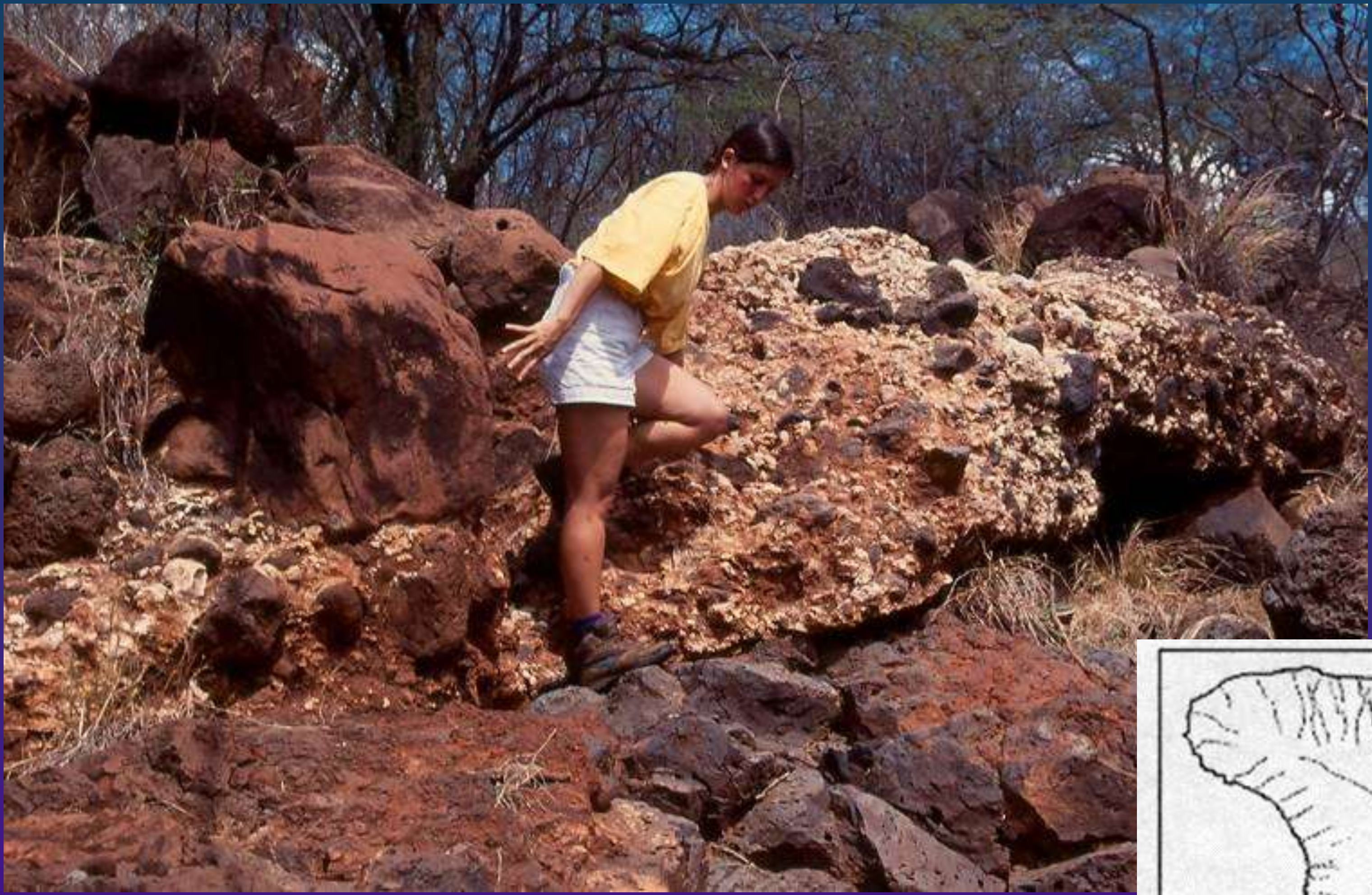


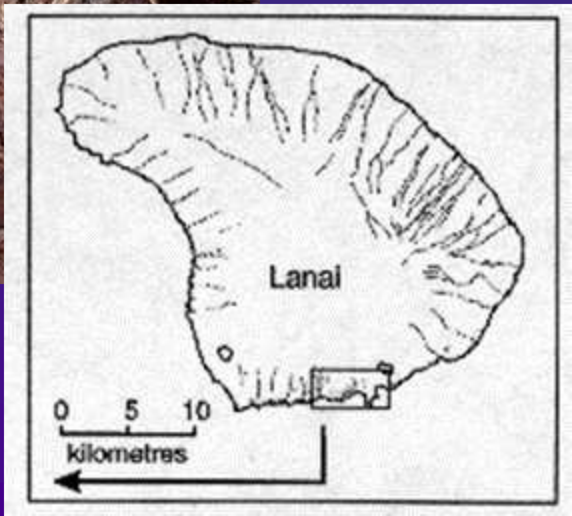
obvious cliffs

after Moore (1964)


subaerially-erupted lavas
pillow lava debris
hyaloclastites
potential giant avalanche slide-plane
pillow lavas

