Types of OIB Magmas

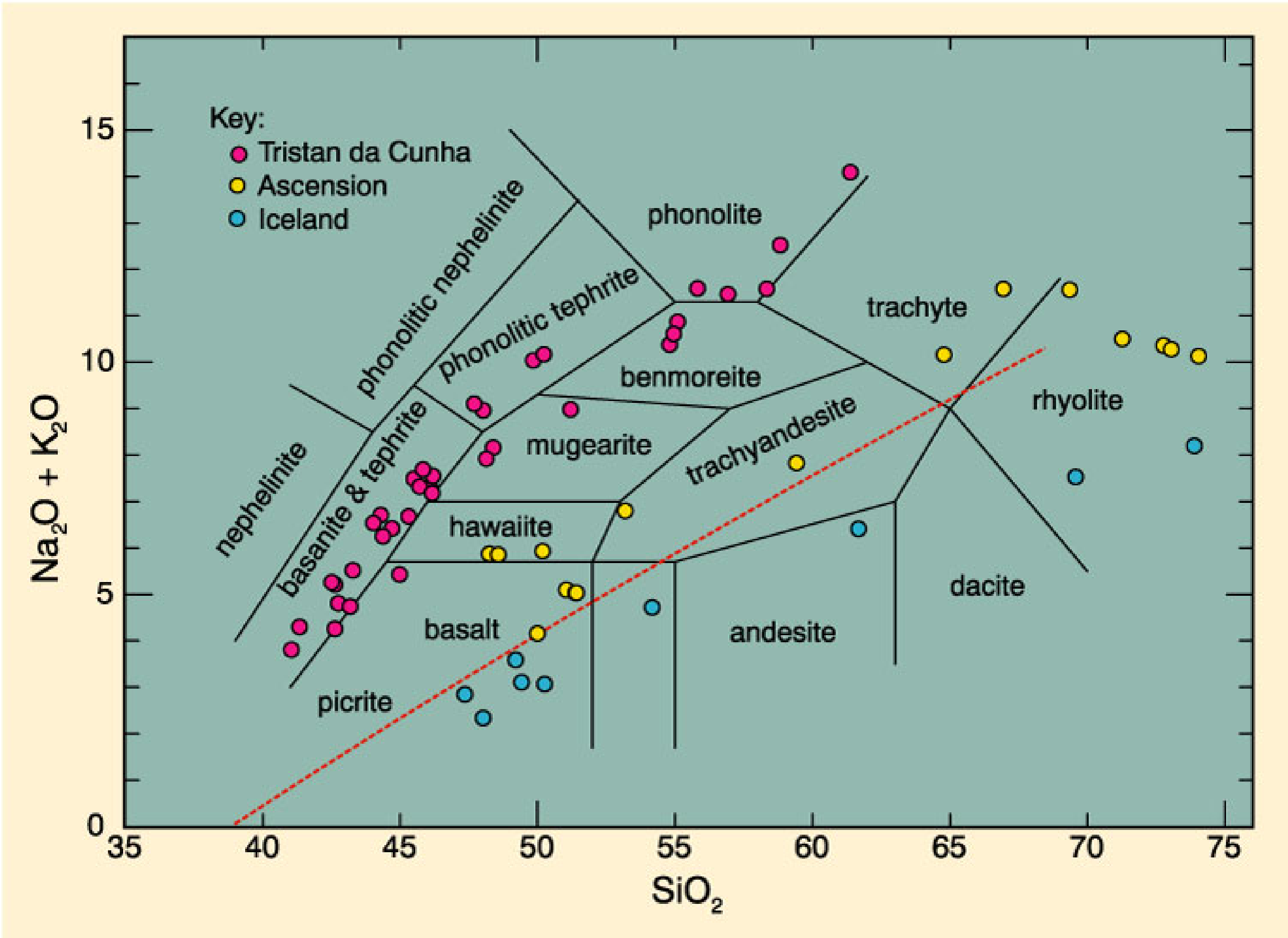
Two principal magma series

- Tholeiitic series (dominant type)
  - Ocean island tholeiitic basalt, OIT
  - Similar to MORB, but some distinct chemical differences

  - Alkaline series (subordinate)
  - Ocean island alkaline basalt, OIA
  - Two principal alkaline sub-series
    - slightly silica oversaturated
    - silica undersaturated

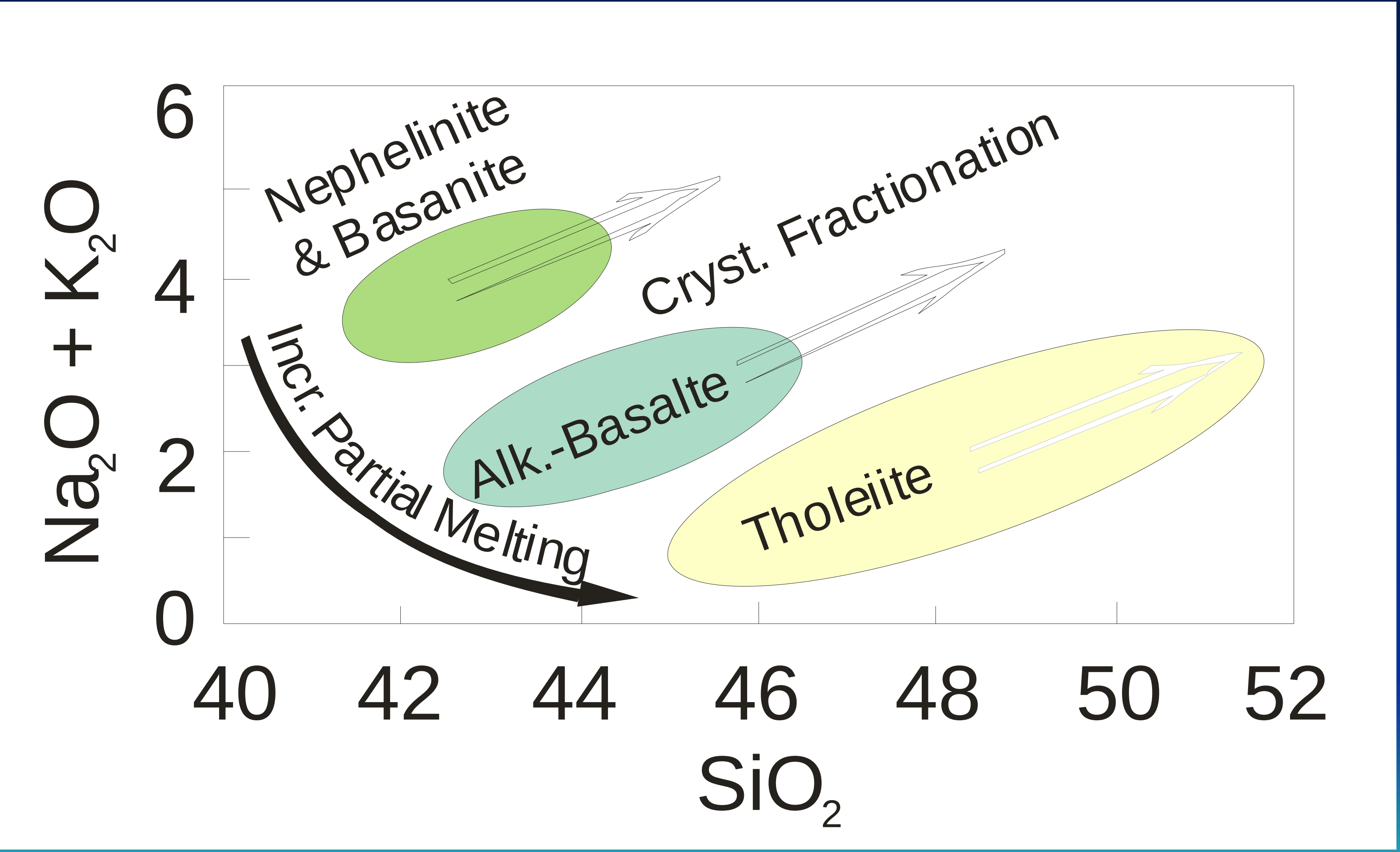
OIBs – evolution in the series

Tholeiitic, alkaline, and highly alkaline

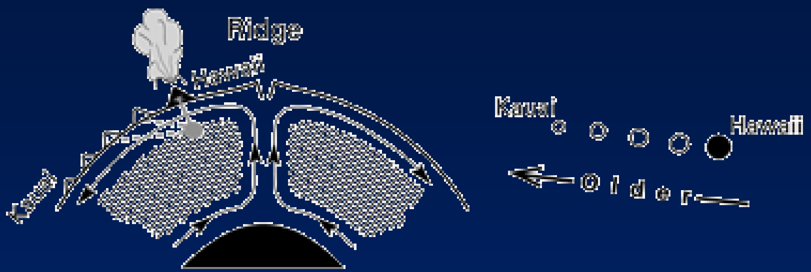


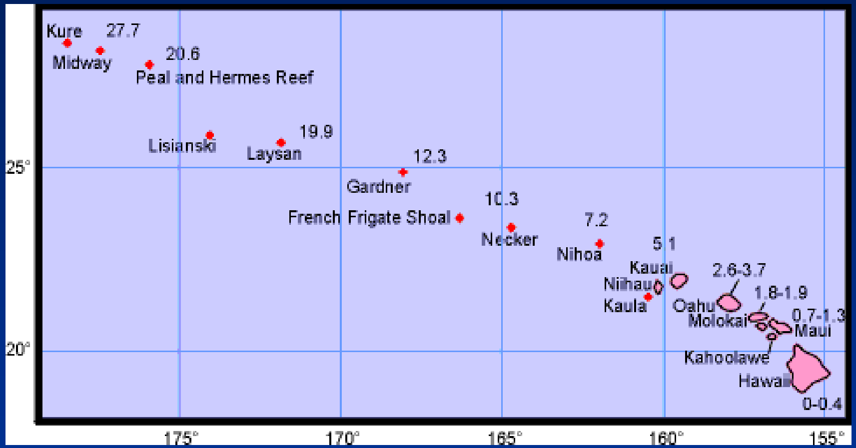
IUGS Volcanic Classification

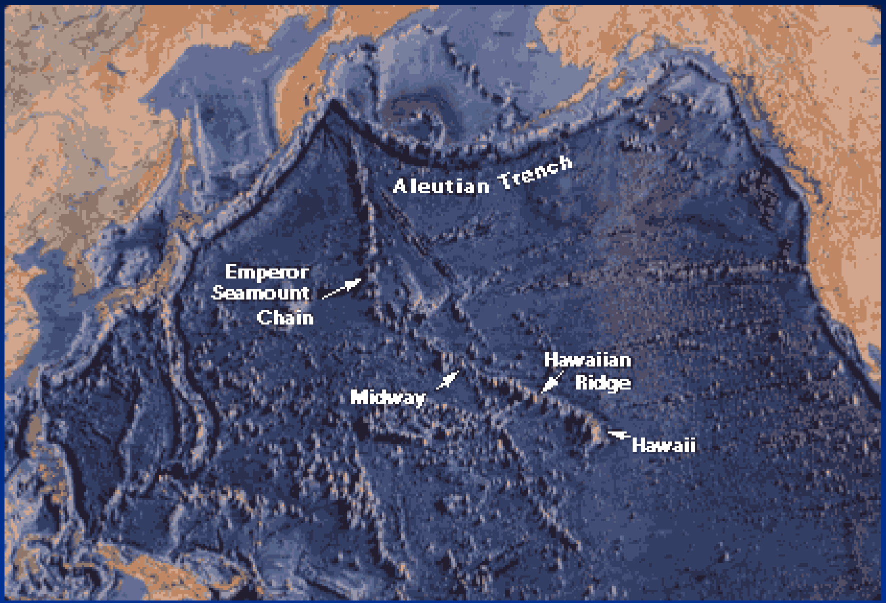
TAS-diagram

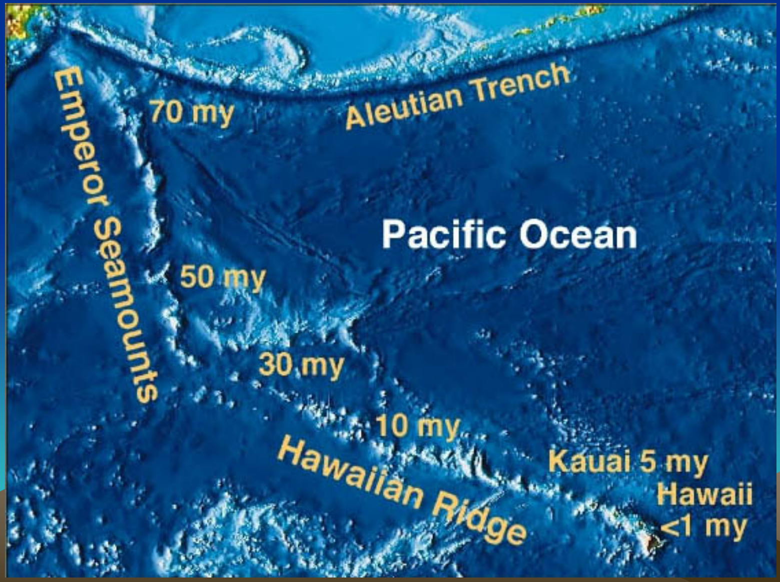

Nephelinite
& Basanite
Cryst. Fractionation
Incr. Partial Melting
Alk.-Basalte
Tholeiite
6
4
2
0
40
42
44
46
48
50
52
SiO2
Na2O + K2O