A deposit of coral and basalt boulders resting ~conformably on basalt flows, ~100 m above sea level, S. coast of Lānaʻi

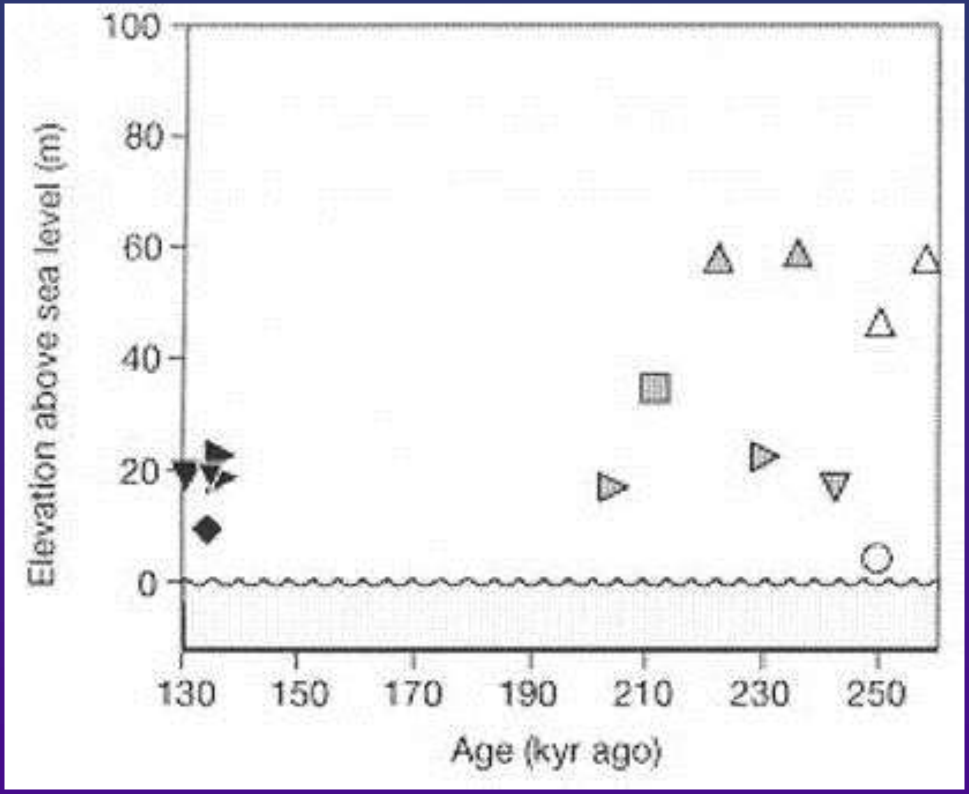


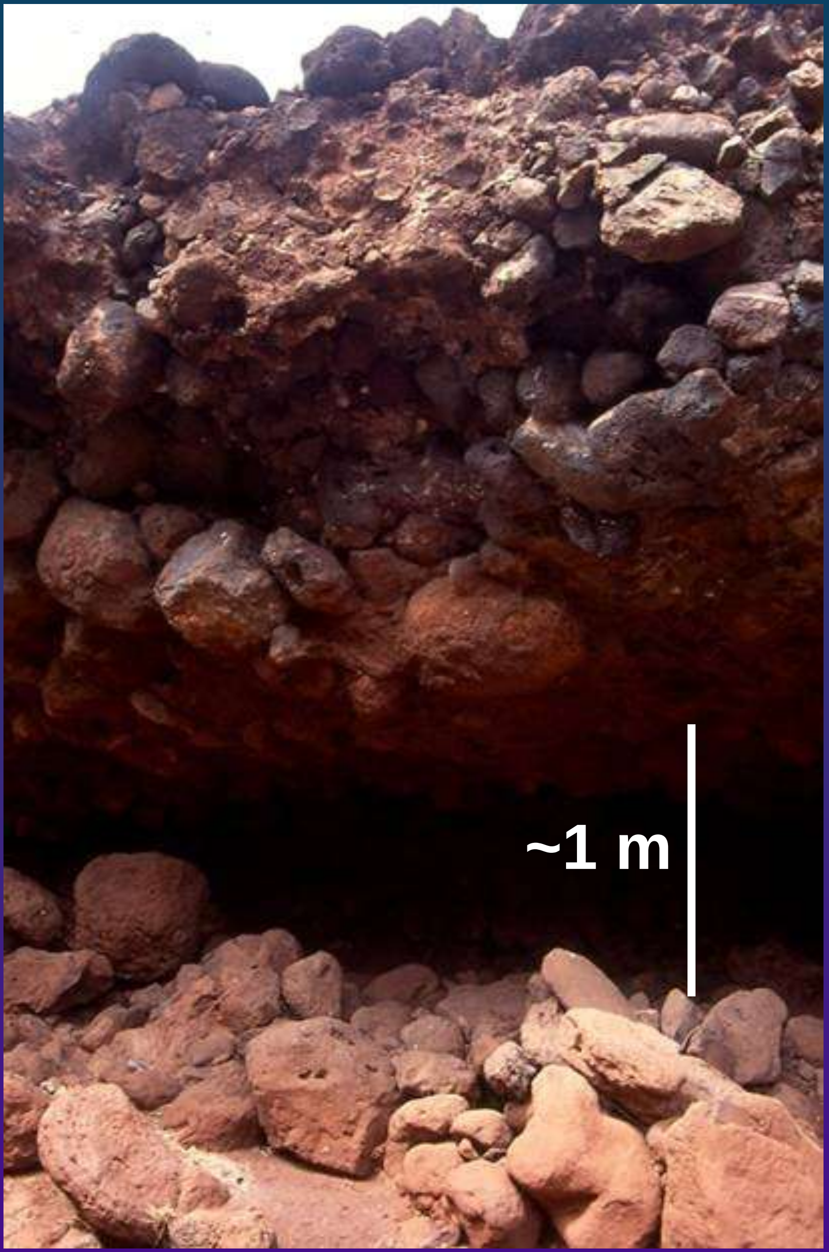