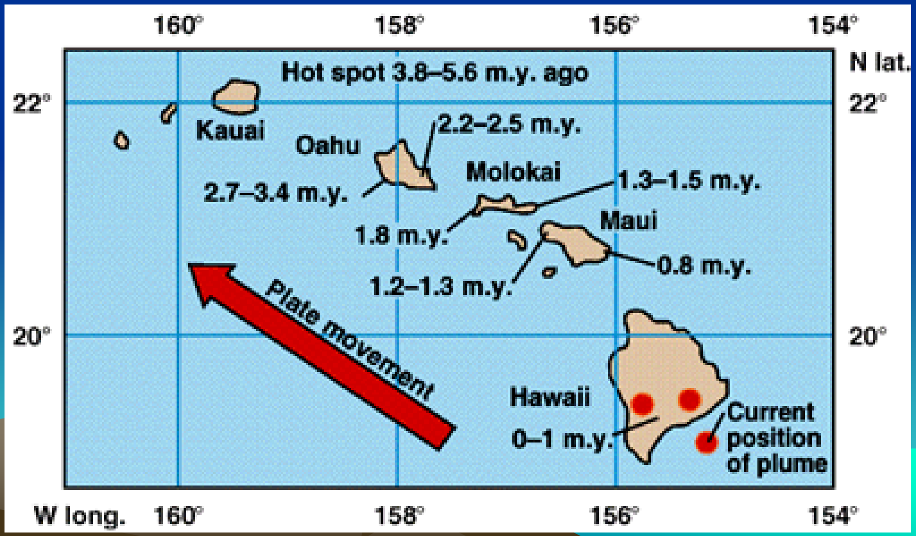
Hawaiian Scenario





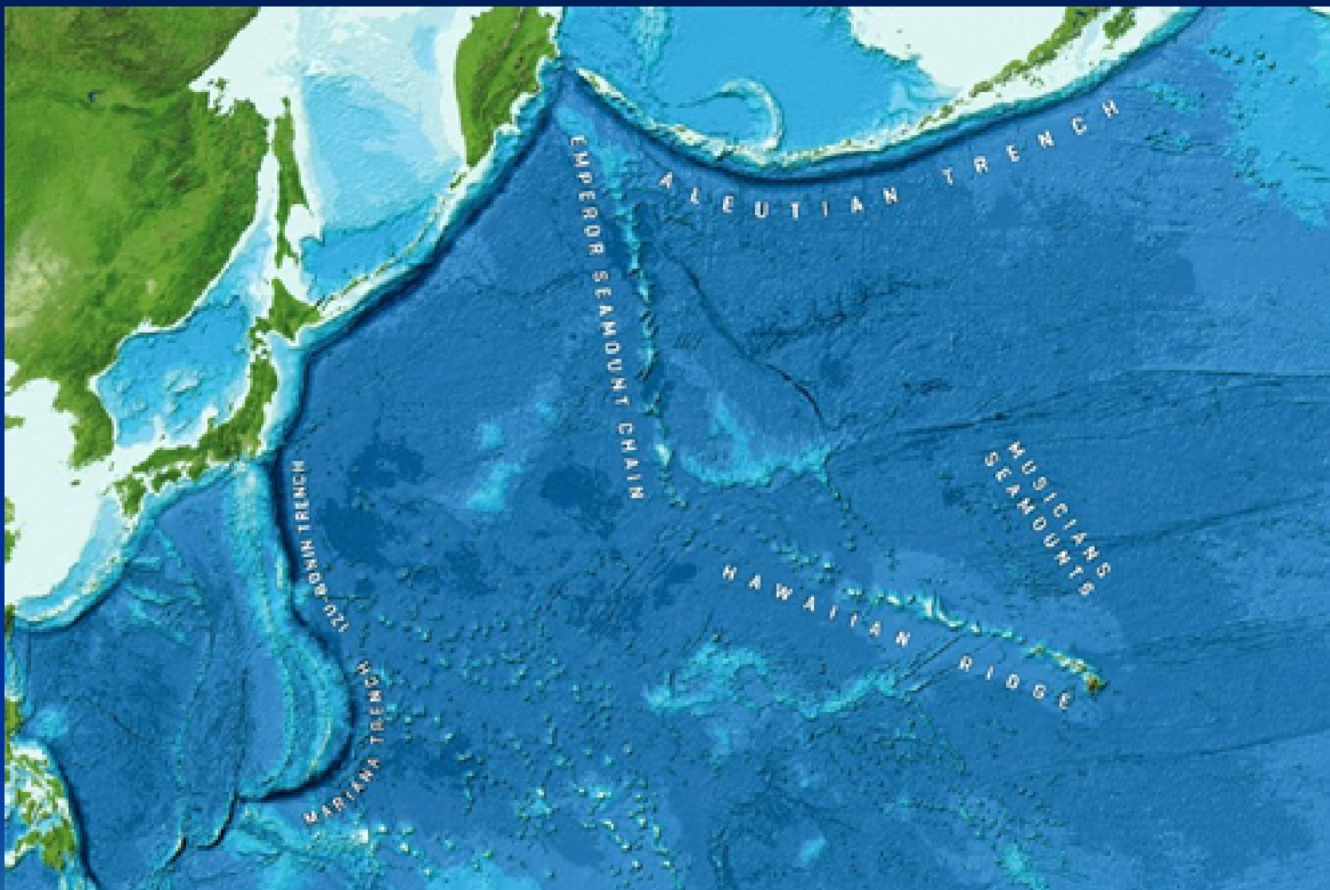






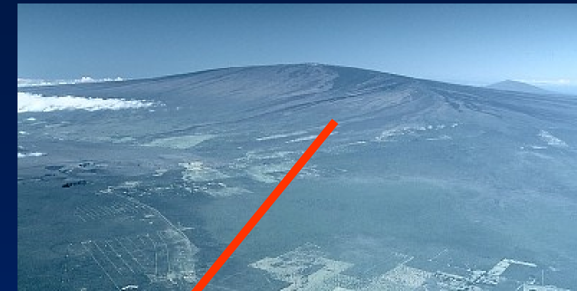
Hawaii-Emperor seamount chain

Global plate motion reconstructions fail to predict the bend

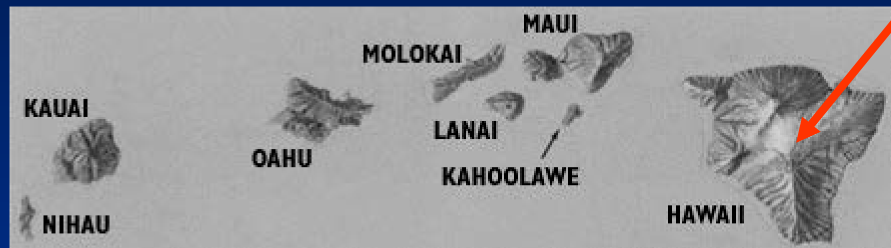


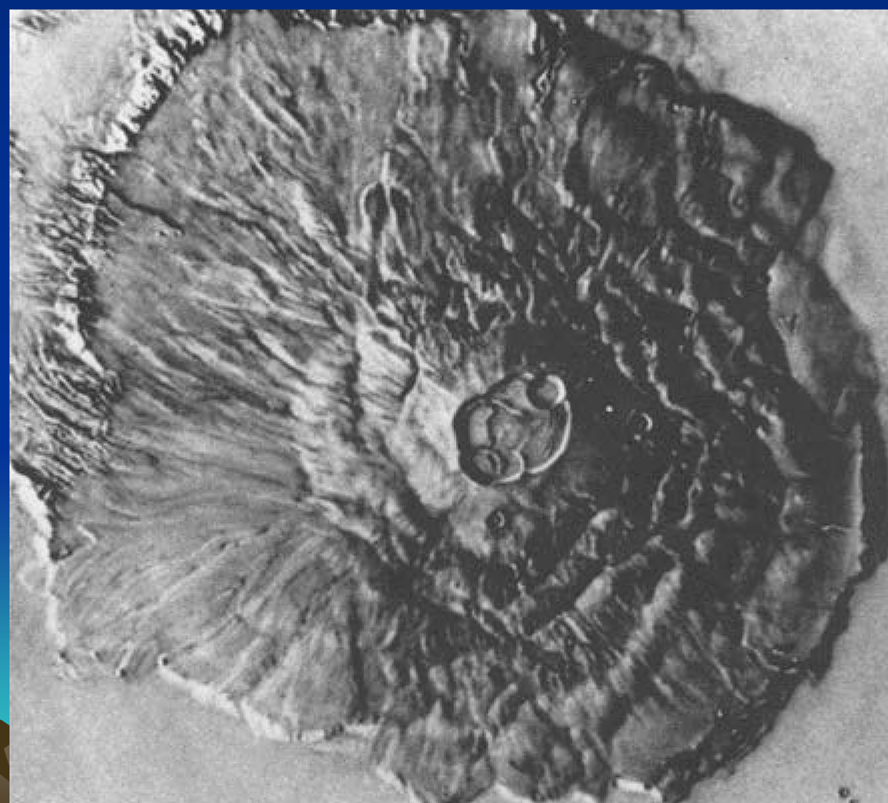
Steinberger et al. (2004) *Nature 430* explained trend by combining global plate motions with intraplate deformation and movement of hotspot plumes through distortion by global mantle flow.

Size of volcanic edifices:
Mauna Loa (still active): 80.000 km^3
average stratovolcano: 500 km^3



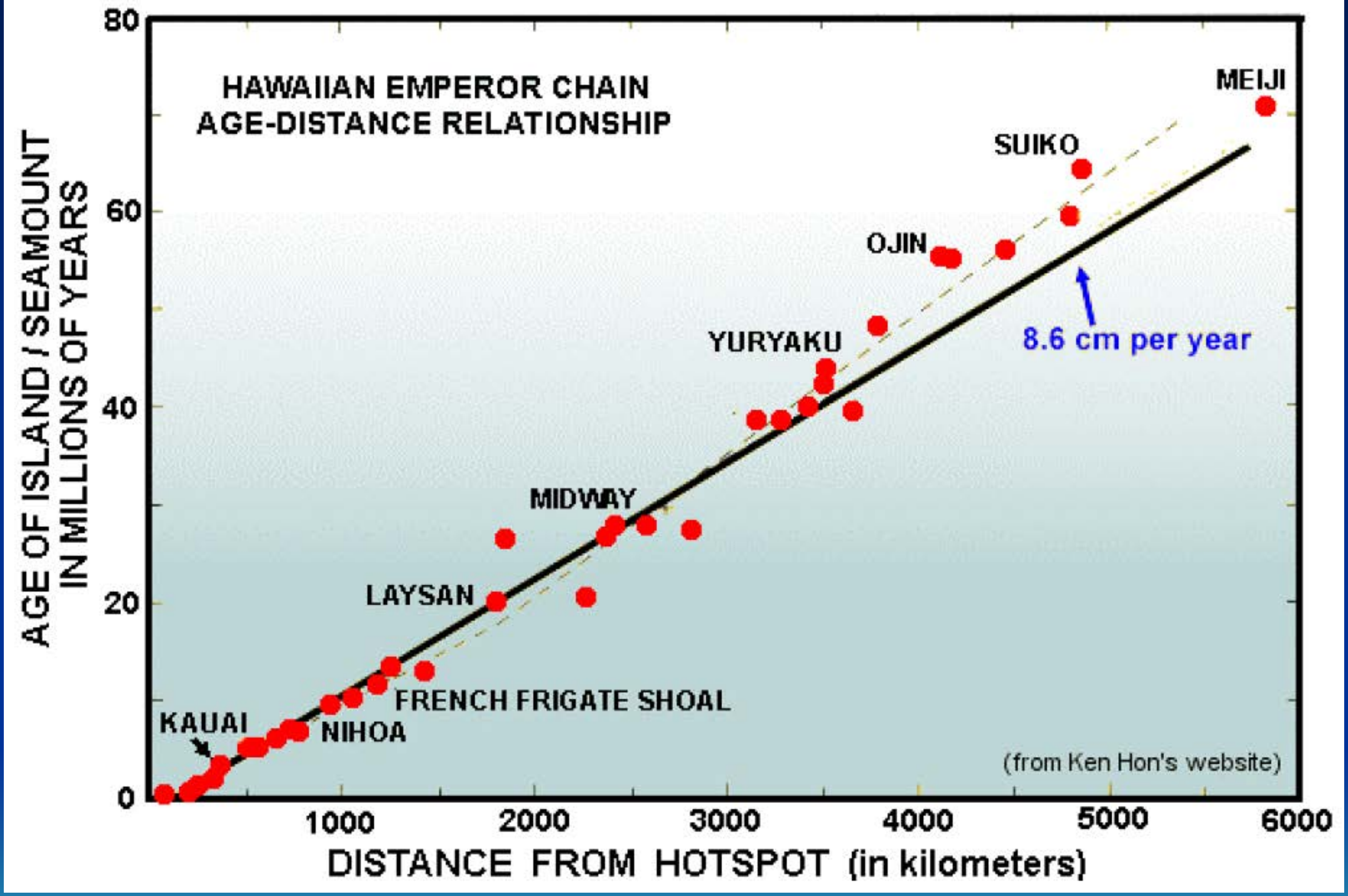
Mauna Loa





Olympus Mons volcano on Mars compared to the principal Hawaiian islands at the same scale.