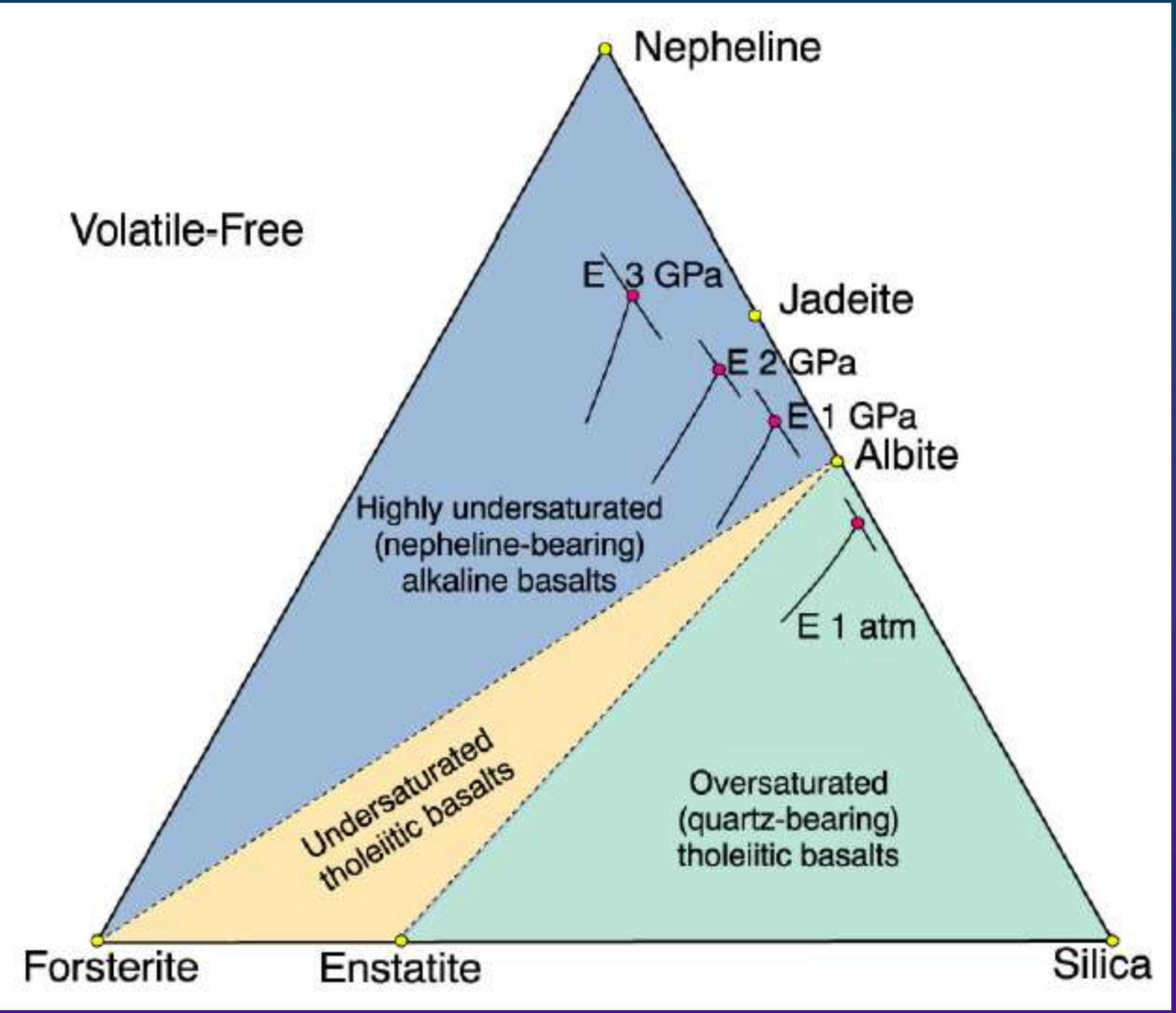
The boulders are sorted by age:

Different sea levels?

Multiple tsunami?







From: http://faculty.plattsburgh.edu/mary.rodentice/courses/petrolpresent/Ch%2010%20Magma%20Generation%20%2707.pdf