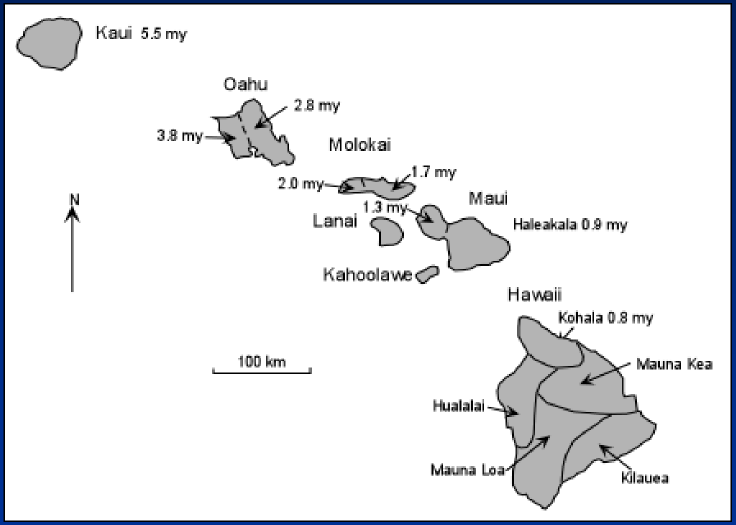
Hawaiian Scenario



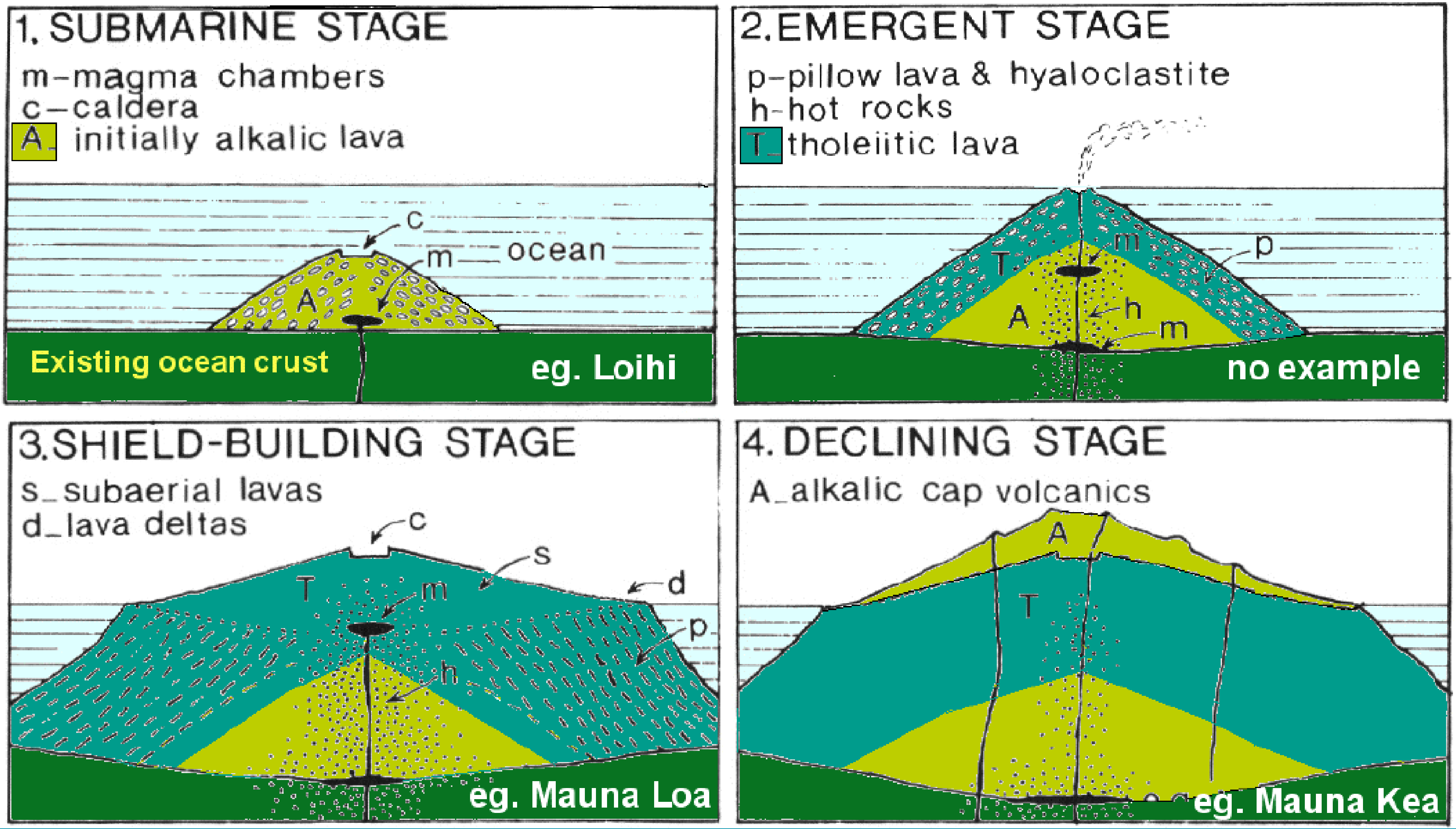
Hawaiian Scenario

Cyclic pattern of eruptive history

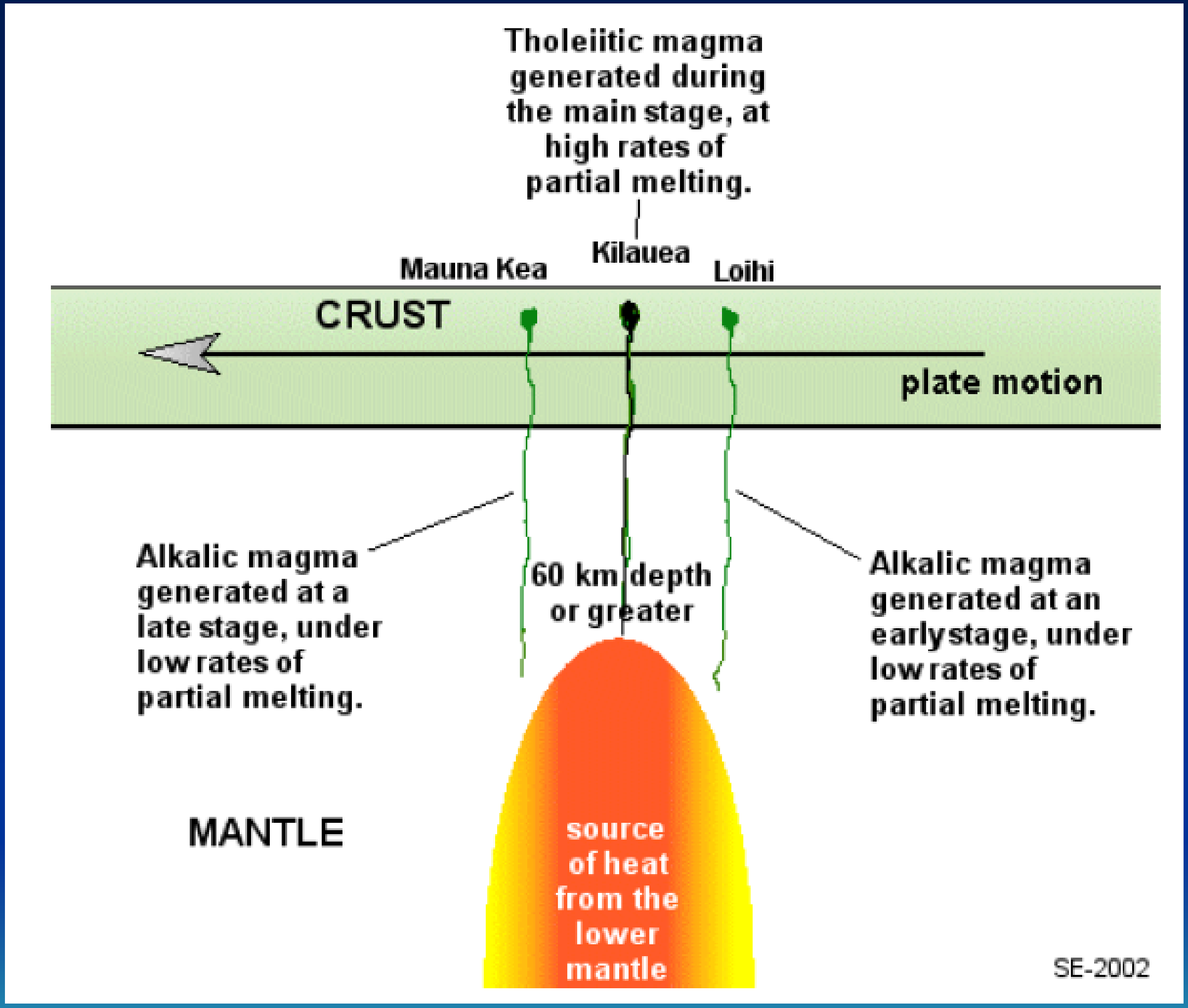
1. Pre-shield-building stage somewhat alkaline and variable
2. Shield-building stage begins with tremendous outpourings of tholeiitic basalts
3. Waning activity more alkaline, episodic, and violent (Mauna Kea, Hualailai, and Kohala). Lavas are also more diverse, with a larger proportion of differentiated liquids
4. A long period of dormancy, followed by a late, post-erosional stage (Oahu). Characterized by highly alkaline and silica-undersaturated magmas



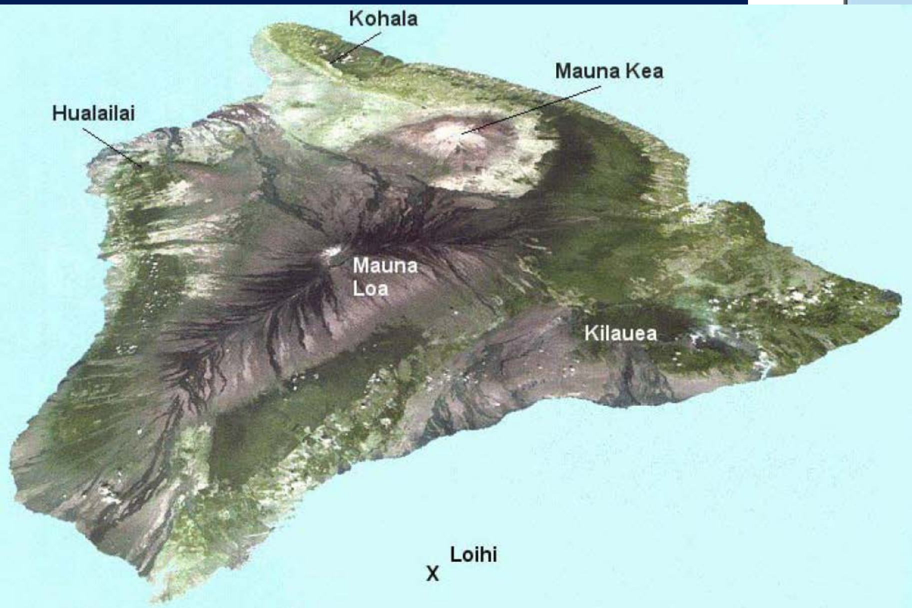
Hawaiian Scenario

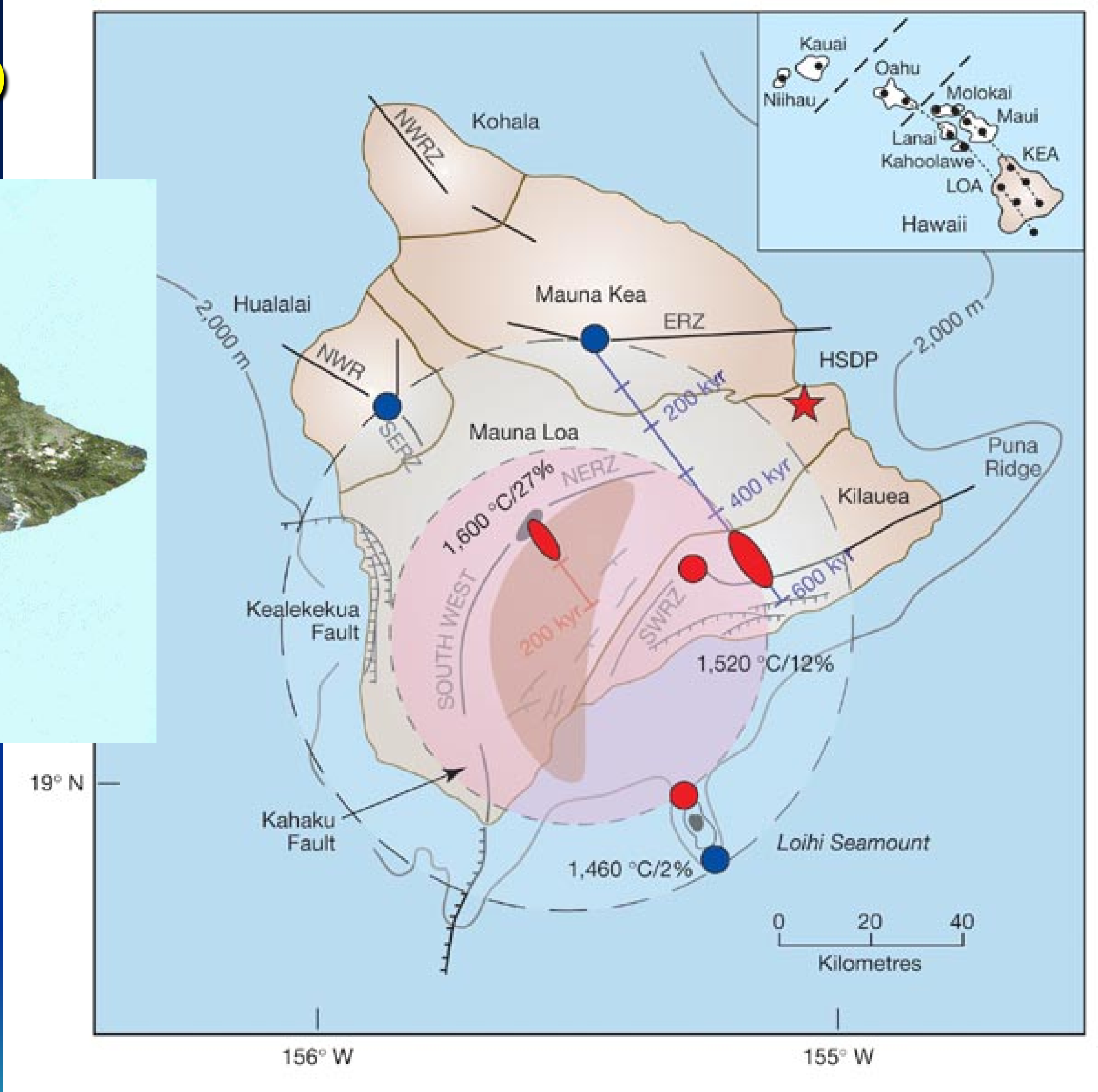


Hawaiian Scenario

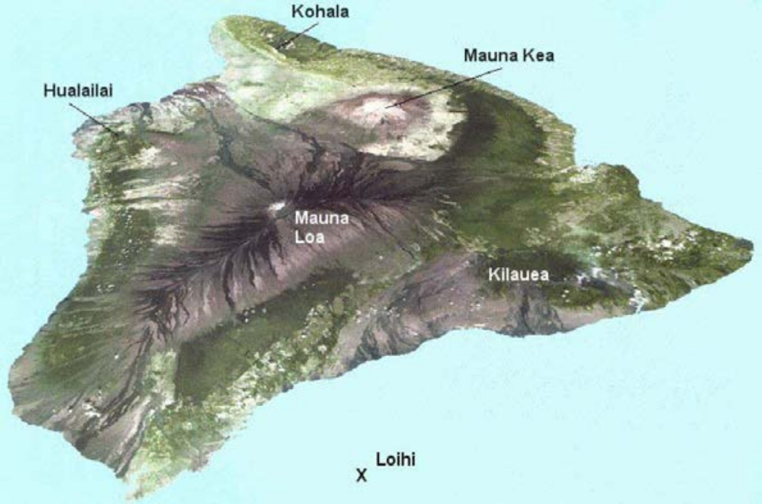


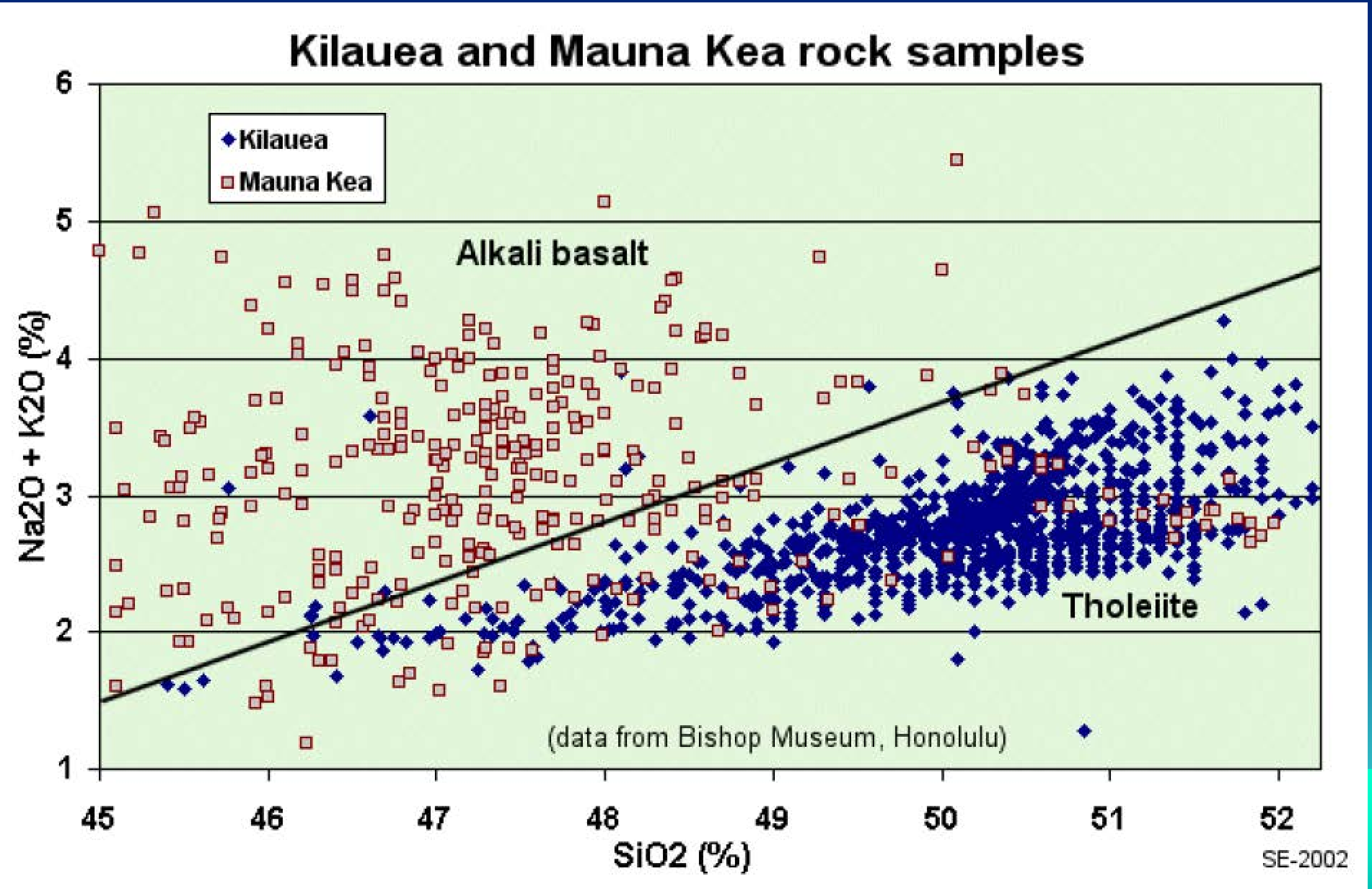
Hawaiian Scenario

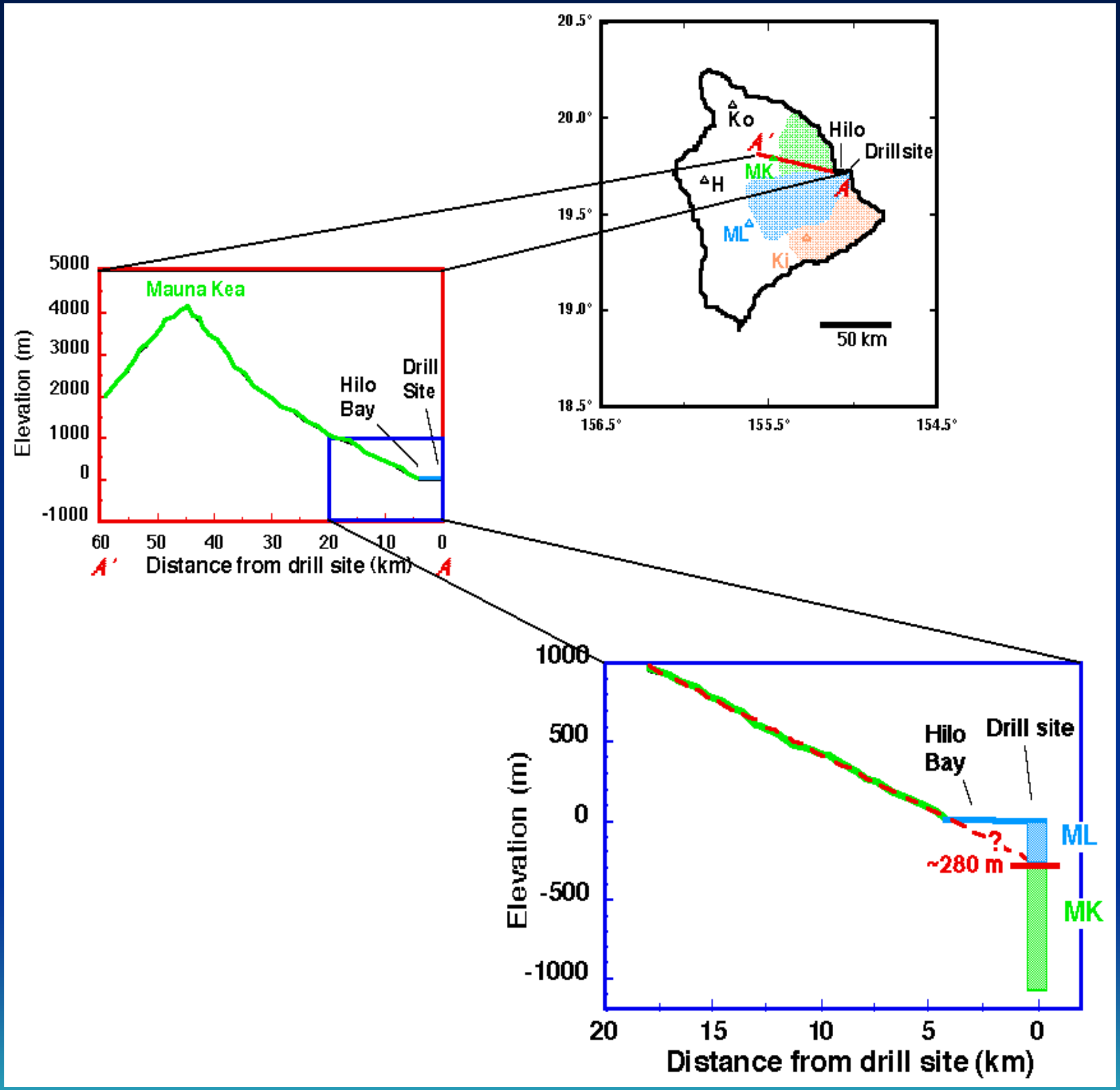




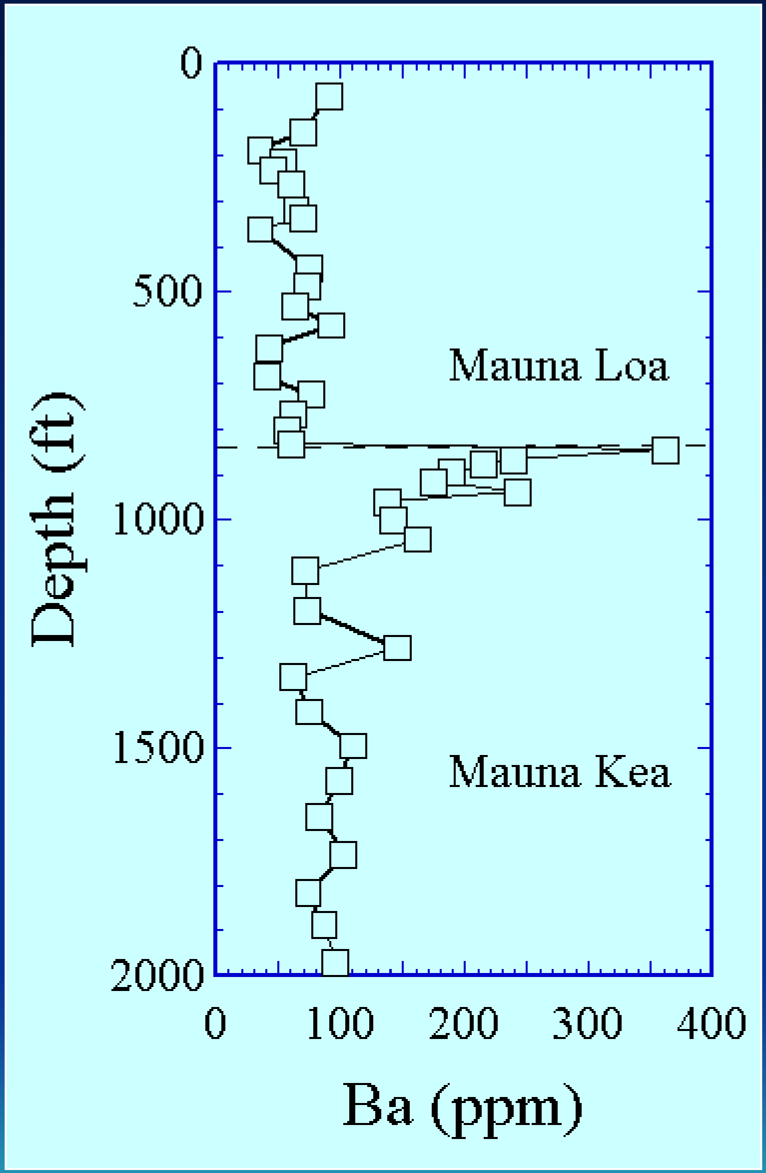
Hawaiian Scenario







20.5°
20.0°
19.5°
19.0°
18.5°
156.5°
155.5°
154.5°
Ko
H
Hilo
Drillsite
A'
A
MK
ML
Ki
50 km
5000
4000
3000
2000
1000
0
-1000
Elevation (m)
Mauna Kea
Hilo Bay
Drill Site
60
50
40
30
20
10
0
A'
Distance from drill site (km)
A
1000
500
0
-500
-1000
Elevation (m)
Hilo Bay
Drill site
?
~280 m
ML
MK
20
15
10
5
0
Distance from drill site (km)



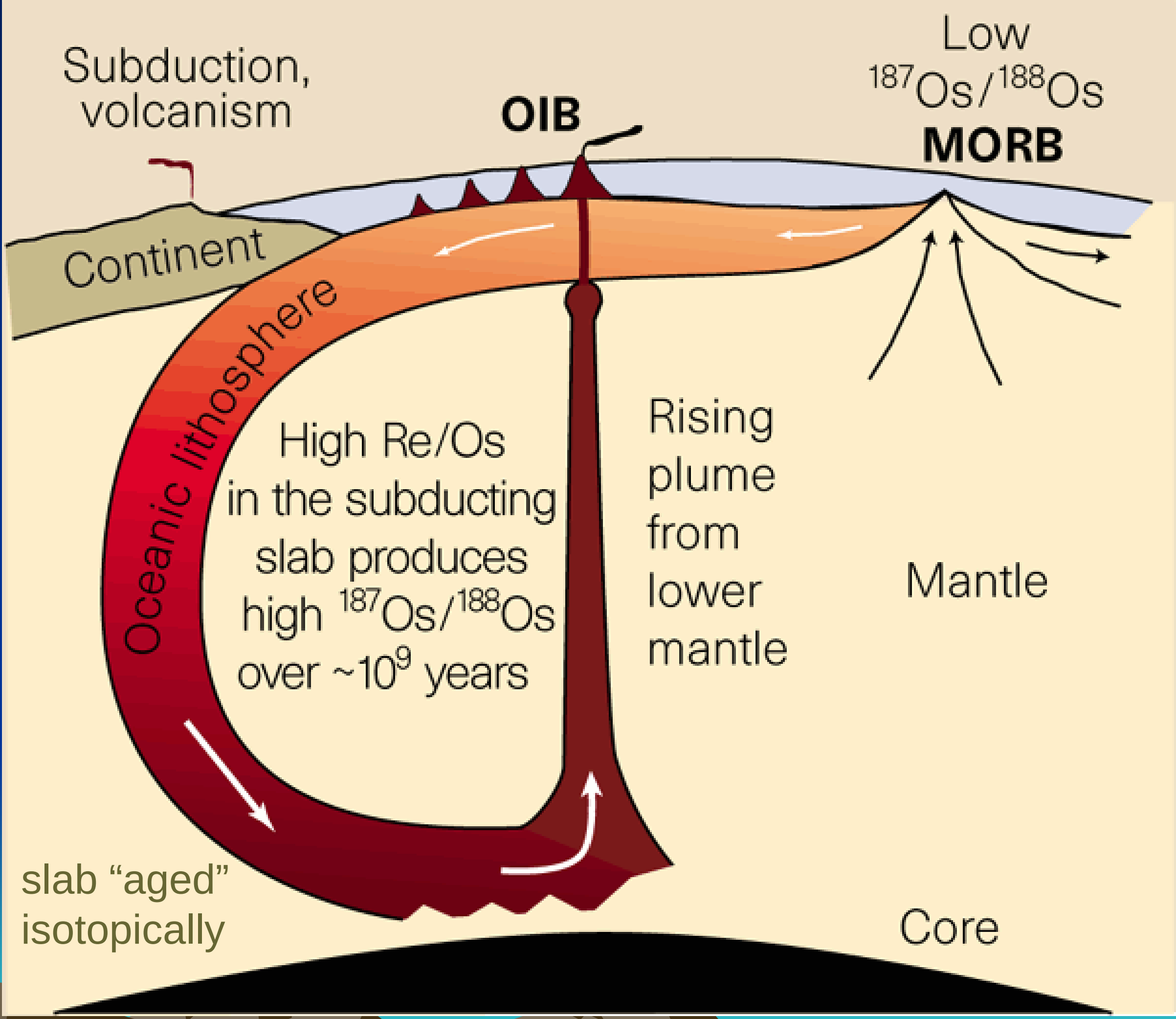
Ba high in the uppermost flows of the Mauna Kea section → alkalic basalts; erupted in the waning stage of shield building phase.

The alkalic basalts form because near the end of its life, the volcano drifts off of the plume, and near edge of the plume amount of melting is lower than over the center.

Re-melting of ancient ocean floor

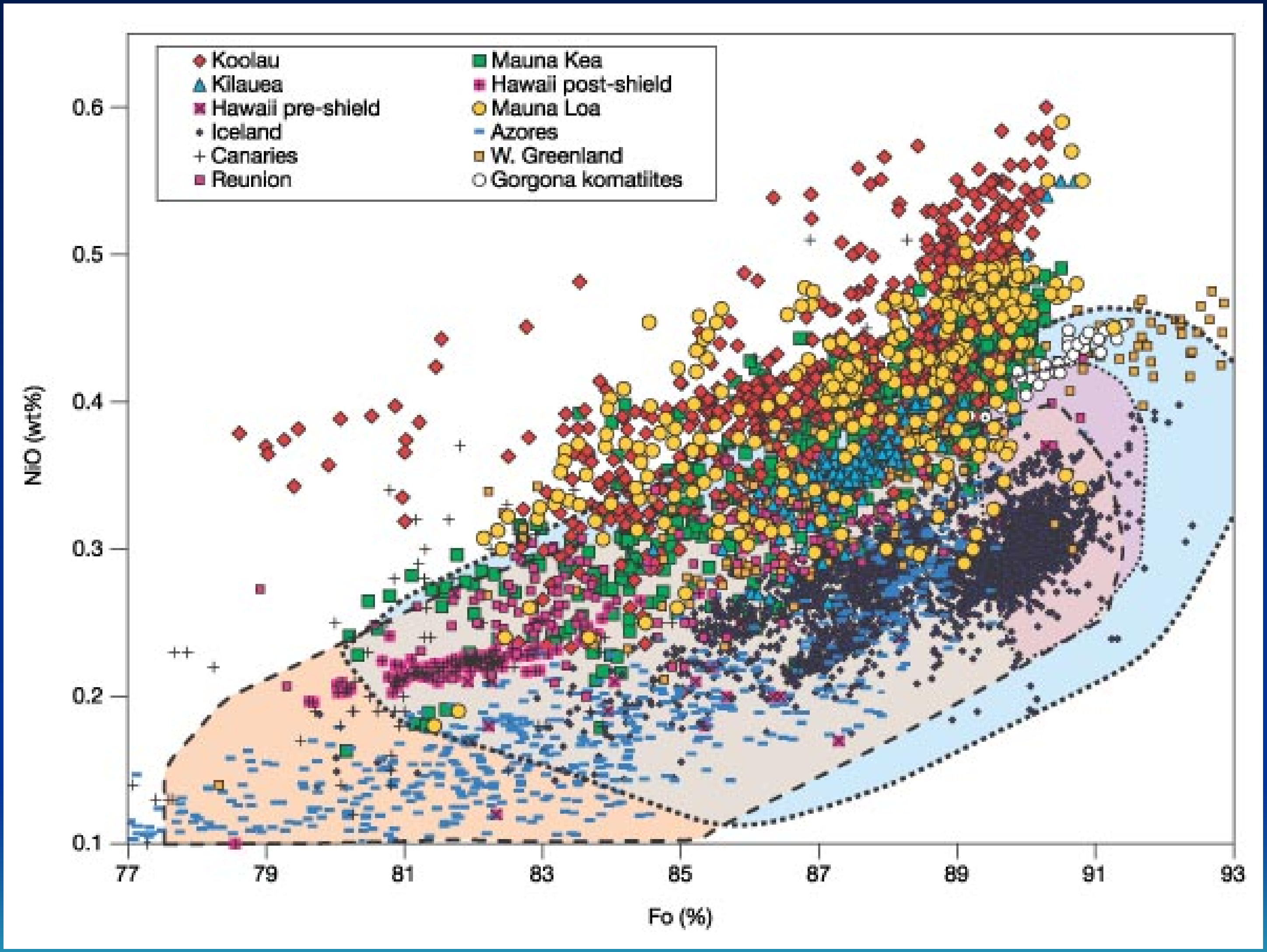
How to unmix Hawaiian cocktails (Halliday *Nature 399*):

The time taken for this recycling process is thought to be typically about a billion years. By the time the plume melts to produce OIB it has 'aged' isotopically and has higher $^{187}Os/^{188}Os$ than the surrounding mantle

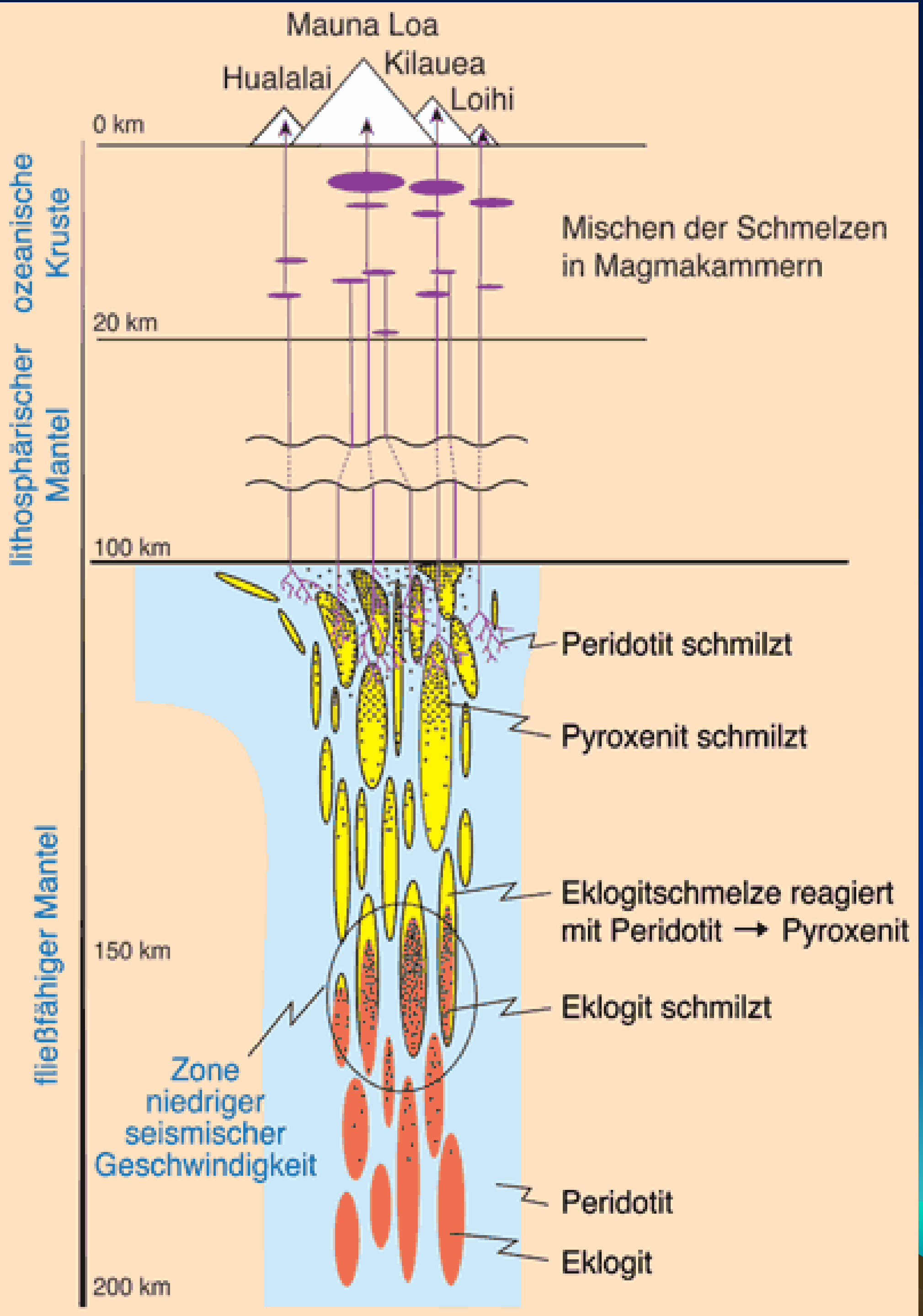


Halliday (1999)

Warum die Vulkane auf Hawaii in den Himmel wachsen



Sobolev et al. (2005) Nature 434



Sobolev et al. (2005)
Nature 434

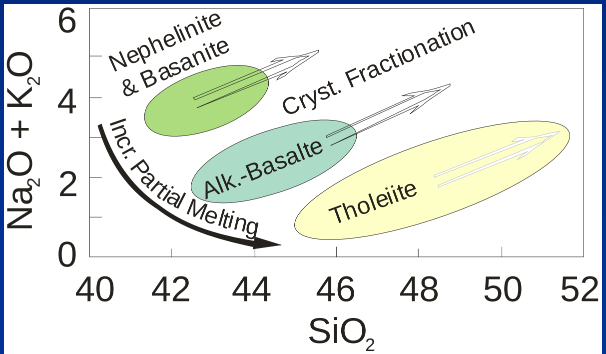
OIB chemistry - highly variable alkalinity

Alkali/silica ratios selected ocean island lava suites

Island	Alk/Silica	Na_2O/SiO_2	K_2O/SiO_2
Tahiti	0.86	0.54	0.32
Principe	0.86	0.52	0.34
Trindade	0.83	0.47	0.35
Fernando de Noronha	0.74	0.42	0.33
Gough	0.74	0.30	0.44
St. Helena	0.56	0.34	0.22
Tristan da Cunha	0.46	0.24	0.22
Azores	0.45	0.24	0.21
Ascension	0.42	0.18	0.24
Canary Islands	0.41	0.22	0.19
Tenerife	0.41	0.20	0.21
Galapagos	0.25	0.12	0.13
Iceland	0.20	0.08	0.12

Strong variation in element ratios (shown in the Table) among the suites

→ mantle is heterogeneous



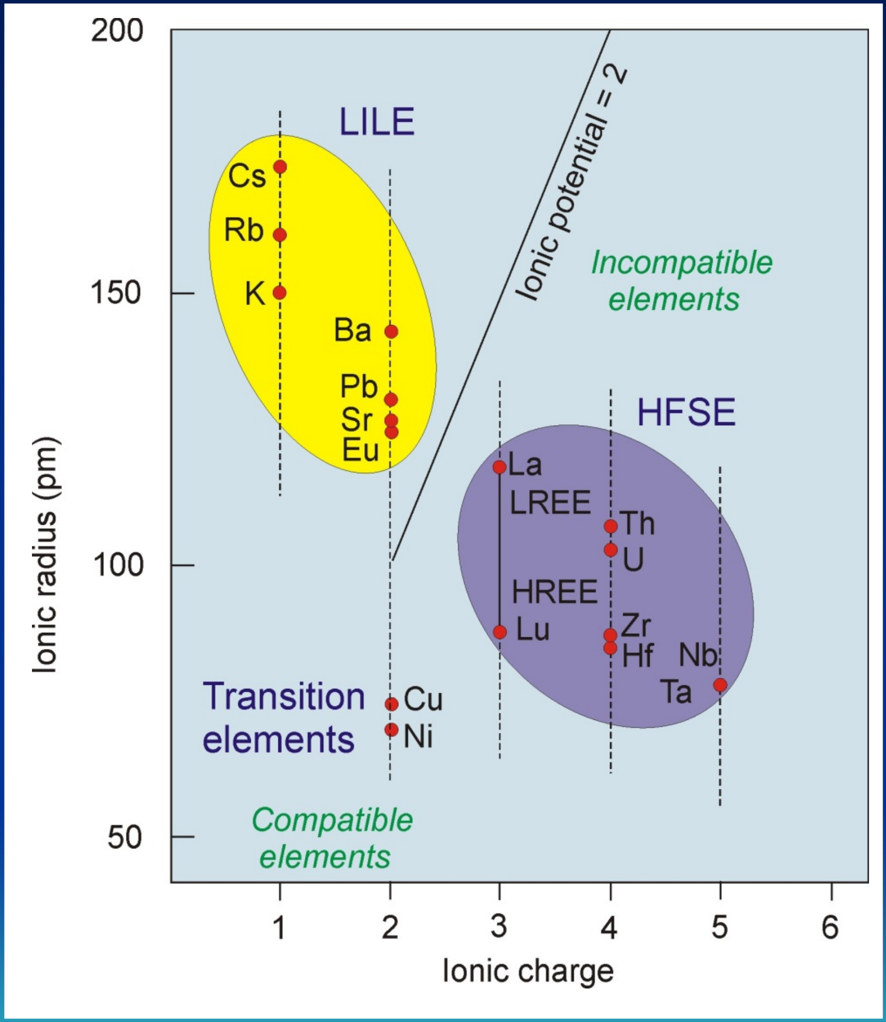
- Alkalis are incompatible elements, unaffected by less than 50% shallow fractional crystallization, this argues for distinct mantle sources or generating mechanisms

Classification of trace elements

acc. to their geochemical behavior

Plot of ionic radius versus ionic charge with fields of large ion lithophile elements (LILE) and high field strength elements (HFSE).

Ionic potential = charge/size ratio



Trace Elements

- LILE are incompatible and are all enriched in OIBs with respect to MORBs
- The ratios of incompatible elements have been employed to distinguish between source reservoirs
  - N-MORB: the K/Ba ratio is high (usually > 100)
  - E-MORB: the K/Ba ratio is in the mid 30's
  - OITs range from 25-40, and OIAs in the upper 20's

Thus all appear to have distinctive sources

Trace Elements

- HFSE also incompatible, and enriched in OIBs > MORBs
- Ratios of these elements are also used to distinguish mantle sources

The Zr/Nb ratio:

  - N-MORB generally quite high (>30)
  - OIBs are low (<10)

Trace Elements: REEs

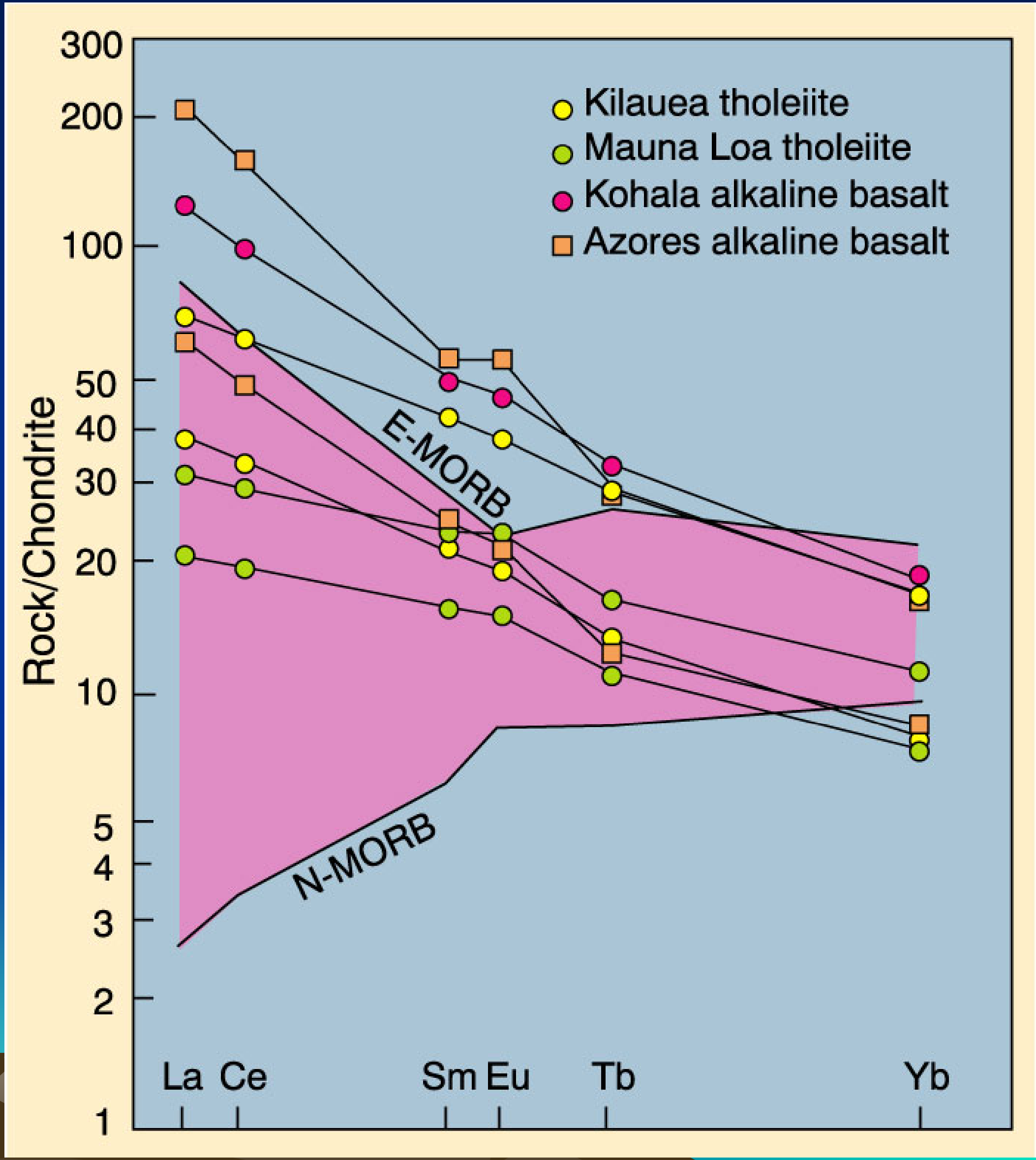
HREEs are fractionated in the OIB samples

→ garnet was a residual phase.

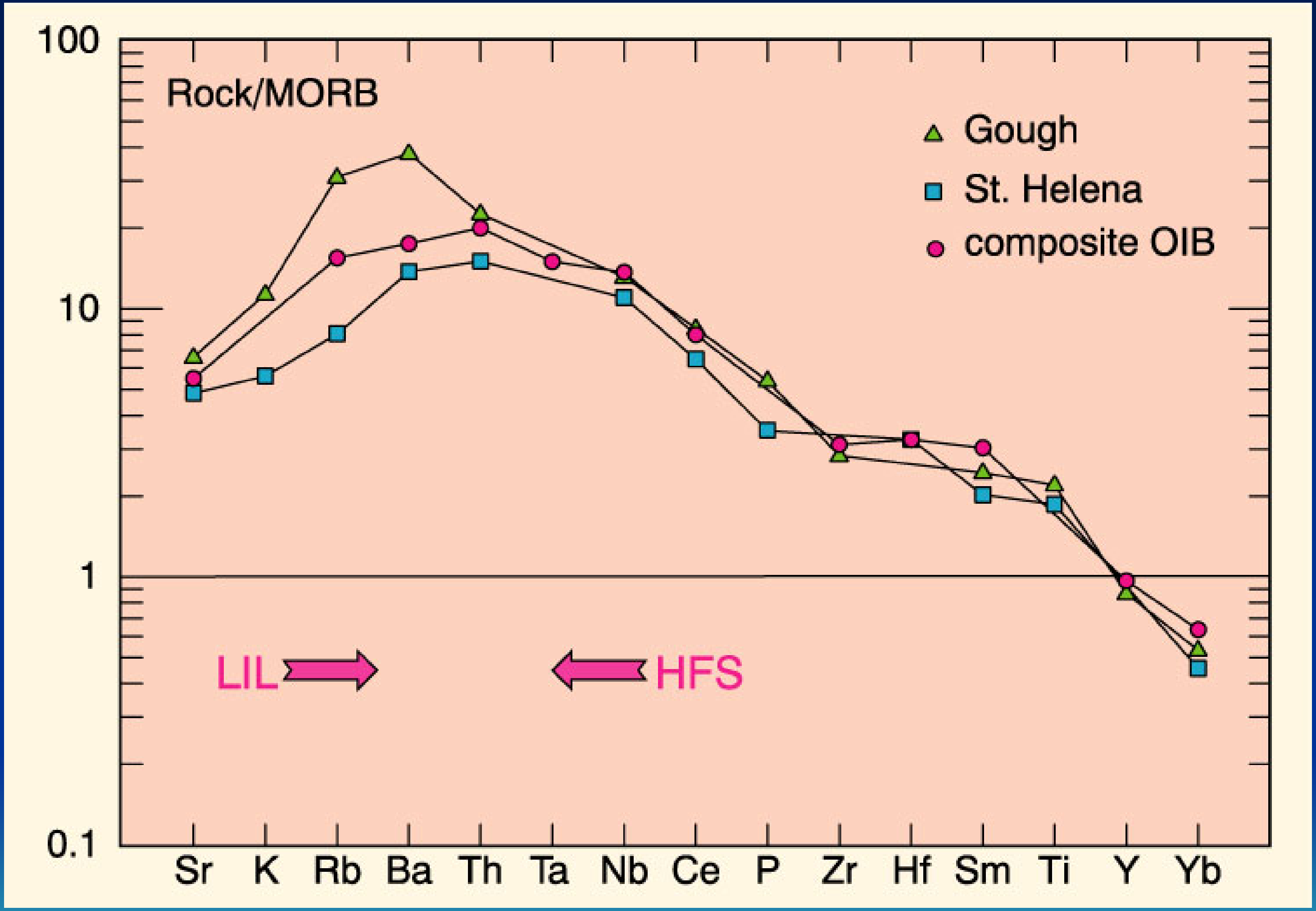
These melts must have segregated from the mantle at depths > 60 km.

La/Yb (REE slope) correlates with the degree of silica undersaturation in OIBs

- Highly undersaturated magmas: La/Yb > 30
- OIA: closer to 12
- OIT: ~ 4
- → E-MORB and all OIBs appear to originate in the lower enriched mantle



MORB-normalized Spider Diagrams



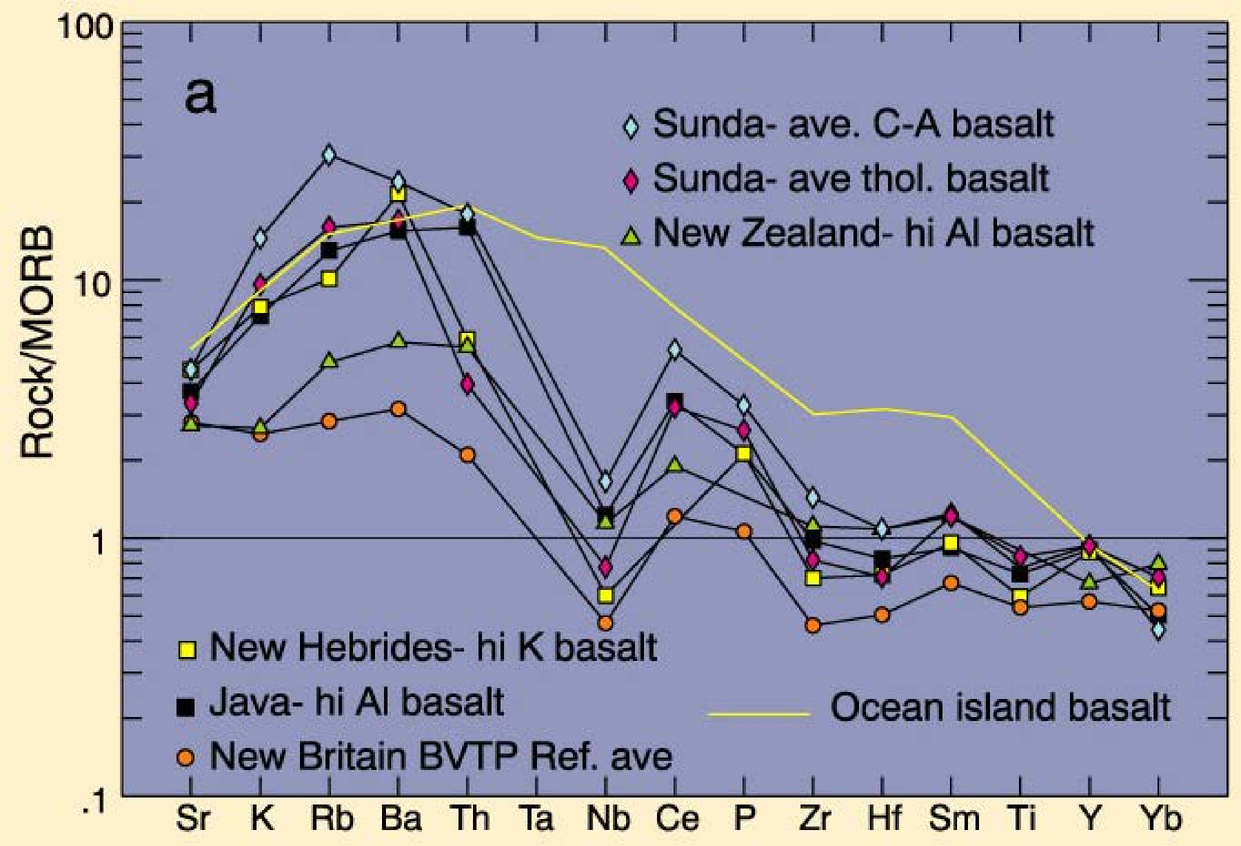
Data from Sun and McDonough (1989)

MORB-normalized Spider diagrams

Island Arc Basalts

Irregular profile

decoupled HFS - LIL (LIL are hydrophilic)



Data from Sun and McDonough (1989)

Concentrations of trace elements normalized to primitive-mantle concentrations in
mid-ocean ridge basalt (N-MORB)
ocean island basalt (OIB)
island arc basalt (IAB